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Music and Science:
Improving Student Engagement Through Art and Electronics

A thesis
submitted in fulfilment
of the requirements for the degree
of

Doctor of Philosophy in Education

at

The University of Waikato

by

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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Year of submission

2026

ABSTRACT

This thesis investigates how interdisciplinary, hands-on learning experiences using the Theremin can support student engagement, collaboration, and inclusion in a Brazilian public school. Motivated by post-pandemic disengagement, fragmented curricula, and fragile peer relations, the study implemented a fourteen-week series of workshops in which students aged 13–15 explored, built, and performed with Theremins across science and arts lessons. The research adopted a qualitative case study design informed by constructivist grounded theory. Data were generated through pre- and post-intervention interviews with science and arts teachers, focus groups with all four Year 8 classes, and a reflective research journal.

Findings show that, for many students, the project contributed to a shift from isolated, on-task behaviour to more organic forms of group work. Make-test cycles, the need to share partial knowledge of the build process, and the ERA arc (Experience → Represent → Apply) encouraged help-seeking, peer explanation, and collective problem-solving. Some students who were previously described as disaffected or disruptive repositioned themselves as competent helpers and co-constructors of the instrument. Social and emotional bonds, practical relevance, and opportunities for creative expression were central to these changes, especially when the artefact travelled between school and home.

This thesis makes an original contribution by specifying how task design and the Theremin's unique affordances worked together to support engagement and peer interaction in this context, and by deriving design principles for low-cost, artefact-based STEAM (science, technology, engineering, arts, and mathematics) interventions. The Theremin's affordances carried much of this work: its direct gesture → sound correspondence and visible hand motion made negotiation audible and visible, supporting imitation, turn-taking, and dialogue.

At the same time, the study shows that a single STEAM project cannot offset structural barriers. Large classes, policies focused on numbers, socioeconomic hardship, and experiences of mistreatment continued to shape how far engagement could be sustained and for whom. The thesis argues that low-cost, artefact-based STEAM interventions such as this Theremin project can inform design principles for supporting multiple dimensions of engagement and peer interaction, while also making visible the systemic conditions that limit their reach.

ACKNOWLEDGEMENTS

“Have I not commanded you? Be strong and courageous. Do not be afraid; do not be discouraged, for the Lord your God will be with you wherever you go” (Joshua 1:9).

I thank God for accompanying me throughout this doctoral journey, which was a true adventure. Thank You, my Father and friend, for Your protection, kindness, and constant presence. Thank You for holding my hand and enabling me to do far more than I thought possible.

I am especially grateful to my supervisors. I am certain that this thesis was only possible because of them. In addition to their strong technical knowledge, they cared about my wellbeing, wanted me to complete this thesis, and were genuinely hoping for my success. Many of the insights that are now fundamental to this work emerged from the sessions I had with them. My supervisors gave me support when I needed their presence and space when I needed to work things out for myself. Thank you, Dr Bronya Dean, for believing in my work and for always replying so promptly, even when I was still living in Brazil, literally on the other side of the world. Thank you, Associate Professor Maurice Man Wai Cheng, for sharing your wonderful Hong Kong culture with me, together with your love for music, guitar, and local food. This doctorate was far more enjoyable because I had both of you as my supervisors. I will never cease to be grateful that you were part of my life at this time.

My deepest thanks go to my wife, Karen, who embraced this adventure with me, together with our three children, one of whom was born during the doctorate. With her, I learned that what is difficult is not necessarily bad. It was not easy to move countries in the middle of the doctorate, welcome another child during this time, and learn to live in a new community, culture, and language. Yet those difficult things were not necessarily bad things. To grow through this experience alongside my wife was something wonderful and beyond compare. Thank you, my love, because you always believed in my work, always strengthened me, always hoped for the best for me, always brought me cookies when I needed them to keep writing, always took care of our boys when I was immersed in my thesis, and always gave me words of encouragement. Those moments were crucial in helping me finish this doctorate. You have been my best friend for more than twenty years, and this experience only made you dwell in deeper places of my heart that I did not even know existed.

I am equally grateful to my three sons, Pietro, Noah, and Joshua. They were more than extraordinary children. They gave so much of themselves and left behind friendships and a life they already had in Brazil in order to build a new life in another country and accompany their father through his doctoral studies. From the beginning, we decided that our family would stay together, and for me this doctorate would not have been possible without them. They were the fuel that helped me finish this thesis. I love drawing, reading, playing, and going into nature with you three, and I am incredibly happy that I will now be able to spend more time doing these things with my beloved children.

I remain deeply thankful to my parents, Gisele and Jeferson. I am grateful to have parents who gave me emotional support and with whom I have a good relationship. Being able to call them every week from the other side of the world, and to receive their smiles and affection through those calls, meant a great deal to me. I also thank my parents for their financial support when it was needed, because without it I would not have been able to complete this doctorate. People do not always realise the cost of supporting a family while producing a doctorate. My parents, my wife, and my children know that cost. This acknowledgement is nothing more than what they deserve.

I am also grateful to the University of Waikato for awarding me the University of Waikato Doctoral Scholarship, without which this dream could never have become a reality. The University never failed in its responsibilities to me and, through its services, always supported me in what I needed. I am grateful to the library and its wonderful librarians, who taught me to navigate the academic world in ways I did not even know were possible. My thanks also go to the School of Graduate Research, which kindly and tirelessly helped to resolve many practical problems and documentation matters throughout this journey.

A special word of thanks goes to Professor Michael Williams. He was the first person to believe in my project and, although he is no longer part of my thesis panel, he was central to one of the most important transitions of my life, between Brazil and New Zealand. I will remember him with gratitude for the rest of my life. I was only able to come to New Zealand and begin this doctorate because of him. When I arrived, he welcomed me warmly and became my first professional point of contact in this country. Those contacts were fundamental at the beginning of my doctorate, and to this day I still reap the good fruit of the opportunities he opened for me at the start of my academic life in New Zealand.

My thanks also go to the School of Education at the University of Waikato and to all my colleagues there who shared this process with me. I am grateful to those who struggled

alongside me, attended conferences with me, shared offices with me, and shared their anxieties with me. I also thank those who finished before me and gave me hope and encouragement. To those who will finish after me, be strong. I wish you all the best.

I am deeply grateful to the members of Hamilton Central Seventh-day Adventist Church. From the beginning of my time in New Zealand, they welcomed me, cared for me, cared for my family, shared my burdens, and became part of this journey in every practical way. They showed me an active faith and confirmed that religion is what you do with what God gives you. Through that church, God gave me friends, and those friends treated me like a brother. I carry deep affection for them, and that affection will not fade.

I am equally grateful to my fellow Brazilians living in New Zealand, who never allowed the good things of Brazilian culture to disappear from my life. You were present throughout almost the entire doctorate, whether by celebrating Brazilian culture together, passing on clothes your children had outgrown, or playing the music of our country.

Finally, I thank you, the reader. I hope this work contributes to your growth and supports you in becoming more fully human and more generous in your relationships with others. I hope it may also offer sparks of creativity for solving the problems you face in life.

To everyone else, I wish you all the best. May God bless you, and may you all be strong and courageous!

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CHAPTER 1 – INTRODUCTION

I became interested in the theremin instrument and different approaches to teaching music while studying for my master's degree. The possibility of reaching others and enabling them to play, even without prior musical skills, is one of the most fascinating aspects of this instrument and led me into building tools, methods, and workshops to promote encounters between students, music lovers, teenagers, and children. This was possible thanks to the theremin's unique combination of playability, tone, and expressiveness. Gesture and sound are impressively linked, and curiosity brings the most timid ones to at least have a try on this exotic machine.

While designing these tools and workshops for my master's degree, I bridged liberation and empowerment, both for me and the students. One of the practical examples of this is in the field of live music. In my career as a musician, I am constantly dependent on electronic instruments or equipment that have connectors, jacks, knobs, and pickups. These are elements that can greatly affect live performances if there is an unforeseen problem, such as a bad connection, broken solder, or dust inside a knob. Not knowing how to fix these kinds of basic, everyday problems left me hostage to any failure in the signal chain, no matter how complex the problem. This apprehension can be summed up as a fear of exploring or damaging one's own equipment by not knowing its concept, and thus having to invest even more resources in fixing it by a third party.

I overcame this apprehension and fear of exploring through interdisciplinarity. It came in the format of understanding and deconstructing something in order to fix it in its reconstruction. This was one of the main drivers behind my master's, and my main objective with it was to "bring that same healing through the empowerment of doing/making/fixing things to the readers" (Quimelli, 2018a, p. 10). The solution came in the form of an optical theremin, but I have left it open so that it can be transformed according to the needs of each teacher who comes into contact with my work.

Right after I finished my master's, I worked in many different schools teaching music while adapting and refining these workshops. In these classes, I was faced with a challenge: the lack of interdisciplinarity in Brazilian schools. Although interdisciplinarity is addressed in the national curriculum, in my experience, it is often left out in practice. The school environment favours standardised testing, and teachers do not have the time – or energy – for interdisciplinary work with their peers due to long working hours. This situation places the

school subjects and contents restricted within predetermined boxes. It also leaves these subjects without practical application or dialogue with one another. It prevents students from observing school-received knowledge as interconnected with real-life situations. This ranges from using, or maybe even producing, augmented reality game apps on a mobile phone. It also includes building rockets and exploring space, which require knowledge of math, physics, chemistry, and geography, all interconnected. In my previous work, I linked science and art – physics and music to be more precise – using the theremin, but I have not used it to address specific curriculum topics in school. This matter is what drives my research in this doctoral thesis.

This study explores student engagement, peer interaction, and interdisciplinarity between science and music through a project using the electronic instrument, the theremin. It investigates Brazilian students aged 13–15 years engaging in workshops with the theremin and examines how students engaged in this specific project, including how engagement appeared across behavioural, cognitive, emotional, agentic, and social dimensions; how peer interaction developed while students explored, built, tested, and performed with the artefact; and how interdisciplinarity was promoted during the sequence of these workshops.

Although there is current research examining engagement in schools, this research is unique in that it uses an electronic instrument, the theremin, to work across music and science. This is a unique approach because the theremin makes the relationship between gesture and sound immediate and visible while also functioning as a buildable electronic artefact. This combination allowed the same object to be used for musical expression and for science-based making, creating a shared focus for experimentation, discussion, and collaboration across the two curriculum areas.

1.1 Science and Art

In my previous interdisciplinary work in the science and art field (Quimelli, 2018b), I tell the story of the theremin inventor – Leon Theremin – and the instrument itself. Along with my master's thesis, I also produced a manual on how to build a theremin (Quimelli, 2018a). This handbook was written for people with no previous skills in electronics or engineering and aims at empowering students with a do-it-yourself (DIY) attitude towards life itself. The activities proposed in these works were applied to higher education students – music educators in training – and proved to be successful in increasing the repertoire of musical–pedagogical activities of the next generation of teachers in two different public universities in the state of Paraná, Brazil, where I lived at the time.

This work was born from a desire to free myself from the inability to deal with basic everyday technologies (Quimelli, 2018a). Being in this hostage position brought me “aversion to exploration” (Quimelli, 2018a, pp. 9-10), and I found the cure for this “illness” through interdisciplinarity. Through learning how to build an optical theremin from the beginning, I, a person with no prior experience in electronics at all, developed a sense of empowerment through this hands-on work. Building the optical theremin opened new possibilities in my life and in the lives of my students, both academically and in daily life.

In the manual, I detailed the step-by-step process for building an optical theremin by a novice in the field of electronics. It was tested with two higher education students, who were able to build the theremin without any extra help from me just by following the instructions given in the manual. One of the goals of this manual was to spread access to this kind of knowledge, which, in prepandemic Brazil, was rare. We are talking about a population with fewer monetary resources and limited access to specialised knowledge. Before the surge of online courses during COVID-19, this gap was even more pronounced. We went from a shortage of specialised knowledge to a flood of information.

I consider that electronics itself is also a kind of art. We have to design (draw) the circuit and use our fine motor skills to build the proposed object using the soldering iron in the same way that we train our muscle memory to refine our touch on the instrument or to hold a paintbrush more securely to produce a painting.

In the manual I proposed building the optical theremin on a printed circuit board (PCB) rather than on an Arduino board. This allows the student to take the instrument home. Being able to show it to the community in which they live motivates them to return to the school system as this builds a bridge between what is done at school and their everyday lives. In this way, school ceases to be a parallel world to the student's life and becomes an extension or, in some cases, a continuation of their community existence.

The intervention I proposed in the 2018 work “presupposed changing people's lifestyles ... [but not in a] ... meaningless action” (Quimelli, 2018a, p. 6) because you cannot do an intervention just for the sake of it. For our actions as educators to be effective, we need to ensure that we provide something that genuinely enhances the recipients' quality of life (Quimelli, 2018a). The idea was to get the students to build something that belonged to them. In doing so “They will take back to their ‘habitat’ something that they have made themselves and this can encourage them to become motivated at school and empower them into making/building things” (Quimelli, 2018a, p.7). In this present study, I took my previous work

further by exploring not only the act of building as a form of empowerment but also how music-based activities – particularly through the use of the theremin – can foster student engagement, peer collaboration, and interdisciplinary learning across diverse school settings.

In an effort to address and understand these challenges, I began exploring integrative approaches as these have been proven to be motivating, capable of generating interest among students, and engaging for them. The integrative approach I have used – STEAM (STEM + Arts), which will be talked about in Chapter 2 – combines science, technology, engineering, arts, and mathematics. Within this approach, key elements include presenting science creatively and adopting a hands-on methodology.

These factors were present in my master's workshops as I not only presented science in a creative way but also in a constructive way, allowing students to build their own instrument. This hands-on construction was a decisive factor in choosing STEAM as it sparked students' interest. As a teacher in the Brazilian system for many years, I have faced challenges in fostering students' desire to acquire knowledge, whether due to the abstract nature of the content or the competition with increasingly pervasive media. Given the dominance of social media, the integrative approach seemed to me to be a promising idea.

1.2 Theremin

Invented in 1919 by the Russian Lev Termen (later anglicised as Leon Theremin), the theremin is considered one of the first electronic instruments ever created and is one of the main foci of this research. It is the direct father of the synthesiser and, hence, is responsible for electronic music existing as we know today (Martin, 1993). The theremin is a peculiar electronic instrument that works with variances in the capacitance of the electromagnetic field that it itself generates. These changes are produced when the player's hand invades this field and, thus, generates changes in pitch, creating an extraordinary effect of extracting notes out of thin air (Braun, 2009). This hands-free approach was largely used by Leon Theremin in his creations, which included the terpsitone – a theremin fused with a platform made for dancers; alarm devices in the 1920s; a colour television prototype in the 1930s; and spy devices in the 1940s that led to diplomatic problems in the United Nations (UN) between the former Union of Soviet Socialist Republics (USSR) and the United States (US; Glinsky, 2000).

The main concept used by Leon Theremin for his instrument is the heterodyne principle, which is a signal-processing concept in electronics that involves combining two different frequencies to create a new frequency that is the difference between the original frequencies.

This principle is commonly used in radio communication, audio synthesis, and frequency conversion. When two signals with different frequencies are mixed or combined, a frequency is generated that results from subtracting the two initial frequencies, and this is known as the heterodyne frequency. This concept is widely employed in radio communications where it is used to convert high-frequency signals into a lower-frequency range for easier amplification and processing. In the case of the theremin, this principle plays its part in generating sound by mixing the signal from the internal oscillator with the signal coming from the antenna.

The heterodyne principle found in the theremin is still used today in different areas such as oceanography and was also used on one of the spy devices used in the 1940s by the former Soviet Union, known as the Great Seal Bug. This consisted of a wireless passive microphone installed inside a Great Eagle Seal carved in wood and given to the US ambassador in the USSR as a gift from the Pioneers (Soviet boy scouts). When this was discovered – after long years of usage – the US used it as proof of Soviet espionage in a heated Security Council meeting at the UN during the Cold War (Glinsky, 2000). One of the unpredicted forms the concepts behind the theremin would take is as an enhancer possibility of a device to detect short-distance variations below water (Theodore & Henry, 2007).

The theremin's possibilities and usage come initially from mimicking classical instruments in a preestablished romantic/impressionist repertoire in the early 1900s. Considering this first school of the theremin, John Cage (as cited in Hicks, 2007) noted his dissatisfaction on the matter – taking the preproduced classical music as the highest standard. In a letter to the music critic and contemporary music advocate Peter Yates (1909–1976), Cage wrote: "Thereminists although theoretically interested in new music for the Theremin showed a preference for displaying their virtuosity and presented programs made up from classic music ending with the modern French School" (p. 511). Cage continues describing the instrument, regarding mostly the no-touching way of playing: "They are quite pleased with the mysterious, sensational way of playing the instrument (Look, Mama, no hands!), and thus have little time to consider what they're playing" (Cage, as cited in Hicks, 2007, p. 511).

In the following years, the theremin was widely used in sci-fi and horror movies in the 1950s, then in experimental pop music in the 1960s/1970s to a later revival in the 2010s where different artists use the theremin as a control voltage gate (CV) to modulate synthesiser parameters, like the French artist Coralie Ehinger, or build loops mixed with different instruments – human voice included. The main thereminist in the later approach is the German Carolina Eyck, an exponential musician who will be discussed in Chapter 4. Some take the

instrument even further with the production of binaural tracks and abandoning time signature and key, which is not something new to the music world but strayed far from the instrument's beginnings. Others use it as a psychological element to show the audience the ambivalence of repressed teenage female sexuality in a patriarchal Catholic society (Martin, 2016). These latter ideas and conceptions are used by Lucrecia Martel in her film, *The Holy Girl* (2004).

1.2.1 Biographical Works on the Theremin

In this section, 1.2.1, I provide a comprehensive exploration of the theremin instrument. The inclusion of details about the life of Leon Theremin serves as a crucial component in understanding the story behind this unique electronic instrument. The examination of Leon Theremin's life, inventions, and the historical context in which he operated is included as a deliberate contextualisation to show the evolution and significance of the theremin. This approach is needed to provide perspective on the instrument's journey from its inception in 1919 to its contemporary applications in education. The life of Leon Theremin, as explored through various biographical works and academic sources, is mixed with the instrument's trajectory, and it offers insights into the inventor's motivations, challenges, and the historical backdrop of both the man and his creation. This inclusive approach includes the technical intricacies of the theremin and its cultural, artistic, and societal implications as it resonates in diverse fields, such as music, science, and art.

There are three main biographical works about the theremin, and each of these has its unique view of Leon Theremin's life and the impact of his invention on the modern world. The first is Albert Glinsky's (2000) *Theremin: Ether music and espionage*. It tells the history of both the instrument and its inventor in a detailed manner – sometimes, the author recreates even small details of important events.

The second main work on Theremin's history is Galejev's (2010) *Soviet Faust: Lev Theremin, pioneer of electronic art*. Galejev was a close acquaintance of Theremin, and they worked together in many Light and Music conferences in Kazan (Galejev, 2010). He was also an admirer of Theremin's work due to his production in both art – music and light – and science – electronic and physics – fields. The author brings a more poetic approach to Theremin's life, comparing him to the late legendary medieval figure, the German medic and alchemist, Faust.

The third major work about Leon Theremin is Steve Martin's (1993) documentary, *Theremin: An Electronic Odyssey*. Martin interviewed close acquaintances of Theremin in the US and enthusiasts of his instrument that used the theremin in pop music and Hollywood

soundtracks. The “eerie” sound of the theremin is responsible for the “haunting” elements in the 1940’s and 1950’s horror and sci-fi movies and the experimentalism in the 1960s and 1970s. The documentary covers this ground, interweaving the detail with the “weird” life of Leon Theremin.

These works describe different aspects of the life of Leon Theremin and his inventions. Glinsky (2000) and Galejev (2010) are also keen on details and facts as they work to demystify key moments in Theremin’s life. One example of this is when Leon Theremin came home from the US in 1938, but the country he returned to was no longer the Russian Empire, it was the USSR. For many years, his friends thought that he had been kidnapped by the KGB and did not have any contact with him during that time – they did not even know if he was alive or not. This fact – the kidnapping belief – was held for decades as truth, although in Glinsky’s work, one can see that it was not the case. Leon Theremin faced mounting difficulties in the United States, including debts and tax problems, alongside broader social and political pressures, and he ultimately returned to the Soviet Union.

Another factor that was complicating Theremin’s life in America was his antidiscrimination view. Leon Theremin was married to an African American dancer called Lavinia Williams. This marriage caused a scandal in the conservative community of New York at the time due to Williams being both black and a dancer while Leon was a scientist and an inventor. This meant many contacts and sponsors boycotted him and this increased his will to go back to the USSR (Glinsky, 2000). However, things did not go as well as he planned – his wife saw him being escorted home by fellow Soviets – and the wrong information was spread. For many years, Leon’s friends thought he was kidnapped back to the USSR. When Theremin arrived in the USSR, he was not allowed to bring his wife or get in touch with her as she was an American, only increasing the misunderstanding of the situation.

Galeyev (2010) writes that, after Theremin came back to the USSR, he was imprisoned in a dishonest manner for unfair – or even no – reasons as many important, political, or scientific figures also were. He was confined in a gulag – a Soviet forced labour camp – in Magadan and forced to do hard labour. After some months, he was released and transferred to a sharashka in Moscow (Galeyev, 2010). The sharashkas were forced labour scientific laboratories that existed during Stalin’s purges and were commanded by Lavrentiy Beria.

1.2.1.1 Other Literature on the Theremin

There is a considerable amount of academic and contemporary literature on the theremin. From earlier articles on the theremin (Mendel, 1931; Vanel, 2008; Weissmann, 1927) – that show the mixed feelings of dislike and curiosity of Theremin’s contemporaneous composers – through to the 1960’s and 1990’s ones that exhibit uses of the theremin in Audio-Kinetic Structures (Mattox, 1969) along with experiments making active use of technology (Galeyev, 1991b; Koleyuk & Polyakoff, 1994). Leon Theremin’s legacy is complex, as narrated by Galeyev (1991a) and Glinsky (1992), and even involves Hollywood-worthy spy action in America in the 1920s and 1930s (Haynes et al., 2009). Psychology and art are debated in Di Sarno (2011; 2012), where he discusses representations of psychoanalysis in North American noir films and the theremin’s role within these cinematic codes.

The international theremin community was firstly represented in Gillard (1996) with many music productions using the theremin being catalogued by Hartnett (1996), Sauer (1996a; 1996b), and Brodsky (2004). Personal experiences from one of Theremin’s close relatives were reported in Kavina and Parcells (1996). A wider philosophical approach to life using the theremin as a comparative of human being relations and how they change to a floating body in space is brought by Hitchcock (1999). Feminine empowerment through music can be found in Frost (2011), and a synthesis of dance, movement, and theremin-like or variants are described in the works of Bevilacqua et al. (2011), Jones (2004), and Miller (2001).

Other crucial sources on both Leon Theremin and the theremin instrument history can be found in newspapers. There are many British Broadcasting Corporation (BBC) articles, such as Bailey (2004), Campbell (2015); Kan (2011), Kavina (2012), Sweet (2014), and Vennard (2012a; 2012b). There are also significant works in *The New York Times* by Grimes (1993); Martin (1993) in *The Independent*; and McGoogan (2016) in *The Telegraph* along with Tikkanen et al. (2019) in the *Encyclopædia Britannica*. A deeper analysis of these works and their significance can be found in my previous work (Quimelli, 2018a).

This is far from being an exhaustive scholarly list, but it suits the task of demonstrating the extensive interest in the theremin. These biographical accounts provide an essential historical and cultural context for understanding the theremin and its inventor. However, they offer limited direct guidance on how the theremin functions as an educational artefact in classroom settings. In particular, they do not explain, with classroom evidence, how the instrument’s affordances can support student engagement and learning across music and

science. This gap frames the focus of the present study, which examines what the theremin affords for engagement, interdisciplinarity, and peer interaction within a specific project.

The unique properties of the theremin – its accessibility, novelty, and capacity to merge artistic and scientific domains – make it an ideal artefact for exploring contemporary educational challenges. In the context of Brazilian schools, where students often experience fragmented curricula, limited resources, and postpandemic disengagement, the theremin offers a tangible way to break disciplinary barriers and foster both individual and collective empowerment. By enabling hands-on construction and collaborative performance, the instrument becomes not only a medium for interdisciplinary learning but also a catalyst for inclusion and peer interaction. These characteristics directly inform the guiding questions of this study, which seek to investigate the impact of theremin-based projects on student engagement, interdisciplinarity, and group dynamics in real-school settings.

1.3 Research Objectives

The main objective of this study is to examine how a theremin-based project can support student engagement in its behavioural, cognitive, emotional, agentic, and social dimensions in a Brazilian public school. A second objective is to understand how the same project can make connections between science and music more visible and available to students in their everyday schoolwork. A third objective is to analyse how peer interaction changes during the workshops with attention to help seeking, student initiative, and collaborative problem-solving.

1.4 Expected Contributions

This study aims to contribute in three main ways. At a conceptual level, it brings together multidimensional models of engagement with evidence from a theremin-based STEAM project in a postpandemic, public-school context. Methodologically, it shows how a qualitative case study using focus groups, teacher interviews, and a reflective journal can be combined to trace changes in engagement, interdisciplinarity, and peer interaction. Practically, it proposes a set of design principles for low-cost, artefact-based workshops – such as immediate make-test cycles, planned interdependence, and sending the artefact home – that other teachers can adapt when working with students who are often described as disengaged.

1.5 Structure of the Thesis

This thesis is organised into the following chapters:

- Chapter 1 – Introduction: Presents the research context of post-pandemic Brazilian public schooling, introduces the theremin project, and states the objectives and expected contributions.
- Chapter 2 – Literature Review: Examines research on student engagement (behavioural, cognitive, emotional, agentic, and social), music and science education, technology in music classrooms, interdisciplinarity and STEAM approaches, and existing work with the theremin as an educational artefact in teaching and learning, and states the research questions.
- Chapter 3 – Theoretical Framework: Details the conceptual models that inform the study, including multidimensional engagement frameworks, Expectancy-Value Theory, Motivational Engagement Theory, and work on high-risk behaviours and adverse experiences, and explains how these lenses are used to interpret the data.
- Chapter 4 – Research Design: Explains the qualitative case study design, the school context and participant groups, the structure of the theremin workshops (artistic and electronics), and the procedures for data collection and analysis, including the use of NVivo and constructivist grounded theory procedures.
- Chapter 5 – Context and Challenges: Describes the school environment and broader structural conditions, including post-pandemic effects, resource constraints, policy pressures, and forms of marginalisation that shape students' lives and their engagement with school.
- Chapter 6 – Findings: Presents and analyses the main themes emerging from the focus groups, teacher interviews, and reflective journal, including changes in group work, hands-on engagement, interdisciplinary connections, peer support, and practices that move between school and home.
- Chapter 7 – Discussion: Interprets the findings in relation to the theoretical framework and existing literature, examines how the design of the theremin project relates to patterns of engagement and peer interaction, and considers the strengths and limitations of the study.
- Chapter 8 – Conclusion: Outlines the study's contributions to theory and practice, notes key limitations, and proposes directions for future research and possible adaptations of the project in other school contexts.

CHAPTER 2 – LITERATURE REVIEW

To situate the workshop findings within formal schooling, this Chapter 2 reviews literature across four connected strands: student engagement in music, technology-supported music education, STEAM (STEM + Arts), and practices sustained across spaces. It moves from music-making as a social practice (informal learning, workshops, and social bonding) to debates about how technological tools reshape participation in music education, then to inquiry-oriented STEAM and the problem of integration, and closes by considering how engagement can persist beyond lesson time as practices travel between school, home, and other settings. Although the theremin is the linking artefact in this study, the review extends beyond theremin-specific sources to clarify mechanisms relevant to this project: collaboration around a shared artefact, iterative making, embodied representation, and student agency.

2.1 Student Engagement in Music

The central territory to be explored in this section is student engagement. Here, I focus on engagement as cooperative participation in small-group music-making, the inclusion and reengagement of students identified as “disaffected”, and persistence and ownership in self-directed tasks.

2.1.1 Informal Learning, Peer Autonomy, and Inclusion

Work on informal learning shows that when students start from familiar music, learn by ear, and work in friendship groups with genuine autonomy, classrooms tend to see stronger cooperation and inclusion (Green, 2008). Green (2008) reports a secondary-school project that adopted these practices across 21 schools in the UK within normal timetable time (about one hour per week). In the initial four to six lessons, students formed friendship groups of four or five, selected a song they knew and liked, and attempted to play it by ear on instruments of their choice, directing their own learning. Teachers first observed and then acted as “musical models” rather than traditional instructors (Green, 2008). At the end of this first phase, interviews with 200 students in 40 groups across seven schools indicated easier cooperation between students that improved over time. In my study, I am strongly inspired by this model because it aligns with my aim to examine how music can mediate group cooperation and the inclusion of disaffected students in classroom settings.

Accordingly, I use Green’s (2008) findings to pose a design-oriented question for this study: if informal, friendship-based, ear-led collaboration worked in Green’s context of popular

songs, what happens when the shared product is the optical theremin, an artefact students build and play, and that is small enough to take home? In other words, which affordances of the theremin enable similar cooperation, inclusion, persistence, and ownership, and how do these practices carry across classroom, peer, and home contexts?

In her work, Green (2008) illustrates the case of Tyler, a previously disengaged student who became actively involved in learning and assumed a leadership role when exposed to an informal, peer-directed learning environment. Tyler's transformation is credited to the autonomy and collaboration offered by the project's approach, which allowed him to reinterpret his relationship with learning. Green notes that Tyler had previously received lower grades (D–E) and had significant behavioural issues, yet during the project he began arriving early to set up equipment. Also, his group was described as almost the most positive in the class, and he and his peers earned mainly A grades. Field recordings also show him coordinating the staging of the final performance (Green, 2008).

Regarding inclusion, the teachers involved in the project observed that the intervention was suitable for learners of varying skill levels. The project employed what is termed “differentiation by outcome,” allowing the same task to adapt to individual abilities based on the outcomes they produced and not by clear “progressive levels of difficulty” (Green, 2008, p. 187).

Green (2008) also found that the absence of direct teacher instruction had a beneficial impact on the students' ability to cooperate in groups. The collective nature of the task contributed to an “organic type of group cohesion” (Green, 2008, p. 185). The students also gave feedback on the project, describing it as “fun” and appreciating the freedom of choice in terms of music choice, instruments, and learning strategies (Green, 2008). In my work, Green's findings serve both as design justification and as a comparative anchor for my workshops. The same mechanisms she documents – friendship-group collaboration, ear-based learning/choice, and teacher modelling – are mirrored when students coconstruct and troubleshoot the theremin, compose pieces, and take the artefact between school and home, which supports cooperative participation, reengagement of previously disaffected students, and sustained persistence/ownership (Green, 2008).

2.1.2 Workshops, Cobuilding, and Iterative Making as Engagement

Figaredo (2009) discusses music workshops as an informal educational response for young people at risk of social exclusion. In his research, reengagement involves both social skills

and changes in habits and attitudes, especially when students experience disrupted belonging and identity (Figaredo, 2009). He argues that learning can begin with experiences and interactions so that students develop a personal reason to learn and then accept new knowledge and values more readily. This emphasis on experience and participation aligns with the logic of artefact-based learning in my study.

Figaredo (2009) describes strategies that position students as contributors to the learning environment. He suggests that groups agree on common behaviour by consensus with students defining the rules in their own words. He also starts from student-proposed listening examples, followed by explanation and moderated discussion, followed by the tutor adding further listening and teaching (Figaredo, 2009). Figaredo notes that some unusual instruments were intentionally included, and he mentions the theremin as one example of the many instruments brought to the students to experiment.

Jakobsen et al. (2016) explored how children with no prior musical skills were empowered to express themselves musically by playing live. They enabled children to cobuild instruments and then perform them within a tangible, open-ended platform. Their project supported cooperative participation, inclusion of learners without prior skills, and persistence/ownership through iterative build-test-perform cycles (Jakobsen et al., 2016). The authors present a four-day workshop conducted at an elementary school in Denmark, facilitated by a tangible music-making platform called the “Hitmachine”.

Jakobsen et al.’s (2016) workshop involved children aged 3–13, who were divided into 11 different age groups. During the workshop, the children built and played their own musical instruments using Lego. The sessions were divided into an initial building/testing phase and a later concert phase where children performed on stage with their final instruments. The workshop aimed to empower children to “make expressive music without the need for prior musical skills” (Jakobsen et al., 2016, p. 46). This is another basic concept absorbed by my work as I brought music-making to students with little, or no, previous music training. Jakobsen et al.’s data analysis was based on more than 500 pictures and 12 hours of video material that revealed that age significantly influenced the children’s engagement and expressivity. They also emphasise the role of the Hitmachine – an open-ended building platform using Lego Mindstorms EV3 – as an expressive tool that was used to achieve a higher degree of musical expressivity. Sensor readings are sent wirelessly to a server that maps them onto a constrained musical framework: notes are limited to a suitable scale and quantised to the beat so beginners can participate without producing off-key or off-time output. The system provides tonal and

rhythmical support while still leaving room for exploration in how the physical instrument is built and performed.

2.1.3 Social Bonding and Reengagement

Engagement with music can also lead to prosocial behaviour. From an evolutionary perspective, Kirschner and Tomasello (2010) link musical behaviour and group cooperation and argue that music evolved to become a “tool that fosters social bonding and group cohesion, ultimately increasing prosocial ingroup behaviour and cooperation” (p. 354). They also explore the evolutionary and social implications of music-making. In their study, 96 four-year-old children were investigated to identify whether engagement in joint music-making activities could promote prosocial behaviour. Kirschner and Tomasello (2010) used a 2×2 design with condition and gender as the independent variables, and voluntary helping and spontaneous cooperative problem-solving as the dependent variables. The results revealed that children exposed to joint music activities, including singing and dancing, were more likely to engage in spontaneous cooperative and helpful behaviour towards peers compared to those in a nonmusical control group.

Kirschner and Tomasello (2010) also discuss various theories about the evolutionary origins of music. According to the authors, understanding these origins is relevant to comprehending music as a tool for building group cohesion and encouraging prosocial behaviours, both of which are important for student engagement. Some theories suggest that music evolved as a form of partner selection, proposing that “music-like behaviours first evolved by means of sexual selection, as individuals advertised for mates” (Kirschner & Tomasello, 2010, p. 355). Other theories suggest that music serves as a tool for social bonding. Once created, music and dance become powerful instruments for strengthening social connections and encouraging altruistic engagement within communities, “ultimately increasing cooperation and prosocial in-group behaviour” (Kirschner & Tomasello, 2010, p. 355). This perspective suggests that coordinated musical activities in educational settings, such as those using the theremin, may promote social engagement and cooperation among students. However, Kirschner and Tomasello’s empirical evidence is based on children singing and moving in synchrony, so the prosocial outcomes they report are linked to coordinated music-making rather than free exploration. In my study, I therefore use this perspective to interpret episodes where students clearly coordinated their actions and supported peers.

Following the line of music promoting prosocial behaviour, Hove and Risen (2009) state that music binds people together, inspires collective action, and deepens feelings of affiliation.

In their study, they demonstrate that peers synchronising movements, which they call interpersonal synchrony, directly increase social bonding and collective affiliation due to the alignment of the participants' actions. They found that participants who tapped in precise rhythm rated their peers as more likable whereas synchrony with an inanimate metronome produced no such effect.

Hallam and Himonides (2022) provide a synthesis of literature that shows how active music engagement can promote reengagement, self-esteem, autonomy, and social cohesion among young people at risk of disaffection. They argue that active engagement in music-making activities can significantly rebuild students' self-esteem, motivation, and sense of achievement, particularly among disaffected learners. They also emphasise the importance of autonomy and choice in music education, stating that young people's emotional investment increases when they are given control over aspects of their musical learning, such as instrument selection and creative decisions. Peer relationships and the development of group identity are also highlighted as outcomes of collaborative music-making. Hallam and Himonides (2022) stress that sustained engagement in music education requires activities to be culturally and personally relevant to participants. These elements will also serve as key foundations for interpreting the findings of this study.

In addition to linking music, engagement, and social cohesion, Hallam and Himonides (2022) situate reengagement within wider social conditions: young people in high-deprivation contexts are more likely to become disconnected from formal schooling. They are also more prone to show related symptoms of disengagement, both at school – such as poor behaviour – or in the wider community – such as involvement in the criminal justice system (Hallam & Himonides, 2022). The authors provide broad syntheses showing that active music-making relates to intellectual, social, and personal development. This is reinforced when programmes are sustained over time, are relevant, and offer genuine learner ownership. This framing is directly applicable to the students in my workshops, whose everyday limitations and local contexts shaped how theremin-based activities were received.

Motivation problems are widely reported across formal schooling. Patterns such as boredom, absence, exclusions, and higher dropout rates are often more visible in large urban systems (Hallam & Himonides, 2022). Rather than a single cause, these are framed as person-environment issues in which identity, feedback, and goals shape behaviour (Hallam & Himonides, 2022). Some students even describe school as a “game” done with “as little effort as possible” (Hallam & Himonides, 2022, p. 319).

One of the major long-term effects of the lack of motivation is that young individuals from disadvantaged socioeconomic backgrounds are less likely to participate in higher education (Hallam & Himonides, 2022). This perpetuates systemic inequality, an issue that has been tackled for decades in the Brazilian system. This lack of representation – of this population in higher education – is also generated by the insufficient motivation “to sustain engagement with formal learning in the short-, medium- and long-term” (Hallam & Himonides, 2022, p. 319), and the authors create a link with engaging in learning and being a long-term participant in the school system. Hallam (2015) and Hallam and Himonides (2022) support the central hypothesis of this thesis: that practical and creative music workshops, such as the ones that I held with the theremin, have the potential to reengage disaffected students, improve their social and emotional skills, and strengthen their relationship with the school environment.

Rumberger and Lim (2008) reviewed 25 years of research, based on 203 published studies, to identify statistically significant predictors of high school dropout and graduation. They argue that one of the most important behavioural predictors is student engagement, which includes active involvement in academic work, such as coming to class and doing homework, and participation in the social life of school, such as sports or other extracurricular activities. Rumberger and Lim (2008) also report that high absenteeism, as one specific indicator of engagement, is consistently associated with higher dropout rates. At the same time, Rumberger and Lim (2008) note that it is difficult for any single study to demonstrate a causal relationship between one factor and the decision to quit school, even when many studies point to a strong connection. In this thesis, I use this frame to situate music-making as one possible form of school participation that may support engagement and connectedness.

Burnard (2008) presents a phenomenological, multiple-case study with three secondary music teachers in underachieving English schools. This research examines teachers' perceptions of how inclusive classroom approaches that are grounded in creative, public-facing projects may support the reengagement of disaffected learners. In Burnard's (2008) study, teachers reframed music learning as a social practice with community building, shared authority, and a premium on respect and recognition. They partnered with visiting artists and other external experts while using authentic community venues, such as churches and cathedrals. These arrangements offered an alternative form of producing music and created a concrete reason to commit to music learning, including public performance goals (for example, a concert). These design choices were described by the teachers as supporting cooperative participation, inclusion of pupils who were previously disengaged, and sustained effort around real performance goals (Burnard, 2008).

Burnard (2008) frames these inclusive practices in three strands: “democratizing the music learning process as social practice” (p. 68), “re-engaging learners through high status creative projects” (p. 68), and “re-engaging learners through digital technology” (p. 70). In the first strand, inclusion is treated as a question of how learning is organised. The emphasis is on building a classroom community in which students gain status through participation, and where power and decision making in music learning are shared rather than held only by the teacher. In this account, respect and recognition are not presented as a general positive atmosphere. They are described as practices that are produced and negotiated in interaction, including “performing respect,” while boundaries and power relations are renegotiated in the classroom.

In the second strand, reengagement is linked to “high-status” creative projects that are visible and meaningful beyond routine classroom tasks. Burnard (2008) describes projects supported by external experts and wider community links, often with public presentation, where recognition and authenticity matter to students who have previously disengaged. This strand also links participation to shifts in how students are positioned in the group, including opportunities for learners to “cast off their negative reputations” (Burnard, 2008, p. 68) and reinvent themselves through visible and valued contribution.

In the third strand, digital technology is presented as a practical route into creative and collaborative music-making with information and communication technology (ICT) embedded in the work students do. In this account, technology supports access and recognition, including for learners who feel blocked by prior requirements like instrumental training or specialist musical literacy (Burnard, 2008). Taken together, these strands offer a coherent frame for reading how music activities may support reengagement while also making it clear that the mechanisms depend on what kind of participation the setting enables.

This emphasis on technology as embedded practice is relevant to my project because the therein workshops combined collaborative music-making with hands-on electronics and iterative troubleshooting. In this sense, participation was not limited to performance. Students could enter the activity through building, testing, adjusting, and helping peers, and these forms of contribution could be recognised within the group even when students had limited prior musical training. This also sets up a transition to other literature that examines how structured group music programmes can support behavioural and affective outcomes beyond musical learning, including with students who present challenging behaviours.

Choi et al. (2010), a team spanning music therapy, medical research, and child psychotherapy, report a pilot-controlled study with 48 children (10–12 years) identified as highly

aggressive. A certified music therapist led 50-minute group sessions twice weekly for 15 weeks, combining singing, libretto work, instrument building/playing, and songwriting. Relative to an untreated control group, the music group showed greater posttest reductions in aggression both on parent and teacher ratings. They also reported higher self-esteem and had no attrition across the programme (Choi et al., 2010). The authors note limits (nonrandom allocation, no active/attention control, no blinding) but argue that the comparative design offers practice-relevant evidence for behavioural and affective development via group music.

This section 2.1 explores how engagement can be promoted through music and interdisciplinary activities in educational settings. Drawing on works by Green (2008), Jakobsen et al. (2016), Kirschner and Tomasello (2010), Hallam and Himonides (2022), Burnard (2008), and Choi et al. (2010), it presents the role of informal learning, peer collaboration, group cohesion, emotional regulation, and creative expression in reengaging students, particularly those at risk of disaffection. Research shows that music-making fosters social bonds, encourages cooperative behaviour, enhances self-esteem, and offers alternative pathways into education for disengaged learners. These findings provide the theoretical foundation for my study, which investigates whether interdisciplinary workshops combining music and science, specifically through the use of the theremin, can promote behavioural, social, and cognitive engagement among students in the Brazilian public school system, particularly for those students showing signs of disconnection from formal education. The study also aims to understand how peer collaboration, autonomy, and cultural relevance influence students' willingness to participate actively in learning processes.

While this Section 2.1 examined how musical engagement and collaboration can promote student reengagement, the following Section 2.2 explores the role of technology in music education and its potential to expand engagement opportunities through innovative and socially situated practices.

2.2 Technology, Music Education, and Engagement

In this Section 2.2, I examine how researchers have theorised the role of digital technology in music education and student engagement. I present Tobias's (2017) distinction/assimilation framework and his use of Hayles' (2012) account of technogenesis. I then situate it alongside work by Uptis (2001) on "spheres of influence" between research, classrooms, and communities; VanderLinde's (2017) discussion of inclusion and access in music technologies; Peters' (2017) discussion of participation, multimodal learning, and the social implications of technology-rich music education; Medvinsky's (2017a) discussion of meaningful

and relevant technology integration; Merrick and Joseph's (2023) study of Australian teachers' technology use during and after COVID-19; Howell's (2017) account of technology, play, and informal participation; and Rexhepi et al.'s (2024) quasiexperimental research on digital tools in music education in order to ground my use of the theremin.

Tobias (2017) argues that technology can play a generative role in the music classroom as this "sparks interesting ways of thinking about or engaging in music" (p. 291). Tobias's study is based on his personal experiences as a music educator in the United States. He worked with middle-school students, integrating various technological tools, such as digital audio workstations, mobile apps, and online resources, into music education. He believes in technology's potential to mediate culture, social contexts, and research. Although his discussion is grounded in contexts with widespread access to technology and supporting infrastructure, he is concerned with situating this technology to "address social and cultural issues or contexts and expand opportunities for people to engage with music" (Tobias, 2017, p. 292).

From a broader policy and curriculum perspective, Upitis (2001) notes that large-scale investment in computers and networked technologies has often coincided with cuts to arts and music education, despite strong evidence that sustained musical participation benefits cognitive, social, and emotional development. She argues that technology in music education is justifiable only when it deepens musical experience, supports participation in school and community musical life, and helps young people to become more fully human rather than serving as a symbol of modernity in itself. In this sense, the theremin in my project is positioned not as a replacement for existing musical practices but as a simple, tangible technology that extends collective music-making and the circulation of music between school and home.

Tobias (2017) criticises technicist education that does not create links with artistic and humanist inquiries. He suggests that this lack of connection occurs when technology is isolated from music education and has no link to "social, cultural, or musical contexts" (Tobias, 2017, p. 292). For Tobias, technology, when used by music educators, must be related to different contexts, such as historical, social, and musical. For him, different perspectives, such as curriculum, philosophy, and pedagogy, play fundamental roles in this context. One of his defences is that music educators must rebuild their vision of curriculum and technology to reach these contexts.

In a complementary way, Upitis (2001) uses the idea of "spheres of influence" to argue that music education research should speak not only to academics but also to teachers, children, and families. Through narrative accounts of children composing, performing and using digital

media in school and community settings, she shows how musical learning is distributed across homes, classrooms, and neighbourhood spaces. For Uptis (2001), research and technological tools need to circulate children's musical lives in forms that practitioners can use, reducing the distance between scholarship and everyday practice. This focus on accessible research and on children's creative work as a legitimate site of inquiry strengthens Tobias's (2017) call to narrow the gap between research, curriculum, and classroom music-making.

Howell (2017) adds another layer by bringing technology into conversation with informal learning, play, and innovation. Drawing on examples from youth centres, community centres, youth clubs, churches, and internet cafés, she argues that technologies are most educationally powerful when they support open-ended, playful exploration in flexible social environments rather than being confined to tightly structured, institutionally constrained activities. In her account, context, informality, and play loop together: the available technologies in a given setting shape what young people can do; informal, loosely structured activity invites experimentation and shared problem-solving; and musical innovations often emerge from this playful work with constraints. This perspective speaks directly to the free exploration phases of my project, such as the "conversation between theremins" and drawing/painting as notation where the theremin acted as a simple technology around which students could improvise, test ideas, and coconstruct musical gestures.

VanderLinde (2017) adds an inclusion-oriented lens to this literature by focusing on how music technologies can reduce barriers to participation for learners who are marginalised by conventional formats, including students with physical and motor challenges. Drawing on Universal Design for Learning, she emphasises designing activities with multiple pathways for engagement and expression so that students can participate through different roles and modes of action. In this sense, inclusion depends on how educators structure access to tools, tasks, and peer interaction.

Peters (2017) adds a critical contemporary frame to debates about technology in music education by arguing that the key question is not whether to use digital tools but how and why they are used. He notes that claims about increased access, motivation, and student-centred learning sit alongside concerns about attention problems, isolation, and disparities in learners' comfort and experience with technology, and he argues that technology-rich practice should remain socially and musically meaningful. Peters also points to the way mobile, voice, and gesture-based interfaces can lower barriers to music-making by enabling learners to create without long periods of technical training or traditional notation. This perspective supports my

use of the theremin as a gestural instrument that invites immediate exploration and feedback while keeping questions of purpose, context, and participation in view.

Medvinsky (2017a) adds a practical lens on what meaningful integration looks like in music education. He distinguishes between occasional use of digital tools and integration that treats technology as a central part of everyday music learning rather than an add-on activity. In his account, technology works best as a transparent scaffold that keeps the focus on the musical experience while expanding students' voice and choice. He frames technology as supporting core musical processes, such as listening, performing, creating, improvising, and reflecting, when aligned with clear musical intentions. Read in these terms, the optical theremin in this study was positioned as a regular tool for music-making and discussion so that students could create, perform, listen back, and reflect as part of classroom practice rather than completing isolated technology tasks.

Merrick (2020) adds a pedagogical layer to this discussion by arguing that technology mediated music teaching requires more than transferring existing content to a new platform. In his Adaptive Teaching Framework, the redesign of curriculum, assessment, and learning tasks is tied to opportunities for students to demonstrate understanding in multiple formats and contexts, with increased attention to accessibility, self-regulation, interaction, and participation. Merrick and Joseph (2023) provide a more recent, post pandemic snapshot of technology in school music. Drawing on an anonymous survey of 105 Australian music teachers, they examine teachers' confidence, preferences, and usage of ICT devices, resources, and software after the shift to online delivery. Their findings show that digital tools have become an essential component of music teaching during and after the pandemic shift to online delivery, yet teachers vary in how confidently and creatively they use them. Merrick and Joseph call for ongoing professional learning and attention to teacher education and preparation for online delivery so that technology supports rich musical engagement instead of just reproducing traditional tasks on digital platforms.

Tobias (2017) proposes changing the way educators engage students in music and raises the question of whether there is any transformation of human material after the use of technology and in which areas this change occurs, whether cognitive, social, or physical. He takes a stand against the technological deterministic perspective, "a stance asserting that technology determines or causes change to occur" (Tobias, 2017, p. 293), and, for this, he makes use of technogenesis, a perspective brought by Hayles (2012) that makes reference to the relationship of the human with technology as coevolution, in which both undergo coordinated

and constant transformations. From this perspective, the relationship between technology and the user's daily life is more important than the user's relationship with the technology itself.

Tobias (2017) also borrows the assimilation and distinction frameworks from Hayles (2012). In the case of assimilation, the educator uses technology as a tool to extend what already exists. The curriculum and practices are modified, but there is no transformation in music education as this approach replicates what is already established as practice. This strategy limits the use of tools with innovative potential, such as "gestural control" (Tobias, 2017, p. 294), which is intrinsic to the theremin and was central to how the instrument functioned in my research. If this gesture is just the change of input to an already established practice, there has not been a structural change in the practice. In the case of distinction, the unique or innovative aspects of the technological apparatus are emphasised as well as its relationship with learning, music, and engagement, reaching deeper changes in curricular proposals.

Tobias (2017) demonstrates a clear contrast between assimilation, assimilation-distinction, and purely distinction with three different case studies – which he calls "images of potential praxis" (p. 297) – and clearly advocates for the last. The three images show different proportions of "change, goals, or outlooks on music education" (Tobias, 2017, p. 297). The first case is that of a teacher concerned with the high performance of his students and with the desire to increase the effectiveness of his essays. For these, he uses applications to check the intonation of instruments and automation of pitch and rhythm assessment, digital fingering charts, research on composers on the internet, software to write music, and cloud-based resources (Tobias, 2017). In this case, technology is used as assimilation to renew the way students approach music; however, the students view of music itself is not renewed. Tobias calls this transformation a "modification" (p. 297).

The second case exemplified by Tobias (2017) is of a teacher who used the Kodály and Orff method for several years in her educational path and has a mixture of pedagogies in her classes that makes them interesting – Kodály is a singing based approach using folk songs and solfège, while Orff centres on rhythm, movement, and improvisation with classroom instruments. While she previously used technology for assimilation, now she creates music with students using iPads in ways that would not be possible with Orff instruments. Her students modify and alter sound waves recorded by their recorders in apps, and opportunities are provided to visualise the sound wave in different ways, thus enhancing their artistic expression. Although she took a step further than the previous teacher, her curriculum continues to focus on teaching the traditional elements of music (Tobias, 2017). This case is a bridge between

assimilation and distinction but without reaching the full potential of technological assimilation. Tobias (2017) names this transformation “integration” (p. 298).

In the third case, the focus on musical possibilities goes beyond traditional music practices, exploring new and innovative ways of making and experiencing music. Students build instruments using the computer, manufacture circuits and sensors, explore how music interacts with science, and “relate their engagement to that of other instrument makers across cultures and history” (Tobias, 2017, p. 296). Video games and improvisation are explored as well as nonlinear and dynamic music. Students are also encouraged to explore different positions and points of reflection and perception as a performer, producer, composer, and facilitator as well as analysing the potential of new technologies. The focus on distinction leads the teacher to build an education that is revolutionary and student centred. In this last and real transformation, educators adjust the curriculum and practices inspired by the new possibilities that these technologies offer (Tobias, 2017).

Uptis (2001) raises a complementary concern. She shows that enthusiasm for digital tools can displace time and funding for singing, instrumental work, and composition in schools if technology is treated as an end in itself. Her account of a school community picnic, in which shared musical activity anchors belonging for students, families, and teachers, suggests that decisions about technology should be judged by the quality of musical and social participation they enable. Read together, Tobias (2017) and Uptis (2001) push against technocentrism and keep questions of curriculum, culture, and community at the centre of decisions about music technology.

Empirical work on technology-rich music classrooms adds detail to this conceptual picture. Merrick and Joseph (2023), drawing on Australian music teachers’ experiences of ICT during and after the COVID-19 pandemic, document how teachers combined learning-management systems, notation and recording apps, and video platforms to keep musical activities going when face-to-face teaching was disrupted. They describe new possibilities for student composition, recording, and sharing but also report inequities of access, increased workload, and the need for sustained professional learning if teachers are to use digital tools in ways that genuinely support musical learning and engagement. Their findings underline that distinction-type practices depend on infrastructure, support, and curriculum aims, not on software alone.

A more student-centred account of music technology pedagogy is offered by Pierard and Lines (2022), who examine DAW¹-based learning with secondary school students in Aotearoa New Zealand through a constructivist lens. They argue that music technology classrooms should not simply reproduce conventional music teaching strategies, because DAW learning often involves different multimodal affordances, autodidactic habits, identity work, and creative priorities. Their study is especially relevant here because it frames technology not just as a tool for efficiency, but as a medium through which students make decisions, express who they are, and approach music in ways that may not fit older curricular sequences. Read alongside Merrick and Joseph (2023), this reinforces the point that meaningful technology integration depends not only on access and teacher confidence, but also on whether pedagogy recognises the forms of creativity, agency, and learning that technology-rich music practices actually invite.

On a different scale, Rexhepi et al. (2024) examine digital tools in tertiary-level music learning. In their quasi-experimental study, 40 first-year university students (aged 19–22) took a course in performance history and were divided into experimental and control groups. The experimental group engaged with digital platforms and music technology tools, including resources such as YouTube and Coursera, and a music creation environment such as Soundtrap. The authors report higher posttest performance for the experimental group and survey results indicating more positive engagement-related perceptions while also noting practical challenges for implementation, such as unequal access to equipment and limits in teachers' technical skills. They conclude that clear pedagogical goals and scaffolds are necessary if digital tools are to support learning rather than create new barriers.

Technology per se is not the bringer of change or “impact” as Tobias says. What brings this impact is the way in which educators use, take advantage of, and “situate” technology. As seen before, it is possible to introduce many new technological means without changing the teaching structure or curriculum and maintain the same status quo as hundreds of years ago. To embrace a real revolution through distinction, strategies are needed to change not just the medium of education but how “music teaching and learning look or sound like” (Tobias, 2017, p. 297). According to Tobias (2017), impact does not flow from the mere presence of devices but from how educators and students deliberately situate technology in practice and context.

Tobias (2017) raises the question of whether educators should interrogate and challenge the cultural and social contexts in which they operate. This questioning must be done in case these educators wish to achieve greater student engagement. However, Tobias also puts

¹ Digital audio workstation

his reservations on the question of distinction and how it should not become the primary focus of a music educator who wants to insert technology in their classes. Distinction without a strong pedagogical and philosophical foundation “can result in music educators’ making ongoing changes based on the latest technology regardless of its implications for students’ musical engagement or learning” (Tobias, 2017, p. 299).

Tobias (2017) argues that music education should reduce the gap between scholarship and classroom practice. He also suggests that technology use should address cultural and social problems, and that teachers should move beyond *techné*, the technical craft of teaching and making music. He finishes his point by advocating that technology should be used for students’ musical and personal growth, and in a beneficial way. For this, artistic and humanistic thinking must be used by “thoughtful, creative, and critically minded educators” (Tobias, 2017, p. 306). In this concept, technology should serve students’ musical and personal growth, and, for Tobias (2017), this demands thoughtful, creative, critically minded educators and programmes of teacher education that cultivate such judgement.

Taken together, these authors sketch a continuum of technology-rich music education. Tobias (2017) and Upitis (2001) offer conceptual and narrative frameworks for understanding how digital tools can reshape curriculum, practice, and the relationship between research, classrooms, and communities. Howell (2017) brings attention to the role of context, informality, and play in technology-mediated music learning, showing how open-ended, exploratory work with digital tools can generate new musical practices and forms of participation. VanderLinde (2017) and Peters (2017) keep questions of access, participation, and social implications in view while also foregrounding how interfaces and activity design can lower barriers to music-making. Merrick and Joseph (2023) show how music teachers, under real-world constraints, improvise with available technologies to support participation while negotiating access and workload. Rexhepi et al. (2024) provide quantitative evidence that carefully designed digital environments can improve music learning outcomes and participation, provided that teachers receive support and that tools are integrated with clear pedagogical aims. Medvinsky (2017a) adds a practice-oriented account of meaningful integration, arguing that technology should be central to everyday music learning, support core musical processes, and increase students’ voice and choice without shifting attention away from musical experience.

This study aligns with that body of work by using the theremin as a technology that does more than digitise existing exercises. The optical theremin functions as a gestural interface that links science and music, gives immediate audible feedback, and moves between school and

home. In Tobias's (2017) terms, the project seeks distinction rather than assimilation, and, in Uptis's (2001) sense, it attends to multiple spheres of influence by valuing students' creative work and everyday contexts. In Howell's (2017) terms, the workshops created informal, playful spaces around a simple technological object in which context, exploration, and shared problem-solving were central. In VanderLinde's (2017) terms, the project also treated participation as an inclusion problem, designing tasks and roles so that students with different motor profiles could contribute meaningfully through multiple pathways and peer-supported interaction. In Peters' (2017) terms, the project also treated technology as a pedagogical and social choice, attending to how and why the theremin was situated in tasks that were musically meaningful, collaborative, and accessible within a context marked by postpandemic constraints and uneven access to resources. In Medvinsky's (2017a) terms, the project aimed for meaningful integration by treating the theremin as part of everyday music learning and using it to support core musical processes while increasing students' voice and choice. In Chapter 6, I show how this technology supported engagement and learning in ways that resonate with, and extend, these wider accounts of technology, music education, and student engagement.

2.3 STEAM (STEM + Arts)

This section synthesises STEAM literature by comparing what different authors mean by "integration", what they prioritise (concept development, participation, empowerment, embodied inquiry), and what those differences imply for a theremin-based programme. "Theremin based" here means a programme in which the theremin is the organising locus for the tasks and for the links between science and music rather than just an example used occasionally.

2.3.1 Definition of and Framework for STEAM

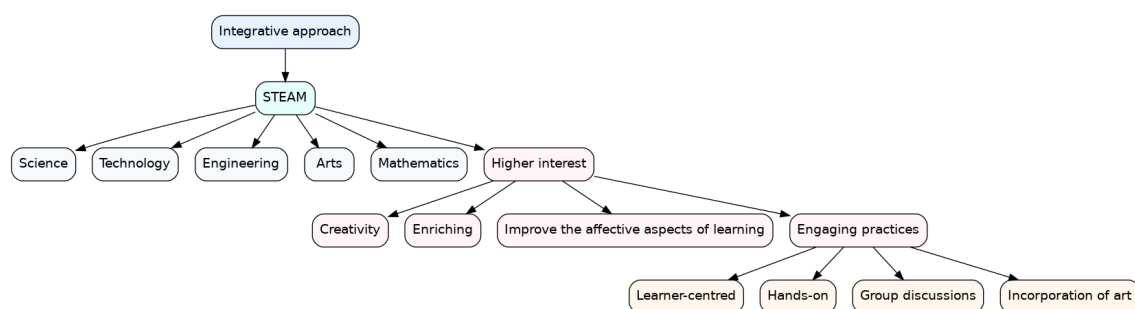
The arts can enhance science teaching and learning. Chu et al. (2019) present a theoretical framework for integrating the arts into an established STEM curriculum. They show how theoretical elements translate into classroom practice and propose intercultural interaction and arts integration in the curriculum (Chu et al., 2019). Grounded in social constructivism, situated learning, and the 5E instructional model for inquiry cycle, the authors explain how these ideas guide lesson design and classroom practice. This design-led account provides the point of comparison for other perspectives that treat "integration" as transdisciplinary reshaping between fields (de la Garza & Travis, 2019), embodied inquiry (Long & de la Garza, 2019), and participation and voice in technology-mediated practice (Medvinsky, 2017b; O'Neill, 2015), alongside a curriculum lens on meaningful task design (Hodson, 1992).

Chu et al. (2019) describe a STEAM programme designed to address both conceptual learning in science and students' affective responses to science learning across different schooling contexts. They designed and trialled a STEAM programme across schools in Australia and Korea, using arts-based activities, small-group discussion, and digital tools to connect students across contexts. Their central argument is that arts integration can support science concept learning while also strengthening affective outcomes, such as enjoyment, confidence, and interest, when it is organised through an inquiry sequence and collaborative model building.

Chu et al. (2019) conducted their research in response to a pressing need in Oceania and East Asia. Australian students were demonstrating both lower science performance and interest in the subject. Korean students, despite achieving higher performance in science, showed low enjoyment and confidence in this area. This is directly connected to my work as the population I catered for in my workshops could also be considered as experiencing similar issues of disengagement and lack of enjoyment.

As previously discussed in this Section 2.3, the STEAM concepts worked on by Chu et al. (2019) are grounded in social constructivism, primarily based on the idea that collaboration and integration between learners, and between learners and their environment, contribute to cognitive development and also result in the collective construction of knowledge. Chu et al.'s (2019) model functions as the main design guide for STEAM in my work. Their approach is summarised in Figure 1.

Figure 1
Chu et al.'s (2019) Integrative Approach



Note. This figure was created by this thesis' author.

Within social constructivism, there is the concept of situated learning, which allows students to experience a scientific concept through their relationship with the environment. To illustrate this, Chu et al. (2019) present the example of understanding the tilt of the Earth's axis

through conversations between students from different hemispheres, held simultaneously. In these exchanges, students can share information about the weather and realise that while some are experiencing the cold of winter and need to dress for snow, others are enjoying the heat of summer, eating ice cream at the beach over the weekend — and that both happen at the same time. This enables students to see, in practice and through social interactions, the effects of a scientific concept while also engaging them in a form of cultural integration, which is part of the STEAM approach.

This example of seasons came from Chu et al.'s (2019) programme, which was trialled in schools in Australia and Korea through six lessons across four science modules, delivered in four primary and two secondary schools; each module integrated arts activities, small-group discussion, and the use of digital tools to connect classes in the two countries. In class, lessons began with engagement with a phenomenon, moved to small-group exploration and the posing of questions, then to the creation, refinement, and evaluation of explanatory models with students representing and testing ideas through diagrams, drawings, and kinetic models, and sharing work via online platforms and video calls between the two countries.

The framework presented by Chu et al. (2019) focuses on aspects such as performance but also on enjoyment, confidence, and interest. There is a balance between doing it well and enjoying doing it in their proposal. They suggest an integrative approach where science is considered an area of knowledge that can be connected with the humanities and mathematics and not a knowledge or skill that is isolated in the curriculum. According to Chu et al. (2019), incorporating the arts into science lessons offers students the chance to learn science concepts in more imaginative and engaging ways.

Creativity and engagement are crucial to stimulate and awaken students' interest in the STEAM approach (Chu et al., 2019). Opportunities should be designed with the learner in mind with "hands-on activities, group discussions and incorporation of interdisciplinary content from the arts, humanities and social sciences" (Chu et al., 2019, p. 1252). In this way, STEAM can attract students' interest while maintaining a focus on conceptual development as this approach enhances students' learning experiences and strengthens the affective and emotional aspects of learning as well as creating opportunities to collaborate with their peers and the teacher (Chu et al., 2019). Chu et al., 2019 offer a design-oriented guide for science educators developing a STEAM programme.

For Chu et al. (2019), the main objective of STEM teaching is the development of concepts, and art serves to catalyse this objective, and not the other way around with STEM

catalysing art. Despite the insertion of art, STEAM's focus is still based on improving the teaching and learning of science itself and engaging students in the study of STEM. For this, the authors are dedicated to building a theoretical framework to strengthen science teaching and learning using social constructivism, collaborative learning, and inquiry-based teaching.

Within Chu et al.'s (2019) framework, learning builds on coconstruction among learners and with the environment, with new findings connected to prior knowledge and used to guide subsequent investigations. Incorporating arts and culture into science education teaches students something they are unlikely to experience in traditional science lessons: the importance and relevance of science in the cultural events they encounter in their everyday lives (Chu et al., 2019).

2.3.2 Inquiry-Based Teaching

Situated learning aims to increase motivation and interest in science (Chu et al., 2019). According to Chu et al., this interest and motivation create an authentic experience for the learning process. To strengthen their case, the concept of the inquiry-based teaching spiral is applied. In this case, the spiral is based on engage, explore, explain, elaborate, and evaluate, or, as the authors call it, the 5E instructional model. For the authors, the approach of using the spiral with inquiry-based teaching supports scientific thinking focused on core science ideas (Chu et al., 2019).

Inquiry-based learning is fuelled by sharing with peers about their own scientific learning and working together to solve problems, thereby increasing student engagement. For Chu et al. (2019), this approach produces ideas and engages the students in science practice and scientific thinking. This integrates culture and arts into science as part of concept development. Recent inquiry-based learning research extends Chu et al.'s design claim by clarifying the enabling conditions for classroom inquiry, and by showing how teachers often combine inquiry with structured instruction to secure both conceptual outcomes and participation.

Strat et al. (2024) synthesise research on inquiry-based science education (IBSE) in science teacher education and show why inquiry can be difficult to enact without strong pedagogical support, especially during school placement. They report that "challenges" are not only about time and resources. They also include pedagogical challenges, such as deciding the content focus and the appropriate scope of an inquiry task, and instructional challenges, such as eliciting students' ideas and curiosity and scaffolding students to interpret and discuss their data. They also describe conceptual challenges in preservice teachers' understanding of inquiry itself

as, for example, uncertainty about the role of hypotheses in inquiry and how hypotheses differ from simple predictions. A further challenge they identify is the tension between university-based ideals and placement realities. Preservice teachers may value inquiry but struggle to implement it when mentors do not use inquiry approaches, when classroom management feels risky, and when curriculum demands push teaching towards more tightly controlled formats. Strat et al.'s (2004) review is based on 142 empirical studies (2000–2022), and it organises reported difficulties into extrinsic constraints, pedagogical challenges, and intrinsic challenges in understanding inquiry and its purposes.

Sturrock et al. (2025) offer a close look at how inquiry and direct instruction actually appear in everyday science lessons in Australian primary and secondary settings. They did not run an intervention. Instead, they combined systematic classroom observations, coded using a structured observation protocol, with teacher interviews that probed reasons for pedagogical choices. Their dataset included 56 observed lessons taught by 19 teachers. They found that inquiry episodes were more frequent in upper primary lessons than in lower secondary lessons. They also found a difference in how inquiry and direct instruction were combined. Primary teachers usually alternated the two approaches within the same lesson, using questioning and practical activity to connect evidence to concepts. Secondary teachers tended to begin with direct instruction for conceptual coverage and then moved to practical work that sometimes included inquiry elements. When teachers explained why they taught this way, they pointed to constraints, such as assessment pressures, curriculum coverage expectations, textbook requirements, the workload and stress of practical work, and beliefs about students' self-regulation, that shape what is feasible. In this account, "challenges" are the practical and institutional conditions that narrow teachers' room to run sustained inquiry, even when they see value in it. In Sturrock et al.'s sample, inquiry was present in 88% of upper primary lessons and 44% of lower secondary lessons, and it accounted for around 48% of coded lesson time in upper primary compared with around 18% in lower secondary.

Xu et al. (2024) examine inquiry-based teaching in a high-pressure upper secondary context in China and link it to student outcomes in scientific creativity. They used a quasi-experimental design in one public secondary school in Taiyuan City. A biology teacher delivered five inquiry-based lessons over two months in three Year 10 classes, taught every two weeks. After data cleaning, the intervention group included 102 students aged 15 to 16 years, and the control group included 245 students across seven classes. The authors measured pre- and postchanges using creativity-related outcomes and compared groups. They report statistically

significant improvements in divergent thinking and convergent thinking for the intervention group but no differences in attainment scores or motivation in scientific creativity.

Xu et al. (2024) also collected lesson observations and interviews with the teacher and students to interpret implementation. This qualitative material points to constraints that are specific to exam-oriented systems where teachers worry that inquiry “covers fewer test points” (p. 13) within a limited time and may therefore risk performance. Xu et al. (2024) provide a recent example of inquiry being beneficial for how students think while also showing that inquiry requires design choices that address time, curriculum priorities, and teacher confidence about what knowledge is being secured. Taken together, these studies help interpret Chu et al. (2019) as a deliberately structured inquiry model: their 5E instructional model sequence, collaborative model building, and guided representations can be read as design responses to exactly the kinds of pedagogical, institutional, and conceptual constraints that often reduce inquiry teaching episodes.

In Chu et al.'s (2019) proposal, STEAM application starts with engagement. For this, students must “view or experience an event or phenomenon in which a science concept plays a role (e.g. the concept of light in light shows)” (Chu et al., 2019, p. 1257). These interactive activities are meant to raise probing questions and discussions among students about why and how this event or phenomenon happens. For the authors, the next steps would be to explore and create models to explain to colleagues, refine this model and achieve elaboration, and, finally, evaluate the discovery against a model that is accurate, as students' collaborative development and enhancement of explanatory models often include arts-based activities and the use of various forms of representation, such as diagrams, drawings, and kinetic models (Chu et al., 2019).

STEAM can also be culturally situated where students “are initiated into the study of a science concept by experiencing or observing a natural phenomenon” (Chu et al., 2019, p. 1257). A trigger situation is brought up that leaves students wondering why a phenomenon occurs. In the case of the electromagnetic field theremin, the question might be: Why does the sound change even if he does not touch the instrument? In the case of the optical theremin, the query could be, “Why does the amount and source of light make a difference in the sound result?” The process of inquiry – in this case triggered by curiosity about how light and sound interact in the theremin – encourages students to explore and manipulate the instrument. This inquiry generates engagement and exploration between the students and the artistic-scientific artefact

and between the students themselves, who try to reach answers through the manipulation or exploration of the object/phenomena and subsequent experiments.

In the case of STEAM, in my workshops, the final artistic quality of the product/artefact built by the students is evidence that the concept was well applied, or that it is necessary to make adjustments and ask questions about what is being built, thus creating a cycle of building, evaluating, and rebuilding. When a product does not work, students investigate causes and iterate, so the cycle of building, evaluating, and rebuilding supports conceptual learning. According to Chu et al. (2019), students grasp scientific concepts when they engage in learning activities that involve creating artistic artefacts. In this process, the precision of the final product serves as a measure of the accuracy of their understanding.

Within STEAM, integrating art with science aims to promote student engagement in learning science. This engagement becomes observable through students' participation and collaboration, and through the artefacts they create. Evidence of engagement can be seen in how students demonstrate understanding and apply scientific concepts through artistic expression as they develop more creative ways to learn science. The final STEAM product can take various forms, depending on the specific project or activity. It might be a piece of artwork, a model, a performance, or any artefact that reflects the collaboration between scientific principles and artistic creativity (Chu et al. 2019), but it is the iterative design and explanation that evidence engagement and understanding.

2.3.3 Agency, Voice, and Transformative Engagement in STEAM

The following authors extend STEAM beyond curriculum structure into questions of agency, voice, and the conditions that make participatory inquiry possible. This matters for my STEAM workshops because the therein tasks were designed to be open ended, collaborative, and technology mediated, so engagement depends on power relations and students' scope to make and test ideas, not only on content coverage. An advocate for liberating education, O'Neill (2015) states that when students are alienated, marginalised, and pressured by high performance demands in the education process, they suffer from "disconnection and lack of engagement in learning and achievement ... [and worsen their own perception] ... about themselves as learners, how they perceive their capacity to learn, and how much energy they have for learning" (p. 388). Students must be guided "through appreciative and dialogical inquiry" and a "reflective process" so that they become capable of "gaining new insights, overcoming challenges and constraints, and taking positive actions to bring about personal and social transformation" (O'Neill, 2015, p. 389).

This line of thought is based on Paulo Freire's (1970) philosophy, which emphasises that in order to foster authentic actions and thoughts, students must be guided to reflect on themselves and the world around them as reflection leads to action. Freire, a Brazilian educator and philosopher, is renowned for his work on critical pedagogy, which highlights the importance of dialogue, reflection, and action in the learning process. His philosophy asserts that education should not be a one-way transmission of knowledge from teacher to student but, rather, a dialogical process where students actively participate in their learning, reflect on their reality, and use this reflection to take action in the world.

Freire (1970) argued that authentic learning occurs when students are encouraged to critically reflect on their experiences and the world, which then leads to action. This process allows students to transform their environment. A central concept in his work is praxis – the cycle of reflection and action. In this thesis, the aim is to encourage student reflection and action, which aligns with Freire's principles. This approach encourages responsive learning where students engage with real-world challenges, empowering them throughout the process. To achieve this, it is essential to use an approach that guides students in responsive learning with direct links to real-world challenges and experiences. It should also “foster potential, and enact positive change through collaborative, active, and transformative forms of music engagement” (O'Neill, 2015, p. 389).

Framing STEAM activities as opportunities for transformative student engagement helps clarify why students' reflection-action cycles matter. In O'Neill's (2015) terms, transformative music engagement arises when young people encounter expansive, learner-centred opportunities to inquire into what interests and matters to them, speak back to their worlds, and take action, developing self-knowledge, supportive relationships, and a sense of empowerment along the way. O'Neill (2015) uses the term transformative vision to describe the act of giving voice to students through educational processes and thereby empowering and encouraging. This vision is translated into transformative music engagement when students come into contact with expansive learning opportunities. According to O'Neill (2015), we, the educators, are responsible for providing students with learning opportunities and processes that are collaborative, that question and transform practices, and that develop self-knowledge, a sense of empowerment, and relationships. This creates deep and meaningful experiences for the student and is part of the transformative music engagement process. Thus, youth empowerment and positive change are achieved when students are encouraged through transformative music engagement and led to understand their potential to create new possibilities (O'Neill, 2015).

Building on the “student voice” literature, O’Neill (2015) warns that listening alone is insufficient; multiple voices must have space to be expressed and, crucially, be acted upon through deliberate changes in classroom practice. In this context, engagement and empowerment go hand in hand as the power imbalance disengages students from the educational process. For empowerment to be real, “engagement needs to be assured, not allowed” (O’Neill, 2015, p. 391). One of the factors that increases students’ engagement in classes is proposals, questions, and activities without a preestablished and closed answer. The construction of knowledge through open proposals gives greater scope for student participation in the process.

Henceforth, activities and understandings that bring about real transformations and student engagement in lessons are: situated in real-world understandings, grounded in participatory and experimental approaches, and free of judgment, and must have support from those around them and the environment in which the activity is being carried out (O’Neill, 2015). By doing this, the teacher will be producing opportunities for impactful and transformative learning. There is, therefore, a direct and inseparable connection between engagement, resilience, and the “ability to thrive in the face of adversity ... [and he recognises that] ... engagement in musical activities should be associated with positive or healthy outcomes for all young people” (O’Neill, 2015, p. 394) because the competence of musical development is in every young person, and not just in a gifted minority.

According to O’Neill’s (2015) ideal, the location of the young person is not as important for engagement as the context in which self-expression and self-direction are provided, where the young person becomes a producer and product of his experience when engaging with music. O’Neill sees transformative music engagement as a tool, or platform, for youth empowerment. For students to engage in learning music, and for this engagement to be lasting, it is necessary that they can realise their potential to accomplish something. For O’Neill, the final result of the process is social justice. Transformative music engagement should lead to “optimizing youth voices, well-being, and musical flourishing” (O’Neill, 2015, p. 401). If educators can understand what is needed to reach the youth in their context, then they will achieve engagement. For this, experimental and student-centred processes should be used that encourage them to engage in active practice.

Continuing the topic of engagement, Michael Medvinsky (2017b) states that “If music educators use technology to do old things in new ways, they are still doing old things” (p. 595). It is not enough that we create new technologies and develop new tools but that we expand the

way in which these apparatuses are put into practice in the lives of students. Medvinsky (2017b) also goes on to say that “Technology best serves music educators when they reimagine musicianship and design opportunities to explore non-traditional ways of being a musician” (p. 595). Engaging with technological devices must be guided by innovation and by the approach built by a new look at how to make music with students.

Lines (2022) adds to the discussion and argues that a contemporary aesthetics in education should not remain confined to disciplinary arts alone. Instead, he suggests that aesthetics can help explain how music learning operates both at a personal level, through learners’ felt, creative, and reflective engagement with music, and at a transdisciplinary level, where music stands alongside other subjects and modes of knowing. This is especially relevant in contemporary education, where digital and hybrid contexts increasingly blur boundaries between media, spaces, and forms of expression. Read in relation to STEAM, this perspective supports an understanding of integration that is not limited to adding the arts to STEM, but that recognises music as a way of sensing, thinking, and making meaning across curriculum areas.

2.3.4 Transdisciplinarity, Embodiment, and the Nature of Integration

Moving from student engagement to the nature of the discipline itself, de la Garza and Travis (2019) bring transdisciplinary approaches to the STEAM subjects. The authors argue that science can be strengthened by incorporating philosophical, ethical, and aesthetic perspectives, helping it address uncertainty and unpredictability more effectively. In the same approach, arts “can be energized by scientific understandings of dynamic processes, technological innovations and the process of exploration and discovery” (de la Garza & Travis, 2019, p. 1). The authors nominate transdisciplinary links in famous productions throughout history. Creations that were possible due to perceiving arts and science as parts of the same whole include Leonardo Da Vinci’s *The Last Supper* (1498) and the *Mona Lisa* (1503), James Lovelock’s formulation of the GAIA Hypothesis, and tracing early onset of dementia found in the works of Iris Murdoch, P. D. James, and Agatha Christie (de la Garza & Travis, 2019). In the same way, de la Garza and Travis continue with the idea that humanity will progress to symbiotically evolve along with technology and that STEAM ideas and approaches are needed to create long-term insights, generating “possible social and environmental interactions, impacts, benefits and consequences for our human condition” (de la Garza & Travis, 2019, p. 1). This research programme aligns with these ideas by designing interdisciplinary workshops where students engage with music and science simultaneously, using technologies like the theremin as tools to reimagine artistic and scientific inquiry through collaborative and creative exploration.

Gil-Curiel and de la Garza (2019) argue that interdisciplinarity is important in contemporary education. Drawing on film and the medical humanities, they discuss interdisciplinarity beyond school-based STEAM to clarify what “integration” can look like when methods and questions are reshaped across fields. They describe early interdisciplinary moves as shaped by the “logic of accountability” (Gil-Curiel & de la Garza, 2019, p. 68) where interdisciplinarity is justified in terms of social relevance and engagement. They also trace a shift toward a biocultural approach that joins film analysis with brain-science methods to probe physiological correlates of attention, emotion, and memory, reframing methods rather than merely adding content (Gil-Curiel & de la Garza, 2019). From an interdisciplinary perspective, they note that more negative terms used to describe interdisciplinary research in general such as “trespassing” and “poaching” are “discipline-centric and lack a historical perspective of how disciplines originated in the first place, taking them for granted. [...] The outcome will most likely be problem or issue-centric and post-disciplinary” (Gil-Curiel & de la Garza, 2019, p. 75). Consistently, they observe that moving-image media “excel in capturing attention and triggering emotion” (Gil-Curiel & de la Garza, 2019, p. 70), a mechanism that helps explain sustained engagement in embodied, sensory tasks.

Long and de la Garza (2019) state that “the arts are an arena in which the body is central to the process of inquiry and indeed constitutes a mode of knowing” (p. 83). I use this as a conceptual lens for the theremin’s gesture to sound mapping. This aligns with the theremin’s *modus operandi*: sound emerges from bodily action and real-time sensorimotor feedback, so the body both initiates inquiry and interprets the instrument’s responses. Long and de la Garza (2019) also frame the project as science communication that seeks to “bridge the gap between these fields and between academia and wider society through a participatory approach” (p. 84). In my context, classroom demonstrations and take-home use of the theremin similarly position learners as coperformers who translate and share engineering and musical ideas across school and home spaces, turning embodied exploration into public-facing inquiry. Taken together, this biocultural and embodied stance supports my claim that the theremin is not a mere illustration of concepts but a medium that reorganises inquiry through bodily action and sensorimotor feedback.

Integration in science education has been long debated as we can see discussions about a meaningful practice in the field. Hodson dates this debate back to 1992, when he analyses the validity and philosophy of science integration in a stage where “balanced” (integrated) science teaching was being considered after the consolidation of separating biology, chemistry, and physics. The author considers the “process versus product” (Hodson, 1992, p. 541) in curriculum

designs, along with practice and goals for this (science) or these (biology, chemistry, and physics) subject(s). Hodson also argues that the most powerful route to integration is through the design of the tasks given to the students so that learning science, learning about science, and doing science reinforce one another in a mutual way (Hodson, 1992). Although Hodson writes about integration within school science rather than STEAM, his criteria help evaluate whether “integration” is driven by task design or is only an add-on.

Hodson (1992) examines the challenges of integrating different scientific disciplines in education, questioning the philosophical basis of such efforts and considering other ways to connect them through educational theory. He states that in some situations, “integrating principle (or principles) rooted in educational theory” ... [is necessary and should be prioritised over] ... philosophy of science” (Hodson 1992, p. 547). The article also examines the nature of scientific knowledge, the role of scientific methods, and the impact of “industrialization, commercialization, and militarization” (Hodson, 1992, p. 542) on the direction of scientific endeavours. Hodson argues that there is no “single, universally accepted description of scientific method ... [and that the methods employed are] ... contextually appropriate, ... [varying based on the specific] ... circumstances of individual investigations” (Hodson, 1992, p. 545). He suggests that the focus should not just be on the “disinterested search for knowledge ... [but on what is] ... personally and socially desirable and worthwhile” (Hodson, 1992, p. 543) because “it can be argued that all scientists seek knowledge that renders the world more intelligible, comprehensible and predictable” (Hodson, 1992, p. 541) and that science is “constructed not ‘for its own sake’ but for its value in solving problems” (Hodson, 1992, p. 542). Hodson emphasises that merging sciences into educational environments is a complex matter requiring a balanced approach and a thorough grasp of both scientific principles and theories of education.

In this STEAM review, Chu et al. (2019) provide a design anchor for arts-integrated science inquiry through situated learning, representation, and iterative model refinement. Strat et al. (2024), Sturrock et al. (2025), and Xu et al. (2024) extend this discussion by showing how inquiry is enabled or constrained by pedagogical support, institutional conditions, and assessment pressures, and by documenting how teachers often combine inquiry with direct instruction in everyday lessons. Medvinsky (2017b) and O’Neill (2015) extend this discussion by explaining why open-ended, technology-mediated tasks can strengthen agency, voice, and reimagined participation, which matters for engagement in my workshops. de la Garza and Travis (2019), Gil-Curiel and de la Garza (2019), and Long and de la Garza (2019) further reposition integration as transdisciplinary, embodied, and problem centred, which aligns with

the theremin as a bodily, sensory medium for inquiry. Hodson (1992) then offers a curriculum-level lens for evaluating integration through task design, helping distinguish meaningful integration from superficial “add-on” combinations. The next section, Section 2.4, builds on these ideas to examine how workshop artefacts and practices travel beyond the classroom, supporting practices sustained across spaces.

2.4 Practices Sustained Across Spaces

One of the advantages of STEM education is its potential to promote practices that are sustained across spaces, enabling students to meaningfully engage with learning beyond the classroom. This concept is developed by Calabrese Barton and Tan (2018), who conducted a multi-year, community-based research project with over 100 racially minoritised youth from low-income backgrounds in a midwestern U.S. city. The study was situated in an after-school makerspace hosted by a community centre where participants engaged in STEM-rich activities, such as building toys, designing circuits, and creating neighbourhood-based design projects in a STEM club. The programme provided consistent access to tools, materials, mentorship, and peer collaboration. Calabrese Barton and Tan (2018) sought to understand how STEM learning becomes equitable and consequential when youth are positioned as designers and leaders rather than passive recipients of knowledge. They emphasise the importance of learning experiences that are: sustained across time and space, consistent, and accessible through multiple entry points. When these conditions are met, students are empowered to engage in STEM-rich making in culturally sustaining and academically rigorous ways.

Calabrese Barton and Tan (2018) frame their work as equitable and consequential making: STEM-rich making that generates public, community-relevant outcomes while cultivating critical agency and educated action, including shifts in knowledge and authority relations within the STEM club (Calabrese Barton & Tan, 2018). In practice, youth extended their work into shared community spaces, such as moving toy cars and a racetrack between spaces in the club (from the makerspace to the lobby); taught younger peers; and authored a rightful presence recognised as “community makers” (Calabrese Barton & Tan, 2018, p. 164). The authors believe that by centring youth agency, informed action, and social transformation, these practices aim to challenge and disrupt systemic inequities.

In my research, practices sustained across spaces is evidenced by students’ learning and experiences extending beyond the workshops, with the theremin artefact functioning as a bridge. Practices sustained across spaces refers to how students continue this engagement in everyday environments, such as the home or among peers, extending the impact of the

workshops over time and across contexts. This is built on contextual transposition where students transfer and recontextualise practices, understandings, and interests across settings. Tan et al. (2013) distinguish between narrated identities in practice (how one views oneself in specific contexts and futures) from embodied identities in practice (how one performs and is recognised in activity with tools, people, and discourses); both are open ended and situated within local struggles. In narrating “who they can become”, learners construct possible selves; whether these futures gain traction depends on available resources, recognition by others, and links to concrete strategies in the here and now.

This orientation also aligns with a learning-by-doing tradition, resonant with makerspace practice, in which building and testing are central to learning rather than add-ons (Lowrie et al., 2018). Lowrie et al. (2018) present a framework for STEM education that challenges traditional content-based approaches and offers a broader conceptualisation of STEM learning as a set of social practices rather than a fixed curriculum. As the authors state: “large-scale interventions arrive in the middle of educational environments that are already underway and must recognize that they cannot demand a ‘clean’ starting point” (Lowrie et al., 2018, p. 3). In my case, this means joining a live system and adapting practice rather than trying to pause or reboot it.

Lowrie et al. (2018) argue that effective STEM education must operate across three interdependent domains: semiotic (sayings/representations and reasoning), physical (activity and tool use), and social (relationships and collaboration). This practice-theoretical stance promotes a shift away from content-bound traditions towards developing students’ capacity to enact practices across diverse contexts (Lowrie et al., 2018). The authors emphasise that meaningful engagement with STEM arises not from isolated disciplinary content but from students’ participation in practices that reflect real-world processes of inquiry, design, and problem-solving. This relates to the STEAM education because arts-oriented work can be treated as part of these practices rather than as an extra layer, expanding what counts as representation, inquiry, and application. In this study, musical composition and performance gave students ways to represent and communicate scientific ideas through sound, while the building and testing of the theremin supported peer collaboration and shared problem-solving.

Lowrie et al.’s (2018) work is grounded in the large-scale Early Learning STEM Australia (ELSA) project, which involved over 100 early learning centres, approximately 300 educators, and more than 1,700 students. Although ELSA focuses on early learning settings, the elements drawn on here are the underlying design principles rather than the age-specific activities. ELSA

was designed from the outset to be aligned with Australia's wider policy goals. The authors defend the importance of the scale of the project "because the design brief from the government required a tight alignment between the design work of the project and a wider policy agenda right from the outset" (Lowrie et al., 2018, p. 1). Their project started with multidisciplinary design workshops and gathered knowledge from different fronts in the STEM agenda, including practising teachers, science communicators from radio and television, a major science centre, STEM specialists, and an app-development team.

A key contribution of Lowrie et al.'s (2018) research is the notion that STEM should be approached as a reform initiative, aiming not only to improve pedagogical practices but to redefine the educational purpose itself. As Lowrie et al. (2018) state, "STEM education design does not occur in a vacuum" (p. 8). They further note that in systems that reward content-bound subject knowledge through examinations, tests, and university entry, approaches perceived as weakening those rewarded forms are unlikely to be sustained. Rather than replicating scientific or technical procedures, the framework seeks to induct learners into socially situated practices that are both contextually meaningful and transferable across settings. To operationalise this vision, the authors propose a heuristic called Experience–Represent–Apply (ERA), which guides educators to design learning sequences that connect students lived experiences with symbolic representations (often through digital apps) and with practical application in social settings.

In Lowrie et al.'s (2018) account, ERA is a cyclic sequence of practice: Experience, as the name suggests, starts from lived experience, shared language, and off-app play to ground early sensemaking; Represent engages learners in creating and interpreting representations – often via apps – so that meanings stabilise; and Apply extends those representations into off-app activity in social settings guided by educators and families. The authors also clarify that app use belongs to Represent, while Experience scaffolds understanding, and Apply returns activity off app in student-centred ways. For example, Lowrie et al. (2018) illustrate ERA with patterns: in Experience, students hear a story about patterns in nature; in Represent, they recreate a character's pattern in the ELSA tablet app; in Apply, they put the tablet down to copy a peer's pattern and then extend it in a new story. Importantly, the framework departs from traditional integration models by rejecting the notion that disciplinary boundaries alone can define STEM and instead focuses on the enactment of practices, such as questioning, designing, building, and reasoning. This reconceptualisation allows educators to focus on the development of students' capacity to engage in STEM-related practices in diverse and authentic contexts.

Similarly, Zhai et al. (2018) demonstrate that student-initiated technology use outside school – particularly in after-school remediating activities – has a stronger positive impact on learning outcomes than teacher-assigned tasks, suggesting that engagement sustained beyond school hours is both feasible and beneficial. Zhai et al. (2018) conducted a large scale study with 803 Grade 10 students from 28 physics classes in a high school in China, who used one to one mobile devices in physics classrooms for five months. Their research applied the Substitution Augmentation Modification Redefinition (SAMR) model to classify technology integration levels and investigated how different forms of use impacted student learning. A key finding of the study was that only the higher-level uses of technology (augmentation) were positively correlated with student achievement whereas lower-level uses (substitution) showed no significant effect. The authors employed hierarchical linear modelling (HLM), controlling for prior achievement, physics interest, gender, and class-level mean use to isolate technology effects. In this model, augmentation predicted achievement while substitution was not significant.

Within the augmentation category, Zhai et al. (2018) identified four pedagogical patterns: student-teacher displaying activities, teacher-assigned activities, after-school remediating activities, and learning-aid activities. Among these, the after-school remediating activities, such as note reviewing, mind mapping, and error tracking – all initiated by students themselves – produced the strongest positive effect on physics achievement. These self-directed uses were not required by the teacher but were adopted voluntarily by students as part of their independent study routines. According to the authors, this suggests that engagement sustained beyond school hours is both feasible and academically beneficial, especially when supported by tools that allow students to regulate their own learning.

In contrast, teacher-assigned activities, including watching presentations or following screen broadcasts, had no significant correlation with academic performance. Zhai et al. (2018) speculate that these activities may benefit classroom management or teacher efficiency but do not necessarily promote deep engagement or knowledge construction for students. Similarly, learning aid activities – focused on accumulating resources rather than constructing understanding – were negatively associated with achievement, possibly due to misuse or overuse leading to distraction. Zhai et al. (2018) also report a negative cross-level interaction for “student-teacher displaying”: benefits were greater in classrooms with lower average technology use, suggesting diminishing returns when such routines become heavy or habitual. They note limitations (single-site sample, no random assignment, and analyses confined to lower

SAMR levels) and caution that frequent “learning-aid” functions can distract or enable shortcutting.

Tan et al. (2013) provide compelling evidence for the importance of learning practices that are sustained across multiple social contexts. Their study followed a group of non-White, middle-school girls who expressed aspirations toward STEM-related careers across four urban research sites in the United States (two small Midwestern cities, one large East Coast city, and one Pacific Coast city). Tan et al. (2013) investigated how these students articulated and enacted science identities across three key settings: school, informal after-school programmes, and home and community spaces. Drawing on the concepts of figured worlds and identities in practice, the authors demonstrate that engagement in science is not confined to the classroom but is continually shaped and reshaped through interactions in diverse environments. The girls’ ability to sustain interest and participation in science was strongly linked to their capacity to narrate and perform science-related identities in ways that were contextually responsive and personally meaningful.

The concept of practices sustained across spaces also aligns with Sobel’s (2004) framework of place-based education, which emphasises the value of grounding learning in students’ local communities and lived environments. In Sobel’s (2004) account, place-based programmes start from local people and places to connect work across subjects through hands-on inquiry with real audiences. Synthesising findings from the American State Education and Environment Roundtable’s “Environment as an Integrating Context” studies, he reports gains across core subjects alongside increased enthusiasm and engagement, with attendance and behaviour indicators improving relative to conventional programmes. He further frames the approach as a “three-legged stool” (Sobel, 2004, p. 20) – academic achievement, social capital, and environmental quality – and advocates a near-to-far progression, “from here-and-now to long-ago-and-far-away” (Sobel, 2004, p. 20). In this study, students’ engagement with the therein through music, science, and creative expression reflects these principles. Such transference of learning across contexts echoes the goals of place-based education, reinforcing the potential of STEAM initiatives to create sustained and meaningful educational practices across settings.

2.5 Research Questions

The original objectives of this study, as presented in Section 1.3, were to examine how a theremin-based project could support student engagement, to understand how it could make connections between science and music more visible in students' everyday schoolwork, and to analyse changes in peer interaction during the workshops. After reviewing the literature, I developed the following research questions:

1. In what ways does using the theremin improve student engagement in science and music?
2. In what ways can the theremin be used to improve interdisciplinarity across science and music in Brazilian schools?
3. In what ways can a theremin-based teaching and learning project enhance peer interaction in science and music?

2.6 Summary

This chapter synthesises literature on student engagement through four connected themes: student engagement in music, student engagement in technology-supported music education, STEAM integration (STEM + Arts), and practices sustained across spaces. Rather than treating the theremin as the only topic, I use it as a through-line that links music-making, digital and material tools, interdisciplinary task design, and the question of how engagement extends beyond lesson time.

Across the music education literature, engagement is repeatedly linked to participation structures that make collaboration, autonomy, and belonging possible. Informal and peer-directed approaches support cooperative participation, inclusion of learners identified as disaffected, and persistence through ownership of a shared product (Green, 2008). Schooling research also positions engagement as a key behavioural predictor of dropout and graduation, linking participation in academic and social life to longer-term trajectories (Rumberger & Lim, 2008). Workshop and making-oriented accounts add that iterative build-test-perform cycles can enable meaningful entry points for learners with limited prior skills because contribution can occur through building, testing, adjusting, and helping peers, not only through performance (Figaredo, 2009; Jakobsen et al., 2016). Complementary evidence from sustained group programmes suggests that coordinated music activity can reduce aggressive behaviour and support socioemotional regulation, while social bonding perspectives clarify that outcomes depend on the form of coordination and the interactional demands of the task (Choi et al., 2010;

Hove & Risen, 2009; Kirschner & Tomasello, 2010). Together, these studies position engagement as something produced through how participation is organised and recognised, especially for students whose relationship with schooling is already fragile (Burnard, 2008; Hallam & Himonides, 2022).

The technology and music education literature then sharpens the claim that technology does not “cause” engagement by itself. Engagement depends on how tools are situated within curriculum, culture, and everyday practice (Tobias, 2017; Uptis, 2001). A consistent thread is the contrast between using technology to reproduce existing routines and using it to reimagine musicianship, participation roles, and the purposes of music learning (Medvinsky, 2017b; Tobias, 2017). Complementary accounts emphasise open-ended exploration and play in flexible social environments, inclusion through multiple pathways for participation, and the need to keep musical and social meaning central when digital tools are introduced (Howell, 2017; Peters, 2017; VanderLinde, 2017). Postpandemic and tertiary studies add that infrastructure, teacher support, and clear pedagogical aims shape whether technology increases participation or simply shifts old tasks onto new media (Merrick & Joseph, 2023; Rexhepi et al., 2024).

The STEAM section synthesises debates about what “integration” means and what it is for. Chu et al. (2019) provide a design-oriented model in which arts integration supports concept learning and affective engagement through structured inquiry, collaborative model building, and representations. Other authors extend integration beyond curriculum structure into transdisciplinary reshaping of methods and questions (de la Garza & Travis, 2019; Gil-Curiel & de la Garza, 2019); embodied inquiry where the body is a mode of knowing (Long & de la Garza, 2019); and participation, agency, and voice in technology-mediated practice (Medvinsky, 2017b; O'Neill, 2015). Inquiry literature also clarifies that open-ended tasks still require scaffolding and pedagogical judgement because institutional constraints and assessment pressures often limit sustained inquiry, especially in secondary settings (Strat et al., 2024; Sturrock et al., 2025; Xu et al., 2024). Hodson (1992) adds a curriculum lens for evaluating whether integration is driven by task design that links learning science, learning about science, and doing science rather than by superficial “add-on” combinations. These perspectives provide a basis for the Discussion chapter (Chapter 7) to examine, in this study, what forms of integration actually occurred, and how arts, science, and technology mutually shaped one another through the therein tasks.

Finally, this Chapter 2 brings engagement into a spatial and temporal frame by examining how practices travel beyond the classroom. Equitable and consequential making positions young people as designers whose work gains traction through resources, recognition,

and public-facing outcomes, sustaining participation across time and space (Calabrese Barton & Tan, 2018). Identities-in-practice research shows how narrated and embodied identities are negotiated across school, home, and informal programmes, and why sustained engagement depends on what learners can do with tools and relationships in each context (Tan et al., 2013). Complementary evidence suggests that student-initiated technology use outside school can be more strongly associated with achievement than teacher-assigned use, which supports the idea that voluntary, self-directed continuation matters for durable engagement (Zhai et al., 2018). Place-based education further frames this continuation as learning that starts from local lives and audiences and connects work across settings through consequential inquiry (Sobel, 2004). Taken together, these themes establish the conceptual and design foundations for analysing how theremin-based workshops may support engagement, interdisciplinarity, peer interaction, and practices sustained across spaces in the Findings chapter (Chapter 6), the Discussion chapter (Chapter 7), and the Conclusion (Chapter 8).

CHAPTER 3 – THEORETICAL FRAMEWORK

Adolescent engagement in school has become a pressing concern. Drawing on research synthesised in a US-focused review and survey evidence from California secondary students (Grades 7–12), Griffiths et al. (2022) report that around half of adolescents feel engaged at school, while nearly a quarter are actively disengaged. This pattern worsens with age as older students report feeling less cared for by adults and place less value on their academic work (Griffiths et al., 2022). This chapter, Chapter 3, sets out the theoretical lenses used to analyse my data collected before, during, and after the therein workshops I held. The purpose is not to review all engagement research but to define the concepts that guide my data processing and to show how these concepts help answer my research questions about engagement, interdisciplinarity, and peer interaction in a school setting. I will discuss student engagement and disaffection, dimensions of engagement, and motivation, interdisciplinarity, peer interaction, and academic emotions and how they help explain students' participation, persistence, and collaboration at school.

First, I clarify how student engagement is defined in the engagement literature and why this study treats engagement as multidimensional (Fredricks, 2022; Fredricks et al., 2004; Reschly & Christenson, 2012, 2022). Second, I describe behavioural, cognitive, emotional or affective, agentic, and social engagement, and I explain how engagement differs from disengagement, disaffection, and burnout (Pekrun & Linnenbrink-Garcia, 2012, 2022; Reeve & Tseng, 2011; Salmela-Aro et al., 2022; Skinner et al., 2008, 2009). Third, I connect engagement to motivational theory by outlining Expectancy-Value Theory and Situated Expectancy-Value Theory, and by explaining how academic emotions and motivational engagement relate to participation and persistence (Gladstone et al., 2022; Pekrun & Linnenbrink-Garcia, 2012, 2022; Tamura et al., 2022). Finally, I review research that links disengagement and disaffection to adverse childhood experiences and to later risk outcomes to clarify conditions that can constrain engagement in school settings (Griffiths et al., 2022; Henry et al., 2012; McNeely & Falci, 2004). Throughout, I use these concepts to build an analytic frame for the later chapters.

3.1 Student Engagement at School

To start, I define what student engagement means in school-based research as this definition is the entry point for the rest of the chapter. It clarifies what counts as engagement in my data and what does not, and it sets up the distinctions between engagement,

disengagement, disaffection, and burnout. I also explain why this study treats engagement as multidimensional. In the next sections, I display the engagement dimensions used in my coding and then connect those dimensions to motivation and academic emotions to interpret students' participation, persistence, and collaboration during the workshops.

3.1.1 Student Engagement

There are multiple perspectives on the topic of student engagement, with authors maintaining different views on the aim of student engagement. Some of these views include: to engage in STEAM education (Conde et al., 2021; Engelman et al., 2017); to improve students' performance (Do Lenh et al., 2010); to support cross-disciplinary student learning (Bequette & Bequette, 2012); to enhance students' academic engagement and strengthen the role of parents in the learning process (Ellison & Evans, 2016); to promote learning for students with additional learning needs (Ke & Abras, 2013); to reach a broader range of students (English, 2017); to engage with art (Glass & Wilson, 2016); to reach open-mindedness and self-innovation (Jho et al., 2016); and to position student engagement as a route to address poor achievement and dropout (Fredricks et al., 2004). A more recent study examines the dynamics of motivational engagement in learning (Tamura et al., 2022).

Engagement has appeared in the literature under different terms, reflecting a shift in focus over the last few decades. According to Griffiths et al. (2022), the concept of engagement has evolved from earlier works reflecting the educator's perspective and used expressions like "teacher support". Later, studies focused on the school as a system and used "school bonding", "school connectedness", "school engagement", and "school climate". More recent publications have shifted to the student perspective and have used the term "student engagement" (Griffiths et al., 2022). Student engagement embodies the active participation and commitment of students to goals and learning, hence the evolving nomenclature. Reschly and Christenson (2012) define student engagement as a multidimensional construct. Engaged students not only take part in academic and school-related activities but also find meaning in what they learn. They invest in their current learning and in their future goals. Student engagement drives learning, fuels energy and effort, is shaped by contextual factors, and can be achieved by all learners (Reschly & Christenson, 2012).

Student engagement involves multiple aspects of cognition, beliefs, emotions, and behaviour within education (Griffiths et al., 2022). These elements work together simultaneously to shape how students participate in learning. Defining student engagement involves recognising its dimensions – cognitive, emotional, and behavioural – as it covers various

aspects of how students experience school (Griffiths et al., 2022). According to Fredricks et al. (2004), four things shape engagement: teachers/classrooms, tasks, peers, and school climate/policies. They note family and community also matter, but their review focuses on the school/classroom.

3.1.2 School Engagement

School engagement also plays a key role in shaping students' academic paths (Allen & Boyle, 2022). Rather than treating it as a final goal, Allen and Boyle (2022) describe engagement as both a driving force and an indicator of future outcomes. This view is supported by Russell et al. (2005), who present engagement as both an outcome and a predictor of achievement, including implications for whether students remain at school. From a self-determination perspective, Ryan and Deci (2009) link autonomy-supportive contexts, autonomous motivation, and perceived competence to greater engagement, and stronger learning and adjustment. Consistent with Fredricks et al. (2004), student engagement and positive conduct are associated with higher grades and basic skills. Participation in extracurricular activities also appears to be associated with a decreased likelihood of dropping out of school.

Scholars widely agree that student engagement is essential. Reschly and Christenson (2022) state that engagement is a key factor in both student success and well-being as it affects many areas of a student's experience, including academic outcomes and emotional health. The authors explain that student engagement has active and passive forms, ranging, for example, from passive behaviours, like watching the teacher, to active participation, such as asking questions. This helps explain how students' time and effort relate to learning outcomes. Student engagement is not uniform. It varies in intensity and form. This view is supported by Fredricks (2022), who outlines different dimensions of engagement based on how students interact in the learning environment.

3.1.3 Models of Student Engagement

Reschly and Christenson (2022) compare three integrative models of student engagement: Check and Connect, the development-in-sociocultural-context model (Wang et al., 2019), and the Study Demands–Resources Model of engagement and burnout (Salmela-Aro et al., 2022). The first model, Check and Connect, focuses on helping students complete school. It emphasises the role of mentors, consistent tracking of progress, early interventions, and working with families. This model argues that academic and behavioural efforts alone are not enough – students also need to see the value of education for their future. It works best when

inserted in a system that supports engagement, competence, and school completion for all students (Wang et al., 2019)

The second model, the development-in-sociocultural-context model, works with both external and internal factors as well as engagement, resilience, and long-term outcomes (Wang et al., 2019). It takes culture, social background, family context, and the nature of school tasks as external influences. These shape students' development and self-perception, which then affect their engagement and ability to cope with challenges. The model also recognises the ongoing interaction between context and engagement (Wang et al., 2019).

The final model, the Study Demands–Resources Model of Student Engagement and Burnout includes both engagement and burnout, drawing from research on work environments (Salmela-Aro et al., 2022). It views school as the workplace of adolescents and shows how imbalance between demands and available support can affect student well-being and academic performance (Salmela-Aro et al., 2022).

The three models discussed by Reschly and Christenson (2022) share core elements that are highly relevant to my study. Each model recognises the role of context, such as family, school, and peer relationships, in shaping student engagement. The models also emphasise a direct connection between student engagement and both academic and emotional outcomes. All three models adopt a developmental perspective, acknowledging that engagement changes over time through continuous interaction between students and their environments (Reschly & Christenson, 2022). Rather than adopting a single model, my thesis draws on shared features from all three. This focus on common ground makes the approach more adaptable to school contexts and to diverse student experiences.

In addition, Reschly and Christenson (2022) propose a three-point framework for measuring engagement and disaffection. They stress the importance of distinguishing between different dimensions of engagement – behavioural, emotional, and cognitive – as previously outlined by Fredricks et al. (2004). However, the current field has yet to reach full agreement on these dimensions as more categories have been proposed over time. The dimensions of engagement will be discussed in the next section, Section 3.2. The distinction between motivation and engagement also remains under discussion, with some scholars suggesting that motivation precedes engagement, just as intention precedes action (Reschly & Christenson, 2022).

Disaffection, which includes emotional and behavioural aspects, shows that engagement must go beyond academic performance (Reschly & Christenson, 2022) as

engagement should support students' overall quality of life, not just their success in school (Lamborn et al., 1992). Reschly and Christenson (2022) refer to disaffection as involving emotions, such as boredom, disinterest, and frustration, and behaviours like passivity, withdrawal, and distraction. In parallel to disaffection, Salmela-Aro et al.'s (2022) description of burnout includes exhaustion, a negative attitude toward school, and feelings of inadequacy. In Salmela-Aro et al.'s (2022) model, burnout is not simply the absence of engagement but is a response to sustained academic pressure combined with a lack of adequate support. When school demands exceed the resources available to students, burnout may develop, negatively affecting well-being, learning, and persistence in school. Fredricks et al. (2004) further interpret dropout via Finn's (1989) participation-identification perspective: sustained participation (behavioural) builds identification/belonging (emotional), which, in turn, supports persistence and reduces dropout risk.

Hofkens and Pianta (2022) argue that student engagement is not simply a personal trait but emerges through continuous interaction with classroom practices and relationships. Engagement is shaped by how students respond to daily experiences with teachers, peers, and learning tasks. The authors highlight the importance of supportive teacher-student relationships, which help students feel safe, respected, and motivated. Instead of being an internal quality, engagement is presented as context dependent and is influenced by the social and learning environment. Positive relationships in the classroom can lead to greater involvement, persistence, and emotional connection to learning.

Research in education and child development shows that students' experiences in the classroom have a central role in shaping their learning (Hofkens & Pianta, 2022). Connell and Wellborn (1991) and Pianta et al. (2007) argue that the quality of these experiences is essential for determining the value and impact of education. The classroom is not just a physical space but the environment where learning takes place. It influences how students think, behave, and engage with school. Together, these perspectives reinforce the view that student engagement is shaped by a range of internal and external influences, and it plays a key role in academic, emotional, and social development. To better understand how engagement manifests in practice, the following section, Section 3.2, examines its core dimensions as outlined in the literature.

3.2 Dimensions of Engagement

This section explains how behavioural, cognitive, and emotional engagement are conceptually distinct, even when they cooccur in classroom activity. As discussed above, in Section 3.1, student engagement is a broad concept that helps explain participation in academic and cocurricular contexts. Reschly and Christenson (2012) describe it as active involvement and commitment to educational goals. Engagement in both academic and nonacademic settings is considered essential for supporting meaningful learning experiences.

Understanding the key aspects of student engagement is important for educators and policymakers seeking to improve learning. The initial model created by Fredricks et al. (2004) divides student engagement into three categories: behavioural (participation and conduct), cognitive (strategic processing and self-regulation), and emotional (feelings about school and identification/belonging). The framework developed by Fredricks et al. (2004) has been used as a cornerstone for the past 20 years. These three categories reflect how students feel, think, and act in learning environments.

Although conceptually distinct, the behavioural, cognitive, and emotional dimensions are interrelated in practice. For instance, emotional responses can influence attention and persistence while cognitive strategies may support sustained behaviour. Each dimension highlights a specific aspect of students' involvement in school, and this distinction reflects the importance of addressing different forms of engagement. Together, these dimensions help explain how students interact with the learning environment, pointing to the value of supporting positive behaviours, emotional stability, and cognitive effort to improve educational outcomes (Fredricks, 2022).

While many of the following authors structure their frameworks around these three dimensions, there is currently no clear agreement on how student engagement should be defined or expanded. Over time, additional perspectives such as agentic and social engagement have been proposed, suggesting that the traditional triad may not fully capture the complexity of student participation (Reschly & Christenson, 2022). Each dimension also includes specific elements that help explain how students participate in learning in different ways.

Understanding these dimensions is relevant for analysing how students engage in interdisciplinary, creative, or student-centred learning environments where traditional behavioural markers may not be sufficient. The following sections examine each of these

dimensions in more detail. Each one is discussed in relation to how it contributes to student participation, motivation, and learning across various educational settings.

3.2.1 Behavioural Engagement

Behavioural engagement is often considered the “most easily observable dimension” (Gladstone et al., 2022, p. 58) of student engagement. This dimension centres on students’ active participation in learning activities, and includes positive conduct and the avoidance of disruptive behaviours. Its observable indicators are staying on task, contributing in class, and refraining from behavioural disruptions (Fredricks et al., 2004). Four components illustrate behavioural engagement: responding to school requirements, participating at school, taking initiative in class-related activities, and being involved in extracurricular activities (Gladstone et al., 2022). To Fredricks et al. (2004), behavioural indicators (attendance, participation, prosocial conduct) relate consistently to achievement, and participation in extracurricular participation aligns with persistence in school.

Finn’s (1989) work centres on preventing student dropout and ensuring high school graduation. Finn’s focus on understanding how engagement predicts the probability of students staying in school aligns with the nature of behavioural engagement. This dimension encompasses students’ participation in various activities, as emphasised in Finn’s original definition of behavioural engagement. Factors like attendance, adherence to school rules, and participation in extracurricular activities emerge as facets shaping the students’ overall engagement.

According to Skinner et al. (2009), behavioural engagement goes beyond basic participation and includes deliberate effort, sustained attention, and active involvement in school activities. Their approach is grounded in the self-system model of motivational development, which draws on self-determination theory. They also argue that engagement and disaffection are distinct processes. Disaffection is not simply the absence of engagement; it is a response marked by withdrawal and passivity. This is consistent with Salmela-Aro et al.’s (2022) account of burnout as more than the absence of engagement, and as a distinct process that can cooccur with engagement. However, the constructs operate at different levels. Behavioural disaffection captures classroom-level withdrawal (for example, giving up, being distracted, or coming to class unprepared) whereas burnout refers to a more sustained syndrome that includes exhaustion and feelings of inadequacy.

Martin (2007) presents an integrative framework that connects motivation and engagement. He makes a distinction between adaptive and maladaptive forms of behavioural engagement. Adaptive behavioural engagement refers to a student's sustained effort on a task while maladaptive behavioural engagement involves deliberately withholding effort. Martin's model aligns with Skinner et al.'s (2008, 2009) definitions as both emphasise students' active participation in school and classroom activities as a core aspect of behavioural engagement.

While behavioural engagement captures whether students participate and persist in classroom activity, it does not fully explain the quality of their learning. For this reason, the next section, Section 3.2.2, is about cognitive engagement, which focuses on how students invest in understanding, use strategies, and regulate their thinking.

3.2.2 Cognitive Engagement

Described by Fredricks et al. (2004) as a student's investment in learning, cognitive engagement refers to the thinking side of the learning process. Fredricks et al. also emphasise that cognitive engagement involves the use of deep-learning strategies and the willingness to exert effort in understanding complex ideas and developing academic skills. It also involves setting goals and other self-regulatory processes, such as monitoring and strategic planning. In line with this, Fredricks (2022) later cautions that the label "effort" can be inserted both in behavioural and cognitive engagement, and researchers should specify whether the theme relates to "doing the work" (behavioural) versus "striving for understanding" (cognitive).

Cognitive engagement has mainly been defined in two ways. The first focuses on students' beliefs and values about the importance of school and learning (Gladstone et al., 2022). This includes how much they value learning and whether they see knowledge as relevant to their goals. When students consider learning meaningful, they are more likely to invest effort and attention in academic tasks (Gladstone et al., 2022). The second focus involves self-regulation strategies, such as reviewing homework and managing time effectively. Goal setting is shaped by how students view the role of school in achieving their future objectives (Gladstone et al., 2022).

Cognitive engagement has indicators, such as setting personal goals, regulating learning processes, seeing schoolwork as connected to future plans, and assigning value to academic activities (Griffiths, et al., 2022). According to Fredricks (2022), cognitive engagement can also be seen in behaviours like connecting learning to personal experiences, solving problems, and

seeking further information. Fredricks et al. (2004) add that preference for challenge and use of deep strategies (for example, elaboration) exemplify cognitive engagement.

Adaptive cognitive engagement can be seen when students value academic tasks, pursue mastery goals, and have confidence in their ability to succeed at school. In contrast, maladaptive cognitive engagement, as described by Martin (2010), includes behaviours such as self-handicapping or relying on last-minute study strategies (like studying for a test the night prior). These patterns reflect the range of cognitive approaches students may use (Gladstone et al., 2022).

Greene (2015) defines cognitive engagement as the use of cognitive strategies, self-regulation, and mental effort. She distinguishes between deep and shallow engagement. Deep engagement involves connecting new ideas to prior knowledge and using strategic approaches to learning, while shallow engagement refers to surface-level processing and memorisation.

These perspectives display how cognitive engagement shapes students' approach to learning. Understanding how students think, plan, and invest effort helps explain their overall participation in their academic life and complements the behavioural and emotional dimensions of engagement.

Cognitive engagement helps explain how students approach learning through planning, strategy use, and effort directed toward understanding. However, students' thinking and self-regulation are closely tied to how they feel in school because emotions like interest, enjoyment, anxiety, or frustration can support or disrupt attention, persistence, and the use of strategies. For this reason, the next section, Section 3.2.3, is on emotional/affective engagement, which captures students' emotional responses to school tasks and relationships and how these responses shape their participation.

3.2.3 Emotional/Affective Engagement

Emotional engagement, sometimes referred to as affective engagement, includes both positive and negative emotional responses to school (Gladstone et al., 2022). As Fredricks et al. (2004) state: "Emotional engagement refers to students' affective reactions in the classroom, including interest, boredom, happiness, sadness, and anxiety" (p. 63). It also includes relationships, such as students' connections with teachers, peers, and academic work (Finn, 1989; Fredricks et al., 2004; Gladstone et al., 2022). It reflects how much students enjoy learning and how safe, happy, or excited they feel at school (Fredricks, 2022). This aspects align with Skinner et al.'s engagement and disaffection framing where emotional engagement involves

enthusiasm, interest, and enjoyment, and emotional disaffection includes boredom, frustration, anxiety, and disinterest (Gladstone et al., 2022; Skinner et al., 2009). Skinner et al. (2009) also define “engaged emotions” as energised states rather than the full range of academic emotions.

Finn (1989) introduced the concept of identification to describe how students’ emotional connection to school contributes to sustained engagement. A sense of belonging and valuing school are factors that help students remain engaged, especially when faced with challenges and disruptions. While the behavioural, cognitive, and emotional domains offer a strong foundation for analysing student engagement, scholars have also proposed additional dimensions. The next section, Section 3.2.4, examines some of these proposed expansions, particularly agentic and social engagement.

3.2.4 Other Proposed Dimensions of Engagement

Some authors propose adding other dimensions of engagement, such as agentic and social (Cheon & Reeve, 2013, 2015; Gladstone et al., 2022; Patall et al., 2019; Pekrun & Linnenbrink-Garcia, 2012, 2022; Reeve, 2012; Reeve & Lee, 2013; Reeve & Tseng, 2011). This broader view reflects how engagement involves both individual initiative and interaction with others. Including these dimensions helps to describe more fully how students relate to their learning environment.

3.2.4.1 Agentic Engagement

In addition to the behavioural, emotional, and cognitive dimensions of engagement discussed previously, Reeve and Tseng (2011) introduced the concept of agentic engagement to describe how students can actively contribute to the shaping of their learning experiences. Unlike the other forms of engagement (cognitive, behavioural, and emotional/affective) that focus on how students respond to school contexts, agentic engagement refers to how students proactively influence those contexts. This includes expressing preferences, asking questions, suggesting activities, and seeking additional resources in ways that guide instruction to better suit their needs. Building on this, Reeve (2012) conceptualises agentic engagement as students’ constructive, self-initiated input into the ongoing flow of instruction. He distinguishes it conceptually from behavioural, emotional, and cognitive dimensions, and places it within the two-way interactions that occur between students and teachers. Reeve (2012) argues that agentic engagement is a distinct and essential dimension because it reflects students’ willingness to take initiative and participate actively in the construction of the learning process. Students who display agentic engagement are not merely compliant or passive participants;

instead, they attempt to make learning more meaningful and effective by interacting in a constructive manner with teachers and subjects.

Agentic engagement has been shown to support greater perceptions of autonomy, better motivational outcomes, and more personalised instruction. Reeve and Tseng's (2011) work suggests that when students feel encouraged to contribute, they are more likely to experience motivation and satisfaction in school, which, in turn, reinforces their engagement across all dimensions. Reeve (2012) further clarifies agentic engagement's measurement by excluding items that overlap with cognitive engagement, such as making the material personally interesting on one's own, creating a clearer boundary between agentic and cognitive processes.

Some authors view agentic engagement as related to cognitive processes since it involves self-initiated actions during learning because it reflects students' autonomy, use of self-regulation strategies, and goal-directed behaviour (Gladstone et al., 2022). A work that reinforces this view is Patall et al. (2019). In a six-week diary study of U.S. high school science classes with 208 students across 41 classes, the authors report that "agentic engagement predicted an increase in concurrent and longitudinal perceived teacher autonomy support, need satisfaction, and other forms of engagement" (Patall et al., 2019, p. 77). They also note that on days "when students' agentic engagement was greater than (their own) average, they would experience an increase in need satisfaction and autonomy support" (p. 79). In this sense, agentic engagement plays a role in fuelling students' motivation and reinforcing the exchange of support and autonomy within the classroom.

Patall et al. (2019) also emphasise that agentic engagement is not only a response to teacher support. It can also shape teaching as students' proactive involvement often prompts more autonomy-supportive behaviours from teachers. Furthermore, their findings indicate that agentic engagement is particularly associated with students' experiences of autonomy and relatedness, reinforcing the sense of belonging and willingness in the classroom. Importantly, it also predicts gains in behavioural, emotional, and cognitive engagement, working as a catalyst that strengthens student engagement.

Complementing these findings, Cheon and Reeve (2015) demonstrated through a classroom-based intervention that when teachers adopted more autonomy-supportive practices, students showed lower levels of amotivation and higher engagement. Their intervention spanned 16 secondary school, physical education teachers randomly assigned to an experimental or a control group, and 598 students who completed measures at the beginning, middle, and end of a semester. In Cheon and Reeve's (2015) design, teachers in the

intervention group were also scored by trained objective raters and were perceived by students as more autonomy supportive and less controlling than teachers in the control group. Students taught by intervention teachers reported greater psychological need satisfaction, greater engagement, and less amotivation than students taught by control-group teachers. Cheon and Reeve also treat engagement as a multidimensional construct that includes behavioural, emotional, cognitive, and agentic aspects, which makes their findings relevant to discussions of agency in classroom participation. Together with Patall et al. (2019), this suggests a reciprocal dynamic: students' proactive engagement can elicit greater autonomy support from teachers, while autonomy-supportive instruction further nurtures students' willingness to participate agentially.

Cheon and Reeve (2013) provide empirical evidence of how teacher practices can stimulate agentic engagement. In their study with 20 high school, physical education teachers and 1,018 students in South Korea, teachers participated in an autonomy-supportive training programme involving workshops, feedback, and classroom strategies, such as offering meaningful choices, acknowledging students' feelings, and encouraging initiative. Compared with a control group, students taught by the teachers who had received the training reported increased feelings of autonomy, lower amotivation, and higher engagement, including behavioural and agentic forms. This intervention illustrates that agentic engagement is not merely an individual disposition but can be elicited and strengthened through instructional practices that validate students' intrinsic motivation and encourage active participation.

Reeve and Lee (2013) extend this reciprocal account by testing the reverse pathway – from engagement to later motivation and performance. In a three-wave longitudinal study across a 17-week semester with 313 high-school students in 12 classes across five urban schools in Seoul, South Korea, mid-semester engagement predicted subsequent increases in psychological need satisfaction (especially competence and relatedness) and self-efficacy, and also predicted the final course grade. Conceptually, the authors treat agentic engagement as students' proactive contribution to the flow of instruction, distinct from behavioural, emotional, and cognitive facets. This positions agentic engagement as shaped by autonomy-supportive contexts and driven by motivational gains and achievement.

Extending this reciprocal account in urban U.S. high school science classrooms, Patall et al. (2022) found links over the semester between students' agentic mindset, their agentic engagement, and perceived teacher practice. Agentic engagement predicted later gains in agentic mindset, while perceived support for autonomy predicted subsequent increases in both

mindset and agentic engagement; conversely, agentic mindset predicted decreases in perceived teacher control. Moderator analyses indicated that these relations were stronger and more adaptive for higher achieving students and were dampened under higher stereotype vulnerability, with no reliable gender differences. Together, these results position agentic engagement within a reciprocal, context-sensitive process: students' proactive contributions and teacher autonomy-supportive practice coevolve over time.

3.2.4.2 Social Engagement

Some authors describe social engagement as a subcategory of behavioural engagement as it involves students' participation in the social aspects of school life (Gladstone et al., 2022). Social engagement connects observable behaviours with students' interactions in collaborative and group-based learning contexts. Social engagement refers to the quality of students' interactions with their peers, teachers, and the wider school community. It includes participation in group activities, cooperation during tasks, and a sense of connection within the learning environment. Although not part of early engagement models (cognitive, behavioural, and emotional), social engagement has gained recognition as a dimension that supports both academic and emotional involvement in school (Gladstone et al., 2022; Pekrun & Linnenbrink-Garcia, 2022; Reschly & Christenson, 2022).

Reschly and Christenson (2012) identify social engagement as a key factor in helping students build relationships, feeling a sense of belonging, and maintaining school commitment. These positive interactions with peers and opportunities for collaboration can increase motivation and reduce feelings of isolation. In schools where group work, dialogue, and shared responsibility are encouraged, students are more likely to feel included and remain engaged in their own education.

This dimension is relevant in interdisciplinary or project-based learning environments. In these scenarios, student interaction often plays a central role in sustaining attention and interest. By supporting meaningful relationships and peer cooperation, social engagement contributes to the overall experience of being part of a learning community.

Pekrun and Linnenbrink-Garcia (2012, 2022) note a strong connection between social and behavioural engagement. They describe social engagement as a form of social-behavioural engagement. The authors acknowledge that students' social interactions often appear in observable behaviours at school. Their view supports the idea that the dimensions of

engagement are connected and may influence one another (Pekrun & Linnenbrink-Garcia, 2012, 2022).

Agentic and social engagement are distinct but are seen as complementary to the initial three dimensions of student engagement. Agentic engagement is linked to the cognitive domain and refers to students' proactive efforts to influence their own learning, as seen in the previous subchapter, Section 3.2.4.1. Social engagement, on the other hand, is more closely related to behavioural aspects and includes students' interactions with peers, teachers, and the school environment. Some authors see agentic and social engagement as subcategories that offer more detail and refinement, while others treat them as separate dimensions.

These two extended dimensions of agentic and social engagement offer a broader view of how students interact with their learning environment. However, they do not fully explain the motivations behind students' academic choices. To understand why students engage or disengage, it is important to look at psychological models that address individual beliefs and values. One of these is Expectancy-Value Theory, which explains how students decide to engage or disengage based on how likely they think they are to succeed and how much they value the task.

3.3 Expectancy-Value Theory in Academic Decision Making

Eccles (Parsons) et al. (1983) developed the Expectancy-Value Theory (EVT) to explain how individuals' expectations of success and the value they assign to tasks influence their performance and decision making. This theory was initially created to understand gender differences in academic choices, such as why girls often avoid STEM subjects like mathematics. It defends the idea that students' beliefs about their abilities shape their educational decisions. This is aligned with ongoing discussions about gender imbalance in STEM-related fields and contributes to a clearer understanding of how education and career paths can become more accessible to underrepresented groups.

In EVT, task value is described in four parts: intrinsic/interest value (enjoyment), attainment value (identity/importance), utility value (usefulness), and cost (effort, opportunity, and emotional/psychological costs). Together with expectancies for success, these components directly shape students' choices, persistence, and performance (Wigfield & Eccles, 2000). EVT is based on observed patterns in student behaviour, showing how expectancies and task values help explain preferences across different areas (Gladstone et al. 2022). This displays the theory's relevance for understanding how students make academic and career decisions based on their

beliefs and priorities. Students typically engage more, stay with tasks longer, and opt into related courses in domains where they expect to succeed and perceive high value. However, elevated perceived costs can suppress engagement even when interest is present; that is, a student may feel that they like an activity but still see it as too difficult to pursue (Wigfield & Eccles, 2000).

EVT, as developed by Eccles and colleagues (Eccles (Parsons) et al., 1983; Wigfield & Eccles, 2000), helps explain how students' expectations and values shape their academic and career decisions. Recognising the impact of these factors allows educators and policymakers to better understand student choices and support broader participation in education. When students connect classroom tasks to their own goals, they tend to value those tasks more and are more likely to take follow up courses, especially in maths and science (Eccles & Wigfield, 2024).

This framework was later refined and renamed Situated Expectancy-Value Theory (SEVT) to make the role of context more explicit (Eccles & Wigfield, 2020; Gladstone et al., 2022; Eccles & Wigfield, 2024). It focuses both on the students and the contexts they are in. While EVT focuses on individual beliefs about success and the importance of tasks, SEVT focuses on how these beliefs are influenced by personal experiences, social roles, and contextual factors. Within Tamura et al.'s (2022) framework – which will be seen in more depth in the next subchapter, Section 3.4 – expectancy of success is one of several motivational drivers, reinforcing that engagement depends on more than achievement alone. The connection between Expectancy-Value Theory and the dimensions of engagement reveals how motivation shapes students' choices and outcomes.

According to SEVT, expectancies and values lead to five dimensions of engagement: behavioural, cognitive, emotional, agentic, and social, which then drive learning and future decisions (Gladstone et al., 2022). Students' beliefs change with experience as they weigh options in context, interpret feedback from teachers and parents, and update beliefs over time. These cycles can expand or limit participation in STEM (Eccles & Wigfield, 2020, 2024).

Building on this understanding of how students' expectations and task values influence academic choices, Section 3.4 explores motivational engagement in greater depth. It defines motivational engagement within a multicomponent view of engagement, examines how academic emotions relate to different engagement components, and extends this discussion through Tamura et al.'s (2022) six drivers of motivational engagement.

3.4 Motivational Engagement

In my thesis, I use motivational engagement as one component of student engagement, meaning the motivational processes that shape students' direction, intensity, and persistence in learning activities. This subchapter, Section 3.4, does three things: first, it defines motivational engagement within a multicomponent view of engagement; second, it summarises how academic emotions are linked to different engagement components; and third, it explains why these matter for interpreting students' participation, persistence, and peer interaction during the therein workshops. The discussion draws mainly on Linnenbrink-Garcia and Pekrun (2011) and Pekrun and Linnenbrink-Garcia (2012, 2014, 2022), and then extends this discussion with Tamura et al. (2022), who conceptualise motivational engagement as a dynamic process emerging from interactions among six drivers and examine these relations using psychological network analysis. It also compares Tamura et al.'s six drivers with Pekrun and Linnenbrink-Garcia's engagement components, clarifying how differences in terminology map onto similar motivational processes and why this matters for interpreting the therein workshops. Finally, it briefly contrasts this multicomponent view with Griffiths et al. (2022) to clarify how disengagement can be active rather than simply the absence of engagement.

Pekrun and Linnenbrink-Garcia (2022) describe classroom engagement as a multicomponent construct where all components involve active, energetic, approach-oriented involvement with academic tasks. They organise research on academic emotions by showing how emotions relate to different engagement components, how these links shape learning and achievement, and how reciprocal processes can unfold over time (Linnenbrink-Garcia & Pekrun, 2011; Pekrun & Linnenbrink-Garcia, 2012, 2014, 2022). A key claim in this account is that emotions influence achievement partly by shaping engagement, so engagement functions as a pathway between emotions and learning outcomes. Their evidence base includes both experimental studies and field studies, and they note the importance of emotionally responsive learning environments that can be designed and evaluated (Pekrun & Linnenbrink-Garcia, 2012, 2022).

Pekrun and Linnenbrink-Garcia (2022) classify academic emotions by their object focus and by valence (positive–negative) and activation (low–high). They also group emotions into four broad categories: achievement, epistemic, topic, and social. In parallel, they expand the classic triad of cognitive, behavioural, and emotional engagement by distinguishing cognitive engagement, motivational engagement, behavioural effort investment, cognitive behavioural engagement, and social behavioural engagement (Pekrun & Linnenbrink-Garcia, 2012, 2022).

These categories are conceptually distinct even when they cooccur in practice, and they are used to specify how different emotional experiences connect to different forms of participation and effort.

Within this framework, the same valence does not guarantee the same engagement effect because activation and object focus matter. High-activation negative emotions, such as anxiety, can sometimes increase effort, while low-activation negative emotions, such as hopelessness, can reduce engagement. Low-activation emotions are not automatically harmful because they can support calm focus in settings that require sustained attention. This helps explain why emotional experiences can support or hinder engagement in different ways, depending on task demands and classroom conditions (Pekrun & Linnenbrink-Garcia, 2012, 2014, 2022).

This approach also clarifies a terminology issue that matters in this thesis. Academic emotions are treated as antecedents that influence engagement components whereas emotional or affective engagement typically refers to students' affective reactions as one component of engagement (Fredricks et al., 2004). Pekrun and Linnenbrink-Garcia's (2012, 2022) contribution is to specify academic emotions more precisely and to show how different emotions relate differently to motivational engagement and other engagement components. For comparison, Griffiths et al. (2022) distinguish between active positive engagement and active negative disengagement, challenging the idea that disengagement is simply the absence of engagement. This supports a reading of low participation as potentially deliberate and oppositional rather than only passive or empty.

Extending this discussion of motivational engagement in teaching and learning, Tamura et al. (2022) examine how key components of the motivational engagement process relate to one another. Their study explores how six categories – reasons and values, expectancy belief, goals, social relations, affective experiences, and perceived autonomy – interact to support motivational engagement in learning. According to Tamura et al. (2022), motivational engagement involves a set of related elements that support autonomous self-regulation. It is “a mental category that people subjectively construe from a broad range of underlying components such as values, goals, and affective experiences (e.g., enjoyment and anxiety)” (Tamura et al., 2022, p. 1). The authors do not treat motivational engagement as a single, clearly defined construct that can be measured through fixed methods, “as a unitary construct that can be precisely defined and assessed” (Tamura et al., 2022, pp. 1–2), but, rather, as changing characteristics that emerge from the interaction among these elements. Their study uses

psychological network analysis to explore how these components relate to one another, aiming to reveal how they may influence each other over time.

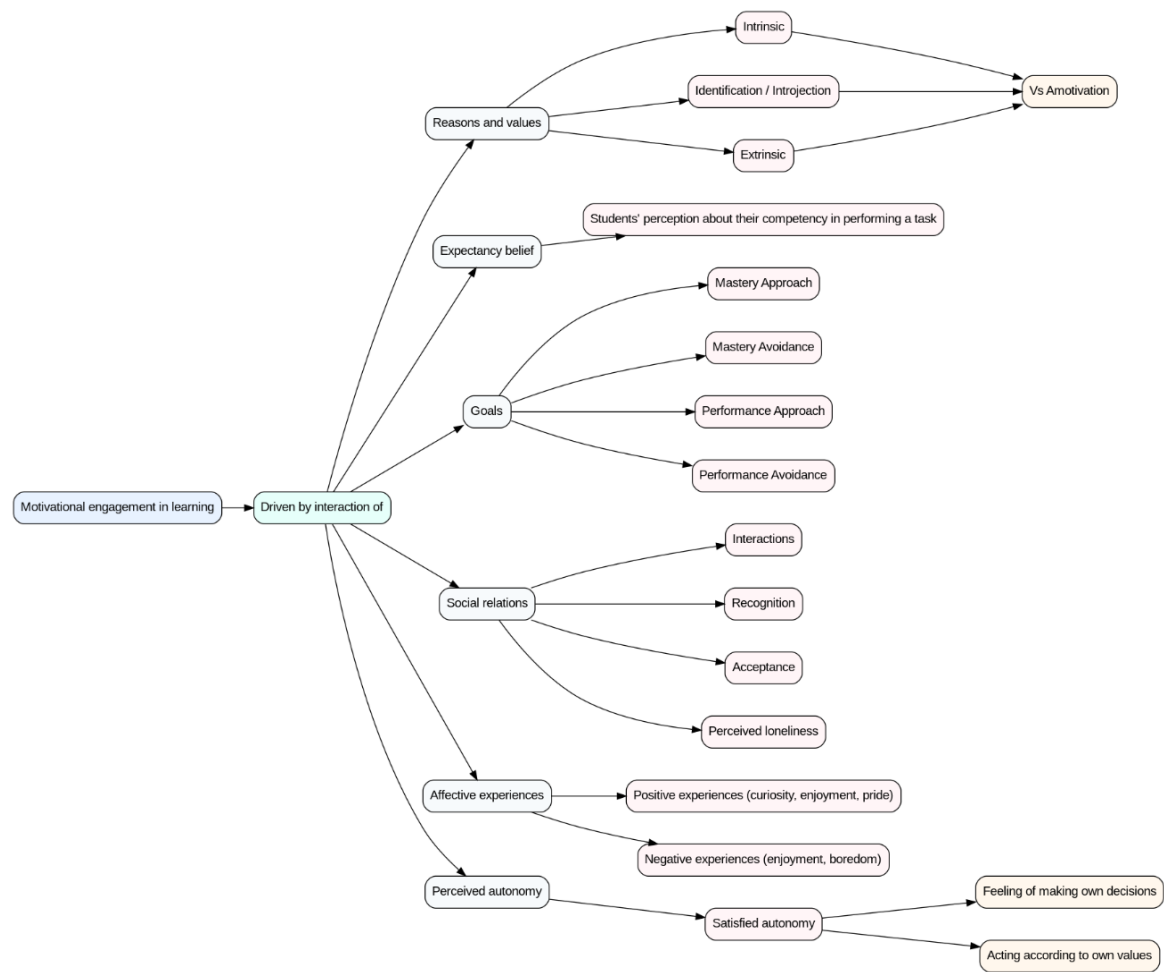
Tamura et al. (2022) analyse how key elements of motivational engagement relate to one another through a within-person contemporaneous network analysis. The study involved following four postgraduate researchers as they worked on new psychology projects over one year, using a daily diary completed each evening. Across these diary entries, the authors assessed 31 components mapped onto six drivers (reasons and values, expectancy belief, goals, social relations, affective experiences, and perceived autonomy) and modelled their within-person links as a contemporaneous network. Their results suggest a complex network that supports autonomous self-regulation, where elements like enjoyment (affective experience) and interest (intrinsic reason) act as central hubs connecting different motivational processes. This approach examines how these elements operate within individuals from the ground up, showing that motivation in the school context is an emergent pattern of interactions rather than a single isolated factor.

Tamura et al. (2022) explore not only how students participate in learning but also why. They argue that classroom participation is driven by different sources, yet factors such as reward, obligation, and a sense of proficiency are not experienced equally by all students. Even unrelated aspects – like the feeling of competence, or the perception of being good or bad at something regardless of grades – can strongly influence whether a student takes part in a subject. According to the authors, students' willingness to participate is also shaped by their confidence and by the social support they receive during learning. Another element is the cost of learning, which refers to the negative value a student assigns to a task. Students weigh this cost before deciding whether to do an activity, and this often plays a decisive role. These perceptions vary from student to student and can present a significant barrier to maintaining motivation (Tamura et al., 2022).

Tamura et al. (2022) conceptualise motivational engagement as a mental category and subdivide motivational investment into six subcomponents as shown in the Figure 2 below.

Figure 2

Tamura et al.'s (2022) Motivational Engagement and Its Six Subcomponents



Note. This figure was created by this thesis' author.

In the first of their six drivers for motivation, reasons and values, Tamura et al. (2022) distinguish between intrinsic and extrinsic motivation. They state: “An intrinsic reason reflects the situation where students are engaged in a task because of the pleasant experiences coming from the engagement itself” (Tamura et al., 2022, p. 2). Intrinsic motivation refers to doing something because it is enjoyable or interesting while extrinsic motivation involves doing something to gain a reward or avoid a penalty, such as earning money or avoiding teacher-imposed consequences.

Although it is straightforward to distinguish between intrinsic and extrinsic motivations, students' reasons for participating often fall into a grey area between these two categories. Tamura et al. (2022) explain that “While the distinction between intrinsic and extrinsic reasons is intuitive and easy to understand, not all types of people's engagement can be captured by this

dichotomy” (p. 2). To describe motivations that fall between these poles, the authors introduce the concepts of introjection, identification, and amotivation. These intermediate forms show how externally regulated motivation can become increasingly internalised. As students begin to recognise personal meaning or value in an activity, their reasons for engagement may move beyond external rewards or consequences, even when the activity itself is not intrinsically enjoyable. This also aligns with Self-Determination Theory (SDT), which describes extrinsic motivation as varying in the degree to which its regulation has been internalised and personally endorsed (Ryan & Deci, 2009).

An introjected reason refers to a situation in which a person is driven by a sense of self-worth that depends on meeting certain expectations – for example, studying to maintain pride or avoid guilt. This is not purely extrinsic as the task holds some personal value, but it is not fully intrinsic either since the focus is on self-esteem – on feeling worthy through completing the task – rather than on genuine satisfaction with the activity itself. When the task is viewed as meaningful for one’s “personal growth and future” (Tamura et al., 2022, p. 2), motivation may shift toward what the authors call identification or an identified reason. In this state, the student recognises the task as important and worthwhile, even if it is not enjoyable. This form of motivation is similar to intrinsic motivation in its depth, but it is based on perceived utility rather than interest or pleasure. In contrast to both introjection and identification, when individuals cannot find any purpose in learning, Tamura et al. refer to this as amotivation and what I refer to in my work as “disaffection”.

When describing goals, Tamura et al. (2022) use a 2 × 2 framework to assess achievement-related aims, as seen in Table 1. This model distinguishes between approach and avoidance orientations within both mastery and performance goals. The four types are: mastery-approach goals, focused on developing competence and fully understanding the task; mastery-avoidance goals, aimed at preventing failure to master the task; performance-approach goals, focused on outperforming others; and performance-avoidance goals, which involve trying not to be outperformed (Tamura et al., 2022).

Table 1
Tamura et al.’s (2022) Goals 2 x 2 Taxonomy

	Approach	Avoidance
Mastery	Mastery approach	Mastery avoidance
Performance	Performance approach	Performance avoidance

A further driver is expectancy belief, which refers to students' belief in their ability to successfully complete a learning task. It refers to students' belief in their ability to successfully complete a learning task. This driver is divided into two aspects: action–outcome contingency and efficacy belief. Feeling capable in a task often matters more than having the skills to do it. For example, a student may have good reasons to study mathematics, but, if they doubt their ability to understand the content, they may avoid the subject. This belief is significant as confidence in one's ability is strongly associated with academic success and is one of the most consistent predictors of achievement (Tamura et al., 2022). Tamura et al.'s efficacy belief overlaps with Bandura's (1977) concept of self-efficacy, as both concern a person's belief in their capability to carry out the actions required for a task. A related concern with feeling capable is also present in the SDT construct of competence, although expectancy belief, self-efficacy, and competence remain distinct constructs (Ryan & Deci, 2009).

Another driver, social relations, concerns the role of peer interactions in educational settings, which play a vital role in academic achievement and may even predict performance. As the authors explain, “the perception that students are recognized and accepted by others predicts academic attainment, ... [while] ... perceived loneliness ... [is] ... associated with negative outcomes” (Tamura et al., 2022, p. 2). This emphasis on recognition, acceptance, and social connection also overlaps with the SDT construct of relatedness, which concerns students' sense of connection and belonging with others (Ryan & Deci, 2009).

Although social relations are closely linked to students' emotional experiences, Tamura et al. (2022) classify affective experiences as a separate driver: “Affective experiences during class have been shown to be proximal predictors of many achievement relevant outcomes” (p. 2). The authors separate this category because emotions can also be directed toward a subject, a teacher, or the school system as a whole and not just peers. These feelings may include positive emotions, such as enjoyment, pride, or curiosity, and negative ones like anxiety or boredom (Tamura et al., 2022). This separation aligns with the emotional/affective engagement literature, which treats emotions as students' affective reactions to learning and to the people and settings around it, not only to peers (Fredricks et al., 2004; Gladstone et al., 2022; Skinner et al., 2009). Such emotions emerge throughout the learning process (Tamura et al., 2022).

The final driver, perceived autonomy, refers to the sense of being independent and self-directed when completing a task (Tamura et al., 2022). This emphasis on autonomy connects directly with agentic engagement, Section 3.2.4.1, where students' proactive contributions to

instruction are most likely when classroom contexts support choice, initiative, and self-directed participation (Cheon & Reeve, 2013, 2015; Reeve, 2012; Reeve & Tseng, 2011). This need is “satisfied when they [the students] have a feeling that they are making their own decisions and acting according to their own values” (Tamura et al., 2022, p. 2). According to Tamura et al. (2022), perceived autonomy reflects the idea that students’ participation in learning is shaped not only by external factors but also by their internal sense of control. When students feel their choices align with their values, it strengthens their sense of ownership and personal commitment to the learning process. Perceived autonomy also overlaps directly with autonomy in SDT, where autonomous motivation is supported when students experience their actions as volitional and personally endorsed (Ryan & Deci, 2009).

These six drivers influence one another and shape students’ experiences in education, contributing either to active participation or to withdrawal and disaffection with the educational system. Their combined effect forms the foundation of the motivational engagement process (Tamura et al., 2022). These drivers do not operate in isolation. Their interaction is essential for meaningful motivation to emerge. As the authors explain, these elements must be “interacting with each other to support people’s autonomous motivational engagement as a whole” (Tamura et al., 2022, p. 8). Taken together, these drivers also show areas of shared elements with SDT. Perceived autonomy connects with autonomy, expectancy and efficacy beliefs relate to students’ perceptions of competence, and social relations connect with relatedness (Ryan & Deci, 2009). These constructs are not equivalent across the different theoretical approaches, but their overlap shows how autonomy, capability, and social connection can interact within motivational engagement.

Tamura et al. (2022) conclude that intrinsic reasons are central to linking “affective experiences and core motivational components” (p. 8). However, these reasons are not the only contributing factor. Curiosity also plays a significant role due to its emotional and motivational aspects and “its strong function of initiating behavior” (Tamura et al., 2022, p. 8). Rather than being a momentary or isolated feeling, curiosity acts as a starting point for sustained learning. As the authors explain, “curiosity is a precursor [...] of developing interest or autonomous task engagement” (Tamura et al., 2022, p. 8). Similarly, emotional satisfaction derived from completing a task often stems from intrinsic reasons. Together, curiosity and intrinsic motivation “play a bridging role in the observed network of autonomous motivational engagement” (Tamura et al., 2022, p. 9).

While Tamura et al. (2022) present six drivers of motivation, Pekrun and Linnenbrink-Garcia (2012, 2022) distinguish between specific types of engagement, and classify these as:

cognitive (attention and memory processes), motivational (intrinsic/extrinsic motivation, achievement goals), behavioral-effort investment (effort and persistence), cognitive-behavioral (strategy use and self-regulation), and social-behavioral (social on-task behavior). (Pekrun & Linnenbrink-Garcia, 2022, p. 110)

Tamura et al.'s categories can be mapped onto this framework, reflecting a difference in terminology rather than in processes. This distinction is important to "clarify the unique ways in which emotions relate to engagement" (Pekrun & Linnenbrink-Garcia, 2022, p. 110).

Having examined the theoretical foundations of motivational engagement and the multiple drivers that influence students' willingness to participate in learning, the next section, Section 3.5, examines how high-risk behaviours and adverse childhood experiences (ACEs) can affect students' participation in school.

3.5 High-Risk Behaviours and Adverse Childhood Experiences (ACEs)

In this section, I focus on high-risk behaviours as outcomes that can cooccur with sustained disaffection and disengagement, and I use ACEs to explain why some students are more vulnerable to this pattern. Griffiths et al. (2022) display a link between disengagement and high-risk behaviours and argue that students most vulnerable to disengagement often display high-risk or disruptive behaviours. They position adolescent engagement research as incomplete if it only considers academic behaviours, and they treat the student's perceptions of school as central when considering troubling and high-risk behaviours.

Understanding adolescent engagement requires placing the student's own view of schooling at the centre. As Griffiths et al. (2022) state, "the student and their personal beliefs and perceptions about school and the schooling process are central to engagement considerations" (p. 301). Their framework, based on social development theory, emphasises that engagement develops when students have meaningful chances for behavioural participation, for building social skills, and for receiving positive responses from peers and teachers when they use these skills (Griffiths et al., 2022).

According to Catalano et al. (2001), their review organises evidence through risk and protective factors linked to adolescent problem behaviours, and it explains why young people who face cumulative adversity are more likely to show negative outcomes. They identify school-

based risk factors that are closely tied to disaffection, including academic failure and low commitment to school. They also describe protective factors, such as opportunities and support for prosocial involvement and recognition for prosocial behaviour, which can strengthen bonding and reduce problem behaviour. This supports the broader view that student engagement is strongly shaped by contextual conditions, and that social factors play a central role in both the level of engagement and its consequences.

High-risk behaviours, which are closely associated with low school engagement, include actions such as self-harm or violence, risky sexual activity that may result in unplanned pregnancy or sexually transmitted infections, substance use, poor dietary choices, and lack of physical activity (Griffiths et al., 2022). Although these behaviours differ in form and seriousness, they show the strong link between school engagement and overall well-being.

Longitudinal evidence supports this link. Using four years of data, a Canadian prospective cohort study of Grade 9–12 secondary school students by Weatherson et al. (2018) found that when students reported higher school connectedness than usual, they also reported less smoking, marijuana use, and binge drinking, and were more likely to meet physical activity recommendations. A meta-analytic review also points in the same direction. Rose et al. (2024) synthesised findings from 90 U.S. articles between 2009 and 2019 and show a consistent pattern: students who report stronger school connectedness tend to report lower involvement in health-risk behaviours across several domains (substance use, mental health, violence, and sexual health). They also found the same pattern when risks cooccur, meaning that a student is involved in two or more risk domains at the same time.

Adverse childhood experiences (ACEs) are powerful factors that influence student engagement, affecting attendance, retention, and long-term educational outcomes (Griffiths et al., 2022). ACEs include events such as parental separation or divorce, financial hardship, exposure to violence, racial or ethnic discrimination, the death of a parent, and living in an unstable household. These difficult situations can affect concentration and participation in school, with effects that may continue into adolescence and adulthood (Griffiths et al., 2022).

The consequences of exposure to ACEs go beyond the school setting and are linked to substance misuse, higher dropout rates, and higher levels of depression (Griffiths et al., 2022). A greater number of ACEs is also associated with a higher risk of becoming both a perpetrator and a victim of violence, and with increased likelihood of incarceration, juvenile arrest, and felony charges (Griffiths et al., 2022). These patterns can continue across generations as people with higher ACE scores are more likely to expose their own children to similar experiences, which

shows the long-term and intergenerational impact of trauma on students and families (Griffiths et al., 2022).

Some groups are disproportionately affected by ACEs. Although ACEs affect people from many backgrounds, they occur more often among racially and ethnically marginalised groups and among families with lower socioeconomic status (Griffiths et al., 2022). This shows the need for school responses that take into account the specific conditions faced by these communities.

A harmful cycle can develop when students affected by ACEs are seen as disengaged by school staff. These views often lead to exclusionary practices, such as suspension, and may increase disruptive behaviour (Griffiths et al., 2022). As students begin to feel rejected by the school environment, they may resist teacher guidance, which creates a setting marked by conflict and low support (Griffiths et al., 2022). Over time, this pattern can become a pathway in which early disengagement is linked to later risks beyond school.

Henry et al. (2012) carried out a longitudinal study in an urban U.S. context using data from the Rochester Youth Development Study in Rochester, New York, which followed 911 adolescents (73% male, 68% African American) from early adolescence into early adulthood. The authors created a School Disengagement Warning Index using school records from Grades 8 and 9, including indicators such as low grades, suspensions, absenteeism, and grade retention. Their analysis showed that higher disengagement scores were linked to a greater likelihood of dropping out of school, and to greater involvement in violent behaviour, property crime, substance misuse, and contact with the justice system during adolescence and early adulthood. Importantly, high school dropout status helped to explain part of the link between early disengagement and these later outcomes, suggesting that disengagement may start a developmental path that increases risk across different areas of life.

From another angle, McNeely and Falci (2004), using data from the U.S. National Longitudinal Study of Adolescent Health, found that students who felt connected to their schools through positive relationships and teacher support were less likely to engage in risky behaviours, such as early sexual activity, substance use, and violence. While teacher support helped students to move away from risk behaviours, a general sense of school belonging was important for preventing these behaviours from starting. These findings show that strong emotional ties to school can act as a buffer during times of greater vulnerability.

3.6 Summary

This chapter treats student engagement as a multidimensional process involving behavioural, cognitive, emotional or affective, agentic, and social dimensions. Drawing on Reschly and Christenson (2022) and Fredricks et al. (2004), engagement is conceptualised as being shaped through ongoing interactions between students and their academic, social, and emotional contexts. These definitions set the criteria for what counts as engagement in my analysis and frame the distinctions between engagement, disengagement, disaffection, and burnout.

To explain why students participate, persist, or withdraw, I connect engagement to motivation. Expectancy Value Theory and Situated Expectancy Value Theory clarify how expectancy beliefs and task values shape academic choices (Gladstone et al., 2022). I then use Pekrun and Linnenbrink-Garcia's (2012, 2022) account of academic emotions and motivational engagement, alongside Tamura et al.'s (2022) six motivational drivers: reasons and values, expectancy beliefs, goals, social relations, affective experiences, and perceived autonomy. Hofkens and Pianta (2022) also emphasise that engagement emerges through everyday classroom relationships and practices, including teacher, student, and peer interactions.

The chapter also situates engagement within wider social and emotional conditions. Exposure to adverse childhood experiences and exclusionary school practices can strengthen disengagement processes and increase vulnerability to later risks (Griffiths et al., 2022). Longitudinal evidence links early disengagement indicators to outcomes, such as dropout and involvement in risky behaviours, while school connection and teacher support can operate as protective factors (Henry et al., 2012; McNeely & Falci, 2004). Taken together, these lenses provide the analytic frame used in Chapters 6 and 7 to interpret engagement, interdisciplinarity, and peer interaction during the therein workshops, including creative and student-centred activity in a constrained school setting.

CHAPTER 4 – RESEARCH DESIGN

In this chapter, I outline the research design and methodological choices guiding this study. Because the study investigates student engagement in a Brazilian public school, I begin by contextualising the research site and educational structure in the state of Paraná, Brazil, and describing the process required to gain access to the school system. I then discuss the qualitative case study framework I adopted, followed by an account of data collection methods, the workshop sequence, and ethical procedures. I also explain how student engagement was examined in this study, and why focus groups, interviews, and the reflective journal were appropriate for capturing participation, emotions, and peer interaction. Attention is given to the strategies for processing, coding, and analysing qualitative data using NVivo and constructivist grounded theory to generate the findings. This chapter establishes the foundation for the subsequent presentation and interpretation of the research findings in Chapters 6 and 7.

4.1 Research Context

This research took place in Brazil, in the state of Paraná, a southern state far away – at least culturally – from the scorching summer of the beaches of Rio de Janeiro and the overlapping cities packed with skyscrapers in the São Paulo megalopolis. This state has approximately 11.89 million inhabitants, and it is about the size of Great Britain – 199.315 km². Its biggest city is the capital Curitiba with a population of more than 3.2 million inhabitants in its metropolitan region (IBGE, 2024).

The public educational system in Paraná is divided into county (*municipal*) and state (*estadual*) schools. The county schools are responsible for the classes from preschool (four years old) until the end of primary school (5th grade) and are managed by the city councils. The state schools are responsible for middle school (6th grade) until the end of high school and are regulated by the state of Paraná (Brazil, 1996). If an institution is commanded by the State Union (Brazilian government in the capital Brasília – DF), it is called a Federal institution. For instance, a Federal Institute of Education is a school managed by the country's central government, but those rare exceptions in the schooling system were not studied in this thesis. Also, they are considered “model” schools and do not correspond to the reality of the majority of public schools in the country.

The gatekeeper of the state schools in Paraná is the Department of Education and Sport (SEED; *Secretaria da Educação e do Esporte*). This institution is responsible for: promoting access

to school and student permanence to school; carrying out surveys in the population served by the state education networks; collecting, analysing, and disseminating educational data and information; implementing projects that promote improvement in the quality of education; providing access for educators and students to technology applied to the improvement of teaching and learning; elaborating and disseminating guidelines, regulations, rules, and instructions required for the functioning of the Network of Teaching Institutions of Basic Education; licensing of teaching institutions; providing technical assistance to teachers and administrative staff; planning the use, construction, improvement, expansion, adaptation, conservation, and reorganisation of the physical network, comprising buildings, equipment, and furniture; offering support services to students with special educational needs; and planning, organising, and following up the state government's policies and guidelines for sports, leisure, and quality of life. All the state schools' management, execution of plans, and assessments are carried out by SEED (SEED, n.d.).

Among all the functions and duties of SEED, those that are most related to this project are the ones that deal with implementing projects to improve education. In this case, it refers to allowing the workshops to be carried out within the school as SEED considered it a project that would promote improvement in the educational quality of the school chosen for the project. Also related to this work is producing guidelines, regulations, rules, and instructions so that this project has a clear pathway to be proposed and implemented in the public system.

To get access to the school where I conducted my research, I had to gain permission from the regional SEED branch, the Regional Education Center (NRE; *Núcleo Regional de Educação*). A standard protocol of documents was required, namely a research proposal, ethics approval, and translated appendices into Portuguese (for example, Interviews, Participant Information Sheet, and Consent Forms), after which a school was assigned to where the research could take place. This assigned school could then accept or deny the research opportunity. If the chosen institution considered that the proposed research would be too difficult, had any kind of conflict of interest, or overloaded its capacity by any means, it could deny the research. In this case, SEED would point out a different institution.

Sometimes, a researcher can arrange to work with a specific school due to previous contacts, and this was the case for me. I did not work in this specific school, nor did I have prior contact with these students. However, I had completed part of my university practicum (internship depending on the culture or *estágio* as we call it in Brazil) in this school in 2010. The principal at the time had since retired, and most of the staff had changed since I was there,

but I did know two teachers with whom I had attended congresses in public state institutions of education. I was familiar with the school buildings and grounds as well. I went to the school's office and asked to book an appointment with the assistant principal to show my research proposal and to ask for permission to do my research in their school. The school where the research took place will remain anonymous due to confidentiality. All data were collected in person at the school.

4.1.1 COVID-19

The COVID-19 situation in Brazil had a slow and ineffectual response with 37,000,000 cases and 700,000 deaths with a peak of more than 4,000 deaths a day, according to the official reported numbers disclosed by the Brazilian Ministry of Health (*Ministério da Saúde*), excluding sub notifications. At the time of data gathering of this research in 2022, masks were encouraged to be worn in most places but mandatory only in health facilities and the same with sanitising hands. Group activities in schools were allowed although social distancing was encouraged. There was no contact tracing in Brazil of any kind at any point during the pandemic, and, although vaccination numbers plateaued at 80% of the total population despite the various kinds of vaccines available (Astra-Zeneca, Pfizer, Coronavac, and Janssen), COVID-19 was still a real factor during the workshops. In fact, the first time I caught COVID-19 was at this school during the workshops², and this affected the progress of the workshops as I was unable to work with the students for 10 days during winter.

4.2 Qualitative Case Study

I used a qualitative case study design because this research examines a contemporary educational phenomenon in context where the phenomenon and the context cannot be separated cleanly (Yin, 2018). In this thesis, the case study is used to examine a bounded system in depth. Here, "bounded system" means that I specify what the case includes and excludes (Merriam, 1988; Yin, 2018). This approach also aligns with qualitative case study discussions that emphasise real-world conditions and the use of more than one source of evidence (Quimelli, 2009; Simons, 2009).

In this study, the case is the implementation of a theremin-based workshop sequence in one Brazilian public school. A central design task in case study research is to define the case and set limits that clarify what the case includes and excludes (Baxter & Jack, 2008; Yin, 2018). I bound the case by the setting, the participants, and the timeframe of the intervention (Baxter &

² Like many others who caught it, I thought I was going to die.

Jack, 2008; Simons, 2009). I also bound it by specifying which forms of evidence constitute the study corpus (Simons, 2009). The case includes the workshop sessions delivered to participating students from four Year 8 classes and the related experiences reported by participants during the intervention period through the study data. It excludes other year levels, other school programmes, and events outside the intervention period that are not documented through the study evidence base (Merriam, 1988).

Clarifying the unit of analysis is a core design decision in case study work (Baxter & Jack, 2008; Merriam, 1988). In this thesis, “unit of analysis” refers to what is treated as the main case for analysis. The primary unit of analysis is the workshop programme as enacted in one school. I also treat each of the four Year 8 classes as an embedded unit within the broader case (Yin, 2018). Here, “embedded unit” means a subunit within a single case. The classes shared the same intervention structure but operated as distinct classroom groups (Yin, 2018).

4.2.1 Considering Action Research

Action research was also considered as a possible methodological approach for this study. This was a reasonable possibility because I was not a detached observer of the case. I designed and facilitated the workshops, responded to students while activities were taking place, and inevitably influenced the environment in which the research was conducted. Action research similarly gives an active place to practitioners and researchers within the practices being investigated (Kemmis et al., 2014). The distinction between action research and the qualitative case study adopted here therefore required consideration.

Action research encompasses different methodological traditions, but it is broadly concerned with inquiry connected to change in practice (Somekh, 2006; Kemmis et al., 2014). Kemmis et al. (2014) caution against reducing action research to a fixed sequence of stages because actual projects are more fluid than the familiar spiral suggests. Nevertheless, an important cyclical movement remains: action is planned and enacted, its consequences are observed and reflected upon, and this reflection informs subsequent action. The attraction of action research for this project was therefore clear because the workshop were themselves an intervention intended to create possibilities for change. However, the presence of an intervention does not by itself make a study action research.

This study did not implement one workshop cycle, evaluate it, redesign the intervention from that evidence, and then implement a revised cycle. The overall structure was established before I entered the research site. It followed an artistic–electronics–artistic sequence, with the

theremin as the artefact to be explored and constructed across a fourteen-week programme. I made standard pedagogical adjustments while teaching, responding to students, clarifying instructions, and changing my support when difficulties emerged, but these moment-to-moment decisions did not constitute successive research cycles in which one completed intervention was systematically used to redesign the next.

Students also exercised considerable agency within the workshops, (see Chapter 6, 7 and 8). Their agency, however, operated within the workshop structure rather than over the methodological design of the intervention. They did not collectively determine the overall workshop sequence or redesign and reimplement the programme as members of an action research group. This is relevant to even more agentic forms of Action Research, such as the Critical Participatory Action Research described by Kemmis et al. (2014), in which participants themselves take an active role in identifying shared concerns and developing collective plans for change. That was not the methodological relationship established in this study.

Instead, the main methodological iteration occurred in the analysis. As data were coded and compared, patterns that I could not adequately interpret led me back to the literature. Further reading changed what I was able to recognise in the data and sometimes required another return to coding, comparison, and developing categories. Constructivist grounded theory provided the logic for this repeated movement between data, literature, coding, and interpretation, as discussed in detail in Section 4.6. The distinction can therefore be expressed in terms of what was being iterated: in this study, the central methodological iteration was the developing analytical interpretation rather than successive redesigns of the intervention.

There is also a longer history behind the workshops. The activities used in this research developed partly from my master's research and from workshops I subsequently conducted as a teacher. These experiences formed part of the practical knowledge I brought into the school and influenced how I understood what happened there. However, this study did not systematically collect and compare evidence from my master's research, teaching practice, and the present project as successive cycles of change. They therefore belong to my background as a researcher and educator rather than to the unit of analysis. For these reasons, qualitative case study provided a closer description of the research undertaken.

4.3 Examining Student Engagement

Student engagement is crucial to academic success, personal development, and overall well-being. A range of different procedures can be used to examine how engagement works in

schools. Fredricks (2022) mentions self-report surveys, teacher ratings, observations, administrative data, experience sampling methods, and real-time measures. As discussed in Section 3.1, “Student engagement at school”, Fredricks (2022) notes that students who are actively involved in their learning tend to develop stronger connections with their schools. This connection supports the development of skills, values, and attitudes that help with academic success and preparation for adult life. Engagement also works as a protective factor because it helps students deal with difficulties, return to tasks, and continue learning after setbacks (Fredricks, 2022).

One benefit of observational measures is their grounding in real classroom practice, offering insights into specific situations. This makes them useful for practitioners who want a deeper understanding of student engagement within that specific context (Fredricks, 2022). However, these advantages come with methodological challenges. Researchers need to choose how often to observe, for how long, which unit of analysis to use (student, group, or whole class), and in what types of activities (for example, whole-class instruction, group activities, or independent work). There are also concerns about how the presence of a video camera may influence instruction, interactions, and students’ behaviour. In many cases, researchers need specific training and, because observations take time, only a limited number of students can be observed. This affects how far the results can be applied to other situations (Fredricks, 2022).

In measuring engagement, Fredricks (2022) draws on different methods from different perspectives. Observational procedures, for example, make it possible to describe engagement and the classroom context in detail. They help to identify individual and contextual elements that make engagement emerge or fade. Additionally, this type of approach is often less disruptive as it can be represented through narrative or descriptive techniques without the need for structured coding systems, which is useful for studies that want to follow classroom interactions over time (Fredricks, 2022).

Fredricks (2022) also examines interviews as a way to assess engagement. Interviews can be structured, semistructured, or more open. They are useful because they show the reasons for differences in engagement and how students interpret their school experiences. They also show which contextual elements matter more to them and how these elements relate to motivation and participation (Fredricks, 2022). Interviews were the main procedure in my study because they gave access to students’ own explanations about participation and about what supported or limited their engagement.

Another way to assess engagement is to use administrative data. School records, such as attendance, truancy, and completion rates, are collected in a systematic way and can be used as indicators of engagement (Fredricks, 2022). Fredricks et al. (2004) point out that engagement dimensions often overlap in practice and that many studies still rely on a single procedure, usually self-reporting. Later, Fredricks (2022) reviewed new self-report instruments and noted that this overlap continues to appear and that many items still refer to school or classes in general rather than to specific tasks. Because of this, she calls for clearer definitions and stronger evidence across different student groups.

Reschly and Christenson (2022) add to this discussion by revisiting how engagement is measured and classified, arguing that engagement and its negative counterpart should not be treated as a single continuum. Instead, they note that low engagement is not automatically the same as disengagement, disaffection, or burnout, and that researchers need to be explicit about which indicators they are using and what those indicators can and cannot show. This relates directly to data collection because it affects how “low engagement” is interpreted in different measures (Reschly & Christenson, 2022). For example, attendance, task completion, or disciplinary records can show behavioural patterns, but they do not on their own explain whether a student is withdrawing, resisting, emotionally fed up, or burned out. For this reason, interviews and focus groups are useful for clarifying what students mean when they describe boredom, frustration, or giving up, and for distinguishing absence of participation from active disengagement or disaffection. Their model moves beyond a binary perspective, and it recognises that engagement is not a fixed or uniform condition but can appear in different degrees and forms. Measuring engagement is only one part of the problem. It is also necessary to look at conditions that make engagement harder.

In this study, engagement was examined qualitatively rather than measured through a standardised scale or numerical score. Behavioural engagement was identified through patterns such as participation, persistence, withdrawal, and remaining on task; cognitive engagement through problem solving, use of strategies, and efforts to understand; emotional/affective engagement through responses such as interest, enjoyment, frustration, anxiety, and pride; agentic engagement through students initiating questions, searches, choices, or solutions; and social engagement through collaboration, peer support, and participation in group work. These indicators were interpreted across students’ accounts, teacher interviews, and my reflective journal rather than treated as separate quantitative measures.

4.4 Data Collection

To carry out this research, weekly workshops of 50 minutes were conducted with students over a period of 14 weeks. I will describe the workshops in detail in Section 4.5. Most participants were between 13 and 14 years old. Although a few older students were present due to repeating school years, none was significantly older than their peers. The school had four Year 8 classes – designated 8A, 8B, 8C, and 8D – following the Brazilian system of *Ensino Fundamental* (compulsory basic education, equivalent to primary and lower secondary schooling). To make participation in the project available across all four Year 8 classes rather than limiting the research to one class, I conducted the workshops with participating students from each of the four classes. The classes themselves each had between 25 and 35 students and were mixed ability. Not all students enrolled in the classes took part in the workshops. In some cases, families were not interested in having their child participate in the research; in others, parents or caregivers did not provide consent. Students participating in the project worked with me during the workshop sessions, while those who were not participating remained with their arts teacher and continued their usual arts lesson.

I attended the school once a week, and each workshop session lasted 50 minutes. As the students had more than one music lesson each week, participation in the project did not replace their entire weekly music programme. The fourteen-week programme followed three main phases: pre-electronics artistic/creative workshops, electronics workshops, and post-electronics artistic/creative workshops, as described in detail in Section 4.5.

Attendance varied considerably during the semester. For example, some classes had approximately 31 students enrolled at school while around 20 would typically be present on a given day, and in some cases classes that began with around 26–28 students declined to approximately 14 during the second semester. Absence, transfers, and dropout also meant that the number of participating students present during individual workshop sessions was not constant. These attendance patterns are discussed further in Section 5.2.4.

This study does not analyse ethnicity issues. There was one student who had a different ethnic background – a refugee from Venezuela – who was well integrated in Brazilian society and in this particular school. Aside from this student, the remaining students were Brazilian/Latin American.

Before the workshops began, I held focus groups with eight participants from each class to understand the students' perspectives on science, music, and school in general. After the 14-week workshop programme, a second round of focus groups was conducted with the same

students from each class. These follow-up discussions explored the students' reflections on the workshops, including emotional responses, peer dynamics, and perceived connections between their experiences and the broader school context. This second focus group also revisited their attitudes towards science and music to assess any potential shifts. The complete focus group guide is provided in Appendix P. Examples of pre-workshop items included questions about whether students look forward to coming to school, if they enjoyed science and music, and questions about how group projects normally worked. Post-workshop items asked students what it was like to teach or learn from a colleague, what challenges they experienced during the electronics workshop, whether they understood the connection between the workshops and school subjects, and whether the workshops changed their perceptions of science and/or music.

The focus group format provided a safe space for students to share experiences on their own terms. Listening to peers helped participants recall and extend accounts, which improved the richness of the data and supported a sense of agency and validation. I also remained attentive to limitations of group discussion, including peer influence and uneven participation, and I used prompts to invite quieter students to contribute.

In parallel, I conducted two semistructured interviews with the arts and science teachers – one prior to the initial focus groups, and the other approximately two months after the end of the workshops. These interviews provided additional perspectives on student engagement and helped triangulate the data. The first interview aimed to understand student engagement with science and music before the project. The second explored whether the teachers had observed any lasting changes in students' attitudes or understanding of music, science, or creative learning processes. The complete semistructured teacher interview guide is provided in Appendix O. Examples of items included asking teachers to describe student engagement in their subject, their perceptions of student engagement and satisfaction at school more generally, peer interaction among students, and whether they identified disaffected students and possible reasons for this disaffection.

As these were semistructured interviews and focus groups, the questions worked as guiding prompts rather than as individually scored items. Participants were able and encouraged to elaborate on their responses, and follow-up questions were used where further clarification when detail was needed. All focus group discussions and interviews were conducted in person in Portuguese and audio-recorded with the teachers' consent, the students' assent, and parental or caregiver consent. I subsequently transcribed the recordings manually for analysis.

The final source of information was a reflective journal that I kept during the research. After each session, I recorded observations in written or audio format – or both, especially when deeper reflection was needed. I also documented student work through photographs, which captured key moments, such as students playing the theremin for the first time, creating musical notations, constructing the instrument during electronics sessions, and composing and performing during the creative activities.

4.5 Workshops

This section, Section 4.5, introduces the workshop sequence used in this research and explains how the activities were designed for Year 8 students. I begin by outlining key influences from theremin music education, and then I describe the three workshop phases (pre-electronics artistic and creative workshops, electronics workshops, and post-electronics artistic and creative workshops) that structure the remainder of this section.

4.5.1 The Theremin in Music Education

Lydia Kavina and Carolina Eyck are widely recognised practitioners and educators in the theremin community. Their performances and teaching resources inspired the design of the musical tasks and workshop routines used in this thesis. Kavina is the grandniece of Leon Theremin and one of the people responsible for the revival of the theremin in past decades. She has been producing works for the theremin since 1994, the year that she worked on the soundtrack for the movie *Ed Wood*. She also gives workshops worldwide and online, and is the main coordinator of the Theremin Academy, an annual event that gathers the top theremin professionals worldwide to “spread the word” on the theremin with workshops, ensembles, and concerts (Kavina, 2021). Eyck wrote the first comprehensive method of playing the theremin (Eyck, 2006) that explains a step-by-step process from the beginning. This text has been an important milestone in the theremin community. She also gives workshops around the world and makes the theremin accessible to the nonmusician audience through creative and compositional practices (Eyck, 2016) and her YouTube channel (Eyck, n.d.).

Carolina Eyck’s (2016) educational activities have greatly influenced the pedagogical approach used in this research, adding playfulness with deep musical meaning to the activities. From the very beginning of my own study of the theremin instrument, the videos she produced and uploaded to her YouTube channel (Eyck, n.d.) served as a guide and influenced my production, both academically and musically. The inspiration to use musical activities mixed with games and elements that are easy to assimilate between the visual and the technical was

inspired by Eyck's workshops, which I was able to access due to the fact that she made them publicly available. In her workshops, we can see students developing sensitivity to dynamics and pitch refinement through a score produced with raindrops. The bigger the drop, the stronger the note should be, and the further up the paper sheet the drop was, the higher the note should be. Another activity she created was a musical dialogue between two theremins. This conversation takes place entirely in the artistic/musical realm where one thereminist provokes reactions of the other thereminist through gestures and the sounds that their theremin emits with each of these movements. With this, a musical dialogue is produced between the two performers, recalling and making reference at various times to personal everyday interactions.

Other activities were drawn from the common repertoire of educators of the theremin, including my own practice as a researcher-educator. Among these common practices is the free exploration of the instrument, which involves playing the instrument without preestablished rules about musicality, beauty, or what is aesthetically correct. Only the basic technical operating instructions – such as moving the hands away from and towards the antennae – are passed on to the theremin explorers. From this, the engagement of the next performers is affected, inspired, and modified by the previous performers, generating an environment of explorative learning between peers. The curiosity and desire to interact with the instrument is fuelled by the act of watching a colleague produce sounds and the desire to test their own ideas on this platform, which for the vast majority of participants – if not all – is something new.

The workshops were divided into three parts:

- 1) Pre-electronics artistic/creative musical workshops where the students learned to play the instrument;
- 2) Electronics workshops where the students learned how to build and solder an optical theremin; and
- 3) Post-electronics artistic/creative workshops where the students combined the two previous parts, and they composed for and played the instrument they built.

I will write in more detail about the structure of each of these stages in the following sections, Sections 4.5.2–4.5.4. This includes a closer look at the creative strategies employed in the early workshops to introduce the instrument in playful and accessible ways, the technical challenges and learning opportunities presented in the electronics phase, and the ways in which students brought together musical and technical knowledge during the final composition and performance activities. Each stage offered distinct experiences that, together, shaped how

students interacted with the theremin, with their peers, and with the learning environment itself.

4.5.2 Pre-electronics Artistic/Creative Workshops

During these workshops, students were introduced to the theremin. I began by explaining the basic functioning of the instrument: the vertical antenna controls pitch, and the horizontal loop antenna controls volume. The students learned that by moving a hand closer to or further from the vertical antenna, they could produce higher or lower notes. Similarly, approaching or retreating from the horizontal antenna would increase or decrease the volume.

I demonstrated how subtle variations in hand movement around the antennas can generate a wide range of musical effects. For instance, a quick, precise motion near the volume antenna produces a clear staccato articulation while gently shaking the hand near the pitch antenna creates vibrato. Students also explored special techniques, such as opening and closing the hand to produce a siren-like glissando or using broader gestures to achieve smooth crescendos and diminuendos. These exercises helped students connect physical movement with expressive possibilities, and connecting gesture and intention with sound.

In the first session, I performed a live piece for the students, employing techniques such as looping – layering multiple soundtracks in real time using my guitar – and combining the theremin with contemporary effects like delay, tremolo, and octave shifting. These effects can be seen on the floor on Figure 3. I showed the instrument's sonic potential and contextualised it within modern music production.

Figure 3
Theremin Displayed with Effects



Another aspect explored was light and shadow, drawing on a tradition within the theremin community dating back to Leon Theremin himself, as seen in Figure 4. I experimented by turning off the lights in the classroom and projecting moving images onto the ceiling while the music played, creating an immersive environment that felt isolated from the outside world.

Figure 4

Light and Shadow Projection During the Theremin Performance



4.5.2.1 Free Exploration of the Theremin

Next, the students were encouraged to explore the instrument freely. I reminded them how the antennas worked and how their hand movements would change the sound. At this stage, there were no preestablished rules – no right or wrong way to play nor expectations regarding perfect intonation or musicality. The focus was simply on exploring the instrument's possibilities. Some students preferred to explore alone while others felt safer experimenting together with a classmate, as shown in Figure 5.

Figure 5

Students Exploring the Theremin Together and Sharing Ideas



4.5.2.2 Drawing and Its Connection to the Theremin

After this initial exploration, I introduced the idea of connecting drawings to gestures and sounds on the theremin. For example, if a person draws an ascending line and then mimics this line by moving their hand upward, they will produce an ascending pitch. If they draw a downward spiral and move their hand in a similar spiral motion towards their body, the resulting sound will resemble a descending spiral. The interpretation could also go beyond concrete shapes; for instance, larger circles might represent stronger or louder notes while smaller circles could indicate softer or quieter sounds. The vertical placement of a shape on the page could correspond to higher or lower pitches, depending on how high or low the circle was drawn. In essence, anything drawn could be directly connected to sound. The students experimented with their drawings, discovering how these visual cues translated into sound on the instrument, as seen in Figure 6.

Figure 6

Student Testing His Drawings on the Theremin



4.5.2.3 Storytelling

In the following activity, the students were invited to create stories and narratives using the theremin, employing its sound to bring their tales to life. Some of the imaginative scenarios they developed included a bunny, who, late for school, rushed through traffic only to arrive at the gates and realise it was Saturday; a dancing popcorn kernel jumping on a frying pan, startled by the heat, and leaping off the pan; explosions and fireworks; birds chirping; and a motorcycle speeding at full throttle. These descriptions illustrate the playful interaction between sound and imagination. Some students preferred to create stories on their own, as shown in Figure 7, while others worked with a classmate – one telling the story while the other produced the sounds, as seen in Figure 8.

Figure 7

Individual Storytelling and Sound Creation with the Theremin



Figure 8

Collaborative Storytelling: One Student Narrates; Another Produces Sound Effects with the Theremin



In this activity, three types of reactions/uses of sound-gesture were produced and used to tell the stories. The first was the gesture producing the important point of the story to be told and the sound generated as being secondary. So, in this case, the student told her story by gesturing with her hand, and this gesture was the important point for the narrative. One case in which this happened was a story in which a plane was going around a mountain and, while telling this story, the student circled her hand around the antenna. The sound, which did not have a close connection with the sound of an airplane, became secondary as in the foreground were the student's voice with the narrative and her manual gestures. Another case was a popcorn that wanted to dance in the frying pan. To tell this narrative, the student simulated a living popcorn, dancing and jumping with his fingers, imitating the popcorn's small legs.

The second type of reaction/use was the sound being the main element while the gesture had no importance for the narrative. An example is the sound we produce by holding the antenna with a finger and quickly "pulling" it while lowering the volume and bringing our hand to the bass or null region of the instrument. This sound produces an effect similar to what students referred to as a "laser gun" or an "explosion" – although the gesture did not look like something exploding. The same happens when we quickly tap the pitch antenna with our fingers, producing a sound that resembles the chirping of several birds.

The third reaction/use was a combination of the two, gesture and sound, in the elements of the narrative. One of the students' favourite sounds was the imitation of a vehicle accelerating, which is achieved by placing the hand in the bass area of the instrument and slowly bringing it closer to the antenna, thus slowly increasing the pitch. At each five-second interval, a slight quick hand retraction was performed, thus producing the sound of a vehicle changing gear. Combining this with the gesture of accelerating a motorcycle – in this case, turning the wrist as if one was driving a real motorcycle – produced a direct link between the narrative, the gesture, and the sound.

4.5.2.4 Dialogue Between Theremins

The next musical activity was the musical dialogue between theremins. In this activity, two thereminists engage in a sonic dialogue. One player initiates the conversation by using specific gestures to manipulate the sounds emanating from their theremin, thereby eliciting a response from the other player. This back and forth creates a musical conversation, conveying different emotions or ideas, much like the inflections in human speech as each performer responds to the other's musical cues. This musical dialogue mirrors the nuances of everyday interpersonal interactions.

This unique form of dialogue encourages musicians to think beyond the traditional limits of the instrument and to explore how gesture, sound, and even language are connected, making the instrument an extension of communication possibilities. In the case of the students with no prior music training, they usually have to rely heavily on body language along with the sounds created by the theremin. The gestures used to control the theremin become a form of nonverbal communication where each movement has a corresponding sound and meaning, as seen in Figures Figure 9 and Figure 10. This adds a layer of complexity to the musical conversation, making it a powerful tool for understanding and elaborating on the dynamics of musical expression and communication.

Figure 9

Students Building Musical Dialogue with Sound and Gestures (A)



Figure 10

Students Building Musical Dialogue with Sound and Gestures (B)



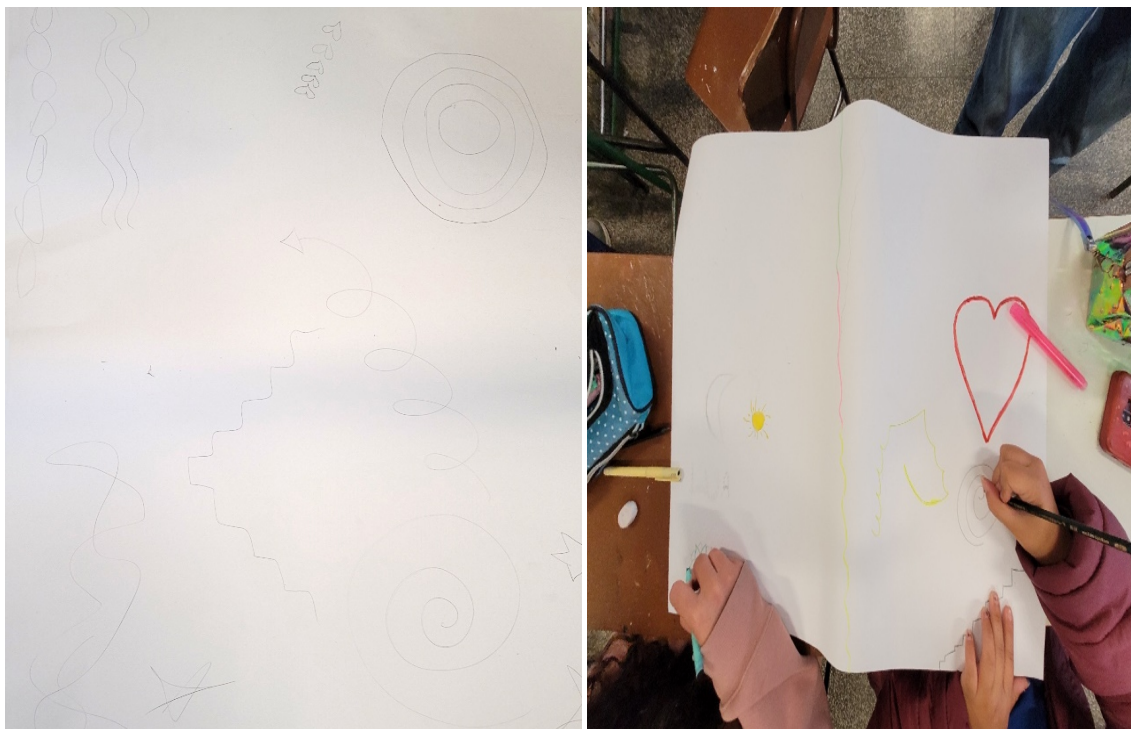
4.5.2.5 Composing for the Theremin

The last musical activity was the composition of a piece for the Theremin. The concept of contemporary or alternative music notation was reintroduced to the students, emphasising the connections between images and the sounds produced by the theremin. In this approach, virtually any drawing can be translated into a corresponding sound on the instrument. The students were divided into groups of three or four, and each group created their own music using coloured pencils, as seen in Figure 11. Some students also highlighted parts of their drawings with markers to improve visibility for both the performer and the audience, as shown in Figure 12.

Figure 11
Students Creating Music for the Theremin in Groups



Figure 12
Students Creating Drafts for their Compositions and Highlighting them with Markers to Increase Contrast



After completing their compositions, the students presented their pieces to the class. One member of each group held the sheet music for the performer while the rest of the class watched, as seen in Figures Figure 13 and Figure 14.

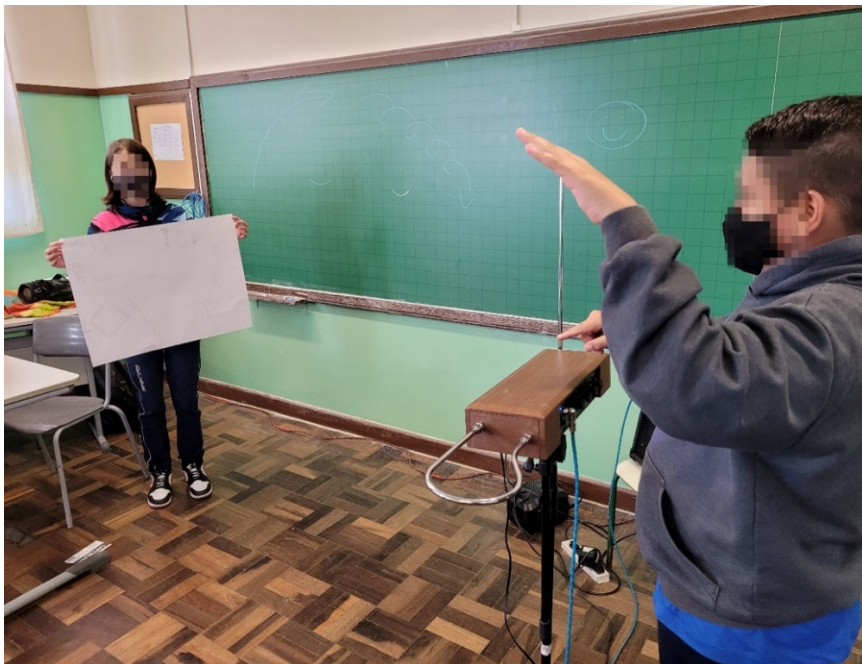
Figure 13

Students Playing their Composition to the Class (A)



Figure 14

Students Playing their Composition to the Class (B)



4.5.3 Electronics Workshops

After the initial artistic and creative workshops, I guided the students into the electronics component of the project. The first session in this section was dedicated to safety, involving all participants. We discussed the potential hazards posed by the soldering iron and ferric chloride, emphasising the importance of proper attire, including closed shoes and the constant use of protective glasses. I then showed them the optical theremin they would build and the tools they would use.

The students were then divided into three groups for the electronics stage, with each group working with me in a separate session while students who were not participating in the research workshops remained with their arts teacher. This arrangement allowed activities involving soldering irons, ferric chloride, and close supervision to be conducted with smaller numbers of students without removing the other students from their normal school programme. Each group learned a specific part of the construction process. The first group was taught how to prepare the printed circuit board (PCB), the base plate where everything would later be assembled. They imprinted the electronic traces onto the board. The second group learned how to etch the PCB with ferric chloride and prepare it for the components to be soldered onto it, as seen in Figure 15. The final group was instructed on how to solder the components onto the PCB, following the trace paths, as seen in Figure 16.

Figure 15

PCB Being Etched with Ferric Chloride



Figure 16

Components Soldered onto the Optical Theremins



Most groups were able to master their tasks in one session. However, the soldering groups required more time, typically needing two classes to fully learn how to solder small components onto the PCB.

After this, I prepared a package for each student containing everything they needed to build their instrument, as seen in Figure 17, and handed one to each participant. They had to assemble their own instrument; however, since each student only knew one third of the entire process, they had to rely on interacting with their peers to complete the task. Figures Figure 18 and Figure 19 show the students working together to build their instruments.

Figure 17

Small Plastic Bags with all the Components Needed to Build an Optical Theremin



Figure 18

Students Working Together to Build Their Optical Theremins



Figure 19
8th-Grader Building Her Own Instrument

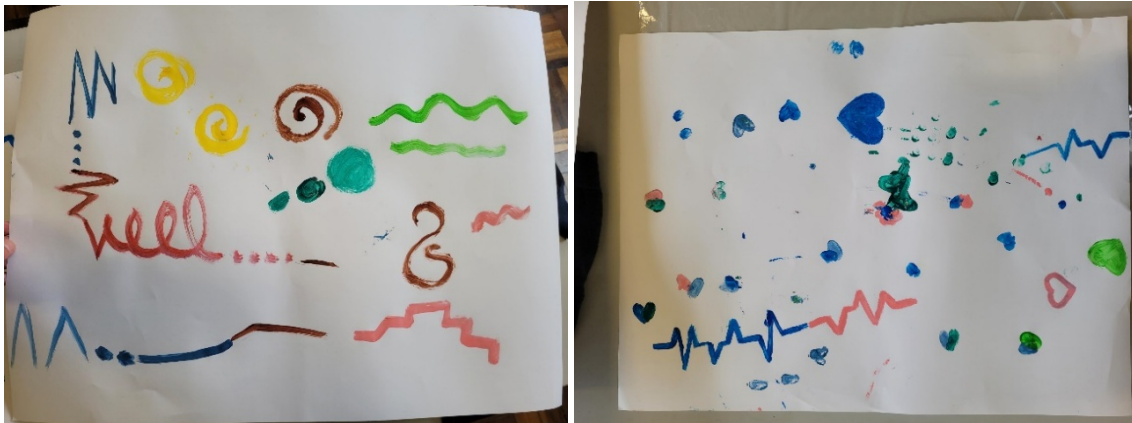


4.5.4 Post-electronics Artistic/Creative Workshops

After building the optical theremin, I conducted a final artistic and creative workshop with the students to deepen their understanding of how to give musical input to the instrument they had built and to bring closure to my intervention at the school. They initially explored the instrument freely, much like in the initial artistic component (see Section 4.5.2.1). Later, I taught them how to play the optical theremin, focusing on various techniques, such as: changing pitch (through light variance), timbre, and volume; performing glissando; learning how to variate rhythm and intensity, and how to perform tremolo and vibrato; and filtering. After this step, they composed new pieces using a different technique – paint – as seen in Figure 20. Just as in the earlier workshops, the students shared their work with the class.

Figure 20

Compositions Made for the Theremin Using Paint



4.5.5 Ethical Considerations

Ethical approval was granted from the University of Waikato Division of Education Research Ethics Committee (see Appendix A). SEED³ has a lot of power over choices involving the school environment. Extra care was taken to not put the teachers in a delicate position. If research that will take place in a school setting is designed to include interviews, and SEED and the chosen school approves it, the teachers might be put in an unfavourable position if they choose not to participate. An option to refuse giving interviews was inserted in the research proposal to remove any uneasiness, or forced or coerced participation. This issue was also addressed with the teachers, and their right to not participate was fully explained to them, as was the assurance that they would not be disadvantaged if they chose not to be part of the research. Fortunately, both teachers decided to participate, giving the analysis a wider perspective on the case.

The music and science content covered in the workshops was the same as the one given in the curriculum for this year level. Therefore, any replacement of music or science classes with the workshops would generate no loss of content or gaps in teaching. Negotiations took place with the principal, the assistant principal (a role called *pedagogue* – *pedagoga* – in Brazil), and the teachers to discuss in which classes the workshops would take place. Due to the nature of the research and my background, music classes were chosen to be used for the workshops to take place. No student was obliged, forced, or coerced into participating in the research. No penalties were to be incurred for nonparticipation. Since the workshops took place during class time, the students who did not wish to participate or were not allowed to by their parents or caregivers had regular curricular music classes.

³ SEED - Department of Education and Sport (*Secretaria da Educação e do Esporte*)

Based on my experience as an educator within the Brazilian school system, I was already aware that schools in Brazil typically possess additional spaces, such as small auditoriums, laboratories, and libraries that can be used for break-out teaching. There were only two occasions on which no classroom space was available for the workshops, and the project happened in open spaces within the school environment with no disruption to the programme. The timing and details of the workshops were negotiated with the principal and teachers, based on what was considered to be the best for the students and teachers in this school in particular.

All participants were provided with the relevant Participation Information Sheet and asked to sign the appropriate consent or assent form. Teachers received a Participation Information Sheet and a Participation Consent Form (see Appendices B and C). The principal received a Participation Information Sheet and a Participation Consent Form (see Appendices L and M). Students who did not participate in the focus groups received a Participation Information Sheet and a Participation Assent Form (see Appendices H and J), and their parents/caregivers received a Participation Information Sheet and a Participation Consent Form (see Appendices D and F).

Students who participated in the focus groups received a specific Participation Information Sheet and a Participation Assent Form, which included details about the recording of the interviews (see Appendices I and K). Their parents/caregivers also received a specific Participation Information Sheet and a Participation Consent Form containing the same additional details (see Appendices E and G). On these forms, the science and arts teachers were asked to consent to give a voluntary audio-recorded interview and review its transcript. The arts teacher was also asked to consent to the use of his class time for the workshop sessions.

The students were younger than 18 years, the legal age of majority in Brazil, and therefore required parental or caregiver consent to participate in the research. Parents/caregivers were asked to consent to their child's voluntary participation in the workshops that took place at the school.

For the focus groups, students were asked to volunteer. In some cases, there were too many contributors. In those scenarios, I took the first ones who offered to participate in each focus group. Students who participated in the focus groups were required to sign a specific Assent Form, in which details about the recording of the interviews were provided (see Appendix K). They also required parental or caregiver consent, which was obtained through a specific Consent Form containing the same additional details (see Appendix G). The students received the Information Sheet and Assent Form because, although they were young enough to

require parental or caregiver consent, they were also old enough to understand what the study was about and assent to take part.

All consent and assent for this research was obtained in Portuguese – the main language of both the researcher and the participants. All the interviews were held in person and were conducted in Portuguese. I come from a similar cultural background to those of the students and teachers I interviewed, and I did all the translations myself.

The identity of the school and the participants is protected. While every attempt was made – and is still being made – to safeguard the participants' identities, participants were made aware that this could not be completely guaranteed. The principal and the teachers who agreed to participate in this study knew which class/es I would work with.

I discussed confidentiality with the students and asked them not to repeat what was discussed in the focus groups outside these forums. However, it was natural for the students to talk to their friends and families about the workshops themselves. Within the school environment, it was known who was taking part in the workshops. Nevertheless, the data is confidential, and every attempt has been made to keep the school and the identities of the individual participants anonymous in my reporting.

I took all due care to ensure the safety of the young people who participated in this research. The students needed to work in groups, and potential harm could have arisen as a result of group dynamics. As an experienced teacher, I did everything within my power to mitigate this, carefully observing group dynamics and stepping in where necessary.

Another potential harm came from the electronic workshop. The children used soldering irons with a burning hazard. There was the possibility that these irons could present first-degree burns in worst-case scenarios. All instructions and safety protocols were presented and discussed with the students and/or classroom teachers and were followed during this activity. No injuries or serious harm occurred during the workshops. Protective goggles were mandatory, along with a ventilated environment.

I discussed the health and safety aspects of the electronics workshop with the principal before conducting it. The relevant health and safety policies/procedures to deal with laboratory classes in the state of Paraná, Brazil, are found in the Guidebook for the Use of the Nature Sciences School Laboratory in the State Education System in Paraná⁴. This guidebook has

⁴ *Caderno de Orientações para Utilização do Laboratório Escolar de Ciências da Natureza da Rede Estadual de Ensino do Paraná*, available at: http://www.Biologia.Seed.Pr.Gov.Br/arquivos/file/pdf/cadern_lab_2013.Pd

information about the laboratory as a pedagogical environment, rules for the school laboratory, dealing with residual waste, and first aid. I used it as a guide for safety protocols inside the school environment and during the workshops.

Interviewed teachers could withdraw up until the transcripts were approved. Students could withdraw at any time. If any student had decided to withdraw from the research, they could have gone back to the regular music class with no sanction or penalty in their grades or school records. They would not have been able to withdraw data due to the group settings of the research. In a lockdown context, the interviews would have been held through online meetings.

I conducted one extra unplanned interview with the principal as she provided me with exceptional insight for my research due to her position. I applied for an extension to my ethics application, seeking approval for this additional step. The extension was granted by the School of Education at the University of Waikato, recognising the potential enrichment it could bring to the overall work.

The arts teacher could decline to give up their class time for the workshops/creative component. In this case, I would have asked the science teacher to give up their class time for the study. In the case of both declining to do so, I would have had to look for another school under the guidance of SEED. This was due to the fact that if I took any other subject class time, such as maths, Portuguese, or physical education, I would have created gaps in the curriculum because this research was only associated with the music and science curricula.

Participants were allowed to withdraw by speaking directly to me in the first instance. No students withdrew from the research. I was the first point of contact if any dispute had arisen, but there were no disputes during the research.

4.6 Data Processing, Coding, and Categorisation

After transcribing the interviews, I began initial coding in Word and then imported the transcripts into NVivo qualitative data analysis software, a programme that “assists qualitative researchers to collect, organize, analyze, visualize, and report their data” (Dhakal, 2022, p. 270), so I could manage coding and retrieval across the dataset. Coding marks the transition from raw data to a structured analytic account. As described by Adu (2023), coding involves assigning labels to meaningful segments of information during close examination. These labels become the building blocks for later stages of analysis where codes are grouped into broader themes, a

process referred to as “categorisation”. Organising coded data into overarching themes is important because it turns numerous coded elements into coherent and meaningful categories.

Theme development does not stop with identification. Adu (2023) notes the importance of sorting in later stages of analysis, which involves arranging codes by their relationships and grouping them into classes or themes. These themes are not simply labels. They represent interconnections within the data and support the development of explanations for the phenomena under study. In this sense, sorting helps make connections between themes visible, moving from data reduction toward the development of explanatory theories.

In my study, these broader themes were developed from the codes and categories generated through the iterative coding process rather than being established as a predetermined coding framework. The developing themes were reviewed across the focus groups, teacher interviews, and reflective journal and refined in relation to the research questions.

4.6.1 Grounded Theory

To analyse the material collected in my research, including transcripts of eight focus groups, four interviews, and a reflective diary in both audio and text formats, I adopted grounded theory and constructivist grounded theory methods as explained by Charmaz (2006, 2017) and Saldaña (2011). Grounded theory is a methodology for systematically generating theory from qualitative data. Grounded theory treats analysis as an iterative process of building concepts from data through coding and constant comparison. It employs an inductive logic that supports the identification of patterns, concepts, and relationships grounded in the qualitative material.

Charmaz’s (2006, 2017) perspective, which builds on Glaser and Strauss (1967), places emphasis on the active role of the researcher in interpreting data and coconstructing meaning with participants, and proposes the expanded constructivist grounded theory. Unlike more positivist versions, Charmaz’s (2006) constructivist grounded theory recognises that both data and analysis are influenced by the researcher’s perspectives, background, and interactions. The focus is not on finding a single “objective truth” but on developing robust, flexible explanations that are meaningful within a specific context.

The analytical process is iterative, involving several key steps:

- Initial coding: breaking down the data line by line and assigning descriptive codes to significant segments;

- Focused coding: refining and condensing initial codes into more analytical categories, guided by what is most relevant in the data;
- Constant comparison: examining data, codes, and categories for patterns and relationships; and
- Memo writing: documenting emerging ideas, clarifying analytical decisions, and tracking connections as a central analytic tool rather than a side note.

This process is not linear but involves moving back and forth between data and analysis. In classic grounded theory terms, this work can also move toward a central or core category that integrates the major categories and supports a grounded explanatory account of the process under study. The ultimate goal is to construct categories and theoretical explanations that are closely tied to the empirical material while remaining attentive to the social, cultural, and contextual factors shaping participants' experiences. Rather than presenting the researcher as a neutral observer, this approach recognises the interpretive work involved in making sense of qualitative material (Adu, 2023).

I started with inductive initial coding, staying close to participants' words and meanings, and then moved to focused coding to refine the most significant codes into more analytical categories. I used constant comparison and memo writing throughout to clarify category properties and boundaries. After these categories were established from the data, I engaged with relevant literature to refine definitions and strengthen the developing analytic account so that the literature informed interpretation rather than functioning as a predefined codebook.

At this stage, the dimensions of engagement discussed in Chapter 3 – behavioural, cognitive, emotional/affective, agentic, and social – became interpretive lenses to examine how the emerging categories related to different forms of student engagement. These dimensions did not function as predetermined codes; rather, they were used after the initial and focused coding to help interpret patterns that had emerged from the data.

4.6.2 Memo Writing

Memo writing in qualitative research involves creating concise and informative notes that document essential information about codes, their functionality, design decisions, or other relevant details. In grounded theory and qualitative data analysis, memos are integral as they capture the evolving thoughts, insights, and interpretative decisions of researchers engaging with the data. These memos help document emerging patterns, connections, and theoretical ideas that inform the development of a grounded theory (Charmaz, 2006, 2017; Saldaña, 2011).

This process involves recording the reasoning behind methodological choices, the significance of key findings, and reflections on the evolving understanding of the data. Memos provide transparency in the analytical process and offer a detailed account of the researcher's interpretive journey. This practice aids in maintaining internal consistency and contributes to the rigour and trustworthiness of the qualitative findings. Memo writing enhances understanding, collaboration, and the sustainability of the research.

In my research, memos served two related purposes. Some concerned ideas that later contributed to chapters such as the Discussion (Chapter 7) and Conclusion (Chapter 8), while others documented decisions made during the coding itself. More specifically, I used (1) analytic memos to record why codes were created, merged, or refined, and (2) reflective notes to capture ideas for later chapters. These notes served as a bridge between the past researcher (myself) and my future self, ensuring that valuable perceptions gained during the coding stages would not be lost and would not need to be revisited later when writing the final chapters.

Sorting, on the other hand, involves grouping codes that share relationships, and this step was integral to my research. According to Adu (2019), this process includes establishing clusters, labelling them, and forming categories and themes. Sorting is crucial in qualitative research as it methodically categorises codes with meaningful connections. By grouping related codes into labelled clusters, researchers create categories and themes that serve as foundational elements in data analysis and interpretation.

In grounded theory, sorting helps uncover inherent patterns and connections within the data, facilitating the identification of overarching themes that contribute to theory development. Labelling these clusters provides a coherent structure to the emerging insights, aiding in the synthesis of a comprehensive narrative that reflects the qualitative data's richness and complexity. This systematic approach not only clarifies and structures the qualitative findings but also lays the foundation for the theoretical framework derived from the data.

The sorting process involves examining each code's distinctive attributes, discerning patterns, and grouping them into clusters. Once categorised, the clusters are assigned descriptive names, evolving into thematic categories that encapsulate the grouped codes' essence. This approach transforms individual codes into cohesive themes, providing a meaningful framework for analysing and interpreting research findings.

4.6.3 Transcription and Initial Coding

All the audio-recorded interviews and focus groups were manually transcribed by me. This decision was made with a focus on achieving greater depth and understanding of the text and the subject being explored. Although I was the one who conducted the interviews and facilitated the focus groups, the process of reviewing and transcribing them provided me with a deeper layer of comprehension regarding the participants' emotions and meanings. This kind of understanding proved invaluable when later coding and analysing the data. It encompassed nuances, such as tone and emotion, which can be difficult for automated transcription services to convey accurately. Further, quality control was another significant consideration, given that automated services may not always achieve perfect accuracy, especially when dealing with accents, technical terminology, or multiple speakers. By manually reviewing and producing the transcriptions, I maintained direct control over their accuracy.

This hands-on approach built familiarity with the data. It not only allowed me to identify patterns, themes, and outliers early on but also supported a more in-depth analysis. During the manual transcription process, I marked and annotated sections of interest, and I wrote memos to myself to aid later analysis. Despite the time-consuming and resource-intensive nature of manual transcription, the benefits in terms of data quality, understanding, and depth of analysis justified the additional effort invested in this work.

I prepared the transcripts for analysis by removing identifying information about participants and settings, such as names of people, the city, and the school in which the workshops took place. Students were assigned numbers (Student 1, Student 2, and so on). Teachers are referred to by subject – in this case, the arts teacher and the science teacher.

Initially, the plan was to conduct the initial coding of the interview and focus group data in Word, using colour coding. However, it quickly became evident that the tools provided were insufficient for the range and volume of responses captured in the dataset. The focus groups, in particular, generated rich detail about everyday school situations that connected to the research questions. This richness increased the complexity of analysis and contributed to the generation of a large number of initial codes.

After coding approximately 40% of the interview and focus group material collected from teachers and students, excluding the reflective journal, I had generated 22 categories. Once the colour options in Word were exhausted, I began using other formatting options, such as italics, bold, and underlining. This soon required combining multiple formats to indicate new categories (for example, bold and underlined), which made coding difficult to manage and

slowed interpretation. I therefore moved the dataset into NVivo because Word's formatting system could not support the number of categories required at this stage. The initial outline of the categories generated through primary coding of the teacher interviews and student focus groups can be found in Appendix S.

When I coded the interviews and focus groups in NVivo, I could link coding across all transcripts in the project. This made it possible to create nodes and code segments directly in the text without relying on colour coding to track categories. NVivo allows the use of colours, but colour palettes face limits similar to those in Word. Coding through nodes also supports automatic retrieval of coded segments, which reduced manual searching and helped keep the analytic work close to the participants' accounts.

The interview with the principal was not part of the original data collection plan and took place later in the research process. The principal assisted with room organisation, meetings with staff, and observed students participating in the workshops, building instruments, and expressing interest in the programme because of its integration of different school subjects. Her account therefore provided a valuable perspective from a position of authority, including observations that I could not access fully as an outsider.

4.6.4 Coding my Reflective Journal

During the research workshops, I maintained a reflective diary that captured my dual perspective as both an insider and outsider. At times, I took on the role of planner and facilitator, preparing activities and documenting the process. At other moments, I actively engaged with students – listening, participating in activities, and celebrating achievements such as the creation of functional instruments. This ability to move fluidly between roles provided a nuanced understanding of the research context, enriching my analysis of the workshops and their outcomes.

To analyse this material, I coded and categorised the reflective journal using the same evolving codes and categories developed through the constructivist grounded theory analysis applied to the main data sources – the interviews. This approach allowed for a meaningful dialogue between my reflective observations and participants' voices, bridging the perspective of the researcher-planner with that of the students' lived experience. My journal, which consists of over 180 pages of written notes, 45 transcribed audio entries, 28,090 words, and 437 photos, serves as a connecting bridge between the initial and final phases of the research, capturing the evolution of the workshops and the dynamics at play.

In summary, the reflective journal not only provides an in-depth personal account of the research process but also helps contextualise and connect findings from across the different stages of the project. By drawing on this material, I aim to present a more comprehensive understanding of the case study's evolution, bridging the gap between planning, participation, and reflection.

4.6.5 Coding on NVivo

Within NVivo, I organised interviews, focus groups, and reflective journal entries so that I could cross-reference codes and compare patterns across sources during constant comparison. In the first cycle, I conducted inductive initial coding across the dataset. I then moved to focused coding to refine and condense the most significant codes into analytical categories. Throughout these cycles, I used constant comparison and memo writing to clarify category properties and boundaries.

After the initial categories were established from the data, I engaged with relevant literature to refine category definitions and clarify how the developing analytic account related to existing concepts. I then returned to the dataset to check fit and maintain consistency. In this second round of coding, the codes were isolated and written in a separate document. This document was a physical notebook. I wanted to consider my work from a different perspective and writing by hand with coloured pens helped me process the information and take a break from the computer screen. Several authors, such as Mangen and Velay (2010), Mueller and Oppenheimer (2014), and van der Meer and van der Weel (2017), present evidence that handwriting can support deeper processing than typing, including through increased cognitive engagement and multisensory cues. For a visual record of this stage, Appendix T includes pages of handwritten codes, memos, and category sketches that document how the analysis developed over time.

With these data-driven categories and their evolving definitions, I was able to build my initial code tree. I used the same technique of writing it by hand. This hand-drawn initial tree draft served as a skeleton for the final code tree, which I also built using a hands-on approach but, in this case, by printing all the codes and sorting them on the floor. This initial tree can be found in Appendix U.

When I began constructing the parent and child nodes, I found a gap in my understanding in some areas of dimensions of engagement, and high-risk behaviour and adverse experiences. This made me go back to the literature and search for different authors – or more

work from the authors I had already read – in these areas. This return to the literature was consistent with the iterative logic of constructivist grounded theory described in Section 4.6.1. Rather than treating the developing categories as fixed, I continued comparing and reconsidering them as my understanding of the data developed (Charmaz, 2006, 2017). Further reading could therefore refine how I understood a category before I returned again to the data to examine its fit.

As categories were refined through constant comparison, memo writing, and further reading, I developed a working list where themes were separated by areas but still provisional and open to further refinement. This new code tree was printed and generated by hand as a continuation of the previous effort to detach part of the research process from the computer screen and bring it closer to my own palpable world as a researcher.

4.6.5.1 Manual Sorting

This section, 4.6.5.1, features photos I took throughout the process of manually creating the definitive code tree. These images provide readers with a clearer understanding of my work from my personal perspective. During this stage, my family actively participated with me. Pursuing a PhD can often pull parents and caregivers away from the precious, fleeting moments of their children's early years. Therefore, our children are eager to spend even a little bit of time with us, even if it means playing with their LEGO while we work on our own intellectual "building blocks" (which my boys refer to as "Dad's LEGO"). This blending of family time and academic work allowed us to cherish moments together despite the demanding nature of the research.

This blending of roles not only enriches my personal life but also supports my research. The presence of my children in my work environment serves as a constant reminder of the importance of patience, creativity, and flexibility – qualities that are valuable in qualitative research. Their curiosity and fresh perspectives sometimes prompted me to revisit my data from new angles and to adjust my approach to coding and categorisation.

Documenting each stage of my research process through photographs was initially a practical measure to preserve my work from the inadvertent disruptions caused by my active household. However, it also became a reflective practice, allowing me to capture and cherish the moments where my academic and personal lives intersect. Readers can view how I laid out the categories on the floor and observe how they gradually took shape over time in Figure 21. After each session of categorisation, I made sure to take detailed photographs of the newly established categories. This precaution was essential to avoid losing an entire morning or

Figures Figure 22 and Figure 23 show the late stages of this process.

Building Themes and Categories on the Floor – Early Stages

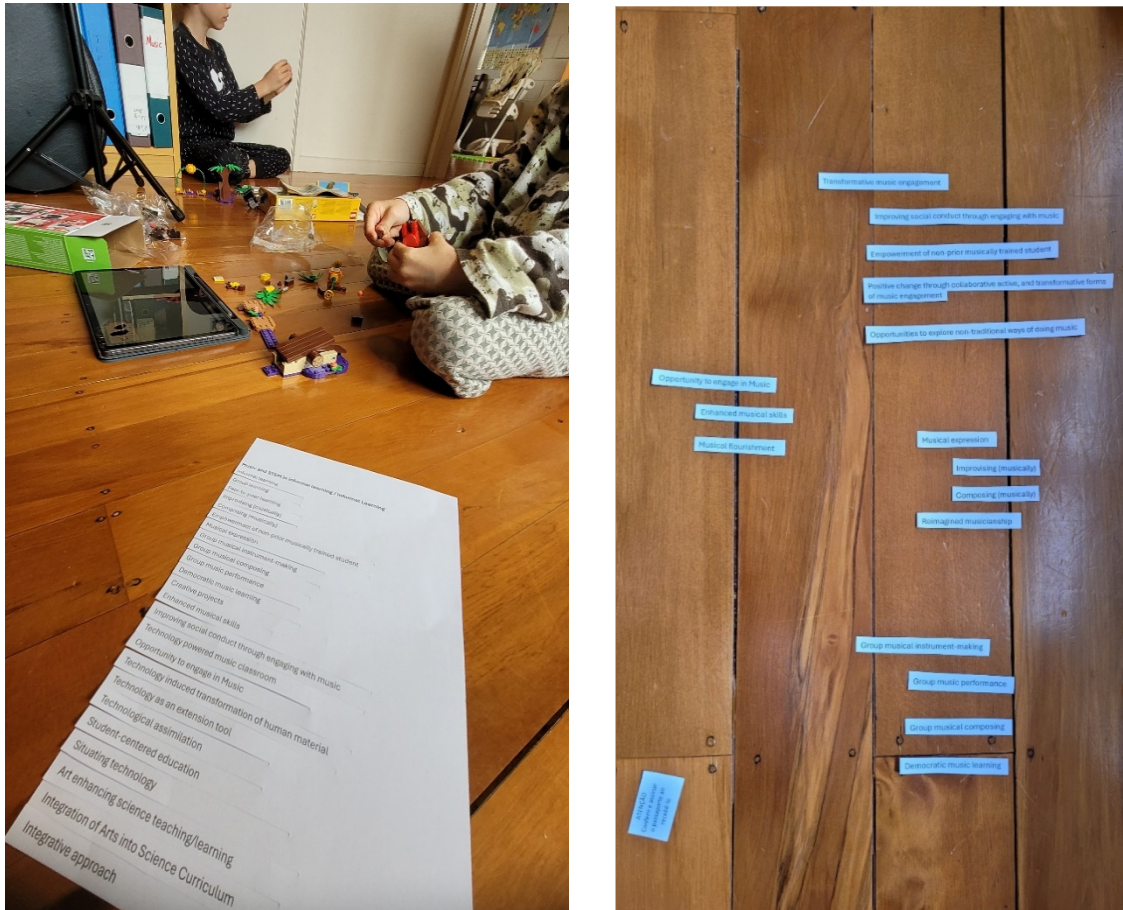


Figure 22

Building Themes and Categories on the Floor – Later Stages (A)

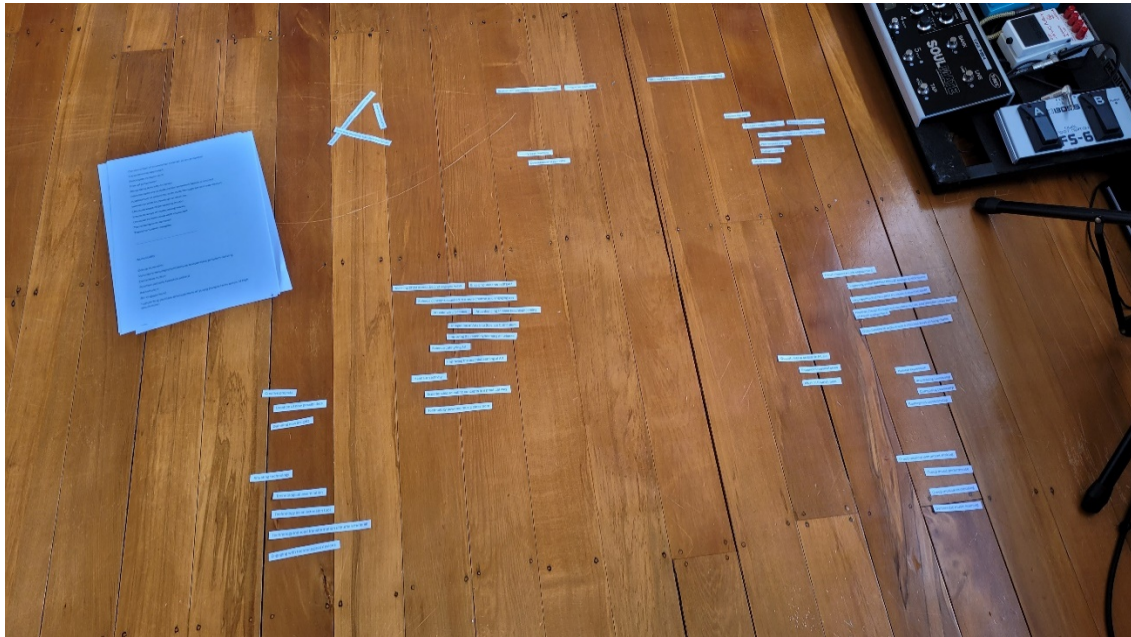


Figure 23

Building Themes and Categories on the Floor – Later Stages (B)



The purpose of Figures Figure 21-Figure 23 is to show the physical process through which codes and categories were compared, moved, and grouped rather than to function as the readable record of individual code labels. Readable records of the analytical material are therefore provided in the appendices. Appendix S presents the categories generated during primary coding, Appendix T provides examples of the handwritten coding process, Appendix U shows the initial handwritten code tree, Appendix V presents the later code tree exported from

NVivo, and Appendix W provides the final codebook in textual form. Read together, these appendices document the progression from initial coding and the manual development of categories to the final coding structure that informed the thematic findings presented in Chapter 6.

After physically sorting the categories, a hands-on process that facilitated deeper understanding, I built my final code tree in NVivo. This tree informed the coding of all interview data (teachers and focus group participants) and my reflective journal entries. While designated as “final”, the code tree remained flexible, allowing for adjustments to existing categories if necessary. However, I remained attentive to categories that were strongly supported by the data and clearly relevant to my research questions. If an interesting pattern did not contribute to answering the research questions, it was set aside to maintain analytic focus. Maintaining focus on the initial research questions was paramount, even if it necessitated setting aside potentially interesting but ultimately nonessential information.

The final outcome of this categorisation process is presented in Appendices V and W. Appendix V provides the visual code tree exported from NVivo, while Appendix W provides the final coding structure in textual codebook form. This allows the individual codes and hierarchical relationships that may not be legible in the photographs or visual tree to be examined directly. These outputs were generated using NVivo’s printing and export functions and then inserted into the thesis document. Not all categories created during coding were retained for analysis. Some served as provisional guides that supported categorisation.

While I was building this tree, I had to address issues such as why I placed “Negative affective experiences” and “Disengagement – Disaffection” as separate fields. A negative affective experience does not always lead to student disengagement. Similarly, a disaffected student does not necessarily stem from a negative affective experience with life or the school system. Negative affective experiences may precede the student’s response, be caused in the student, or be the student’s reaction at the moment of an event (for example, experiences of racism, authoritarianism, or xenophobia). In contrast, “Disengagement – Disaffection” can represent a longer-term response or the longer-term effects of traumatic events, and it captures what becomes active in the student over time. This type of reflection was necessary because it shaped the subsequent analysis and the construction of the code tree.

In this tree, engagement is not the main element but, rather, one of the possibilities for analysing the collected material. Recalling the research questions, “Can using the theremin improve student engagement in science and music?”, “How can the theremin be used to improve

interdisciplinarity across science and music in Brazilian schools?”, and “Can a theremin-based teaching and learning project enhance peer interaction in science and music?”, I was able to connect the literature explored at the beginning of my work with the interviews and material collected during my time actively working on the project at the school. Through this process, the categories emerging from the data were organised and grouped into broader themes.

If a category repeatedly appeared in the data and had not been identified through my review of the literature, I treated this as a prompt to revisit the literature and search for work that addressed that specific issue. This did not automatically indicate a gap in the field, but it signalled that I needed to check whether I had missed relevant studies or concepts. Even when the literature review and coding are designed to align, researchers need to remain open to unexpected patterns and to revisit interpretations as the analysis develops. I did not treat these initial interpretations as fixed conclusions. As the analysis developed, I returned to them, compared them with other parts of the data, and reconsidered what they meant within the case.

As researchers, it is also important to recognise that this type of research generates a large amount of information provided by participants. There is a wide-ranging amount of information to be processed and transformed into findings. Therefore, only what answers or resonates with my research questions was relevant for the analysis. I did not take all the information given and transform it into findings as this would cause the work to deviate from its scope and generate many digressions in the research, thus straying from my initial goal.

Translating this to my coding practice, I renamed some categories to make them shorter and easier to read. For example, “Students unprepared for class”, “Students withdrawing behaviourally”, and “Students being distracted” became “Unprepared for class”, “Withdrawing behaviourally”, and “Being distracted”. When the implied subject was not students, I added an indicator of the new subject, such as teachers. This choice required additional work to rename categories, but it resulted in a cleaner and less confusing system for categorising the data. In the end, it helped compensate for the time spent renaming because it allowed me to code and retrieve material more efficiently (see Appendix X).

4.6.6 Bringing the Analytical Process Together

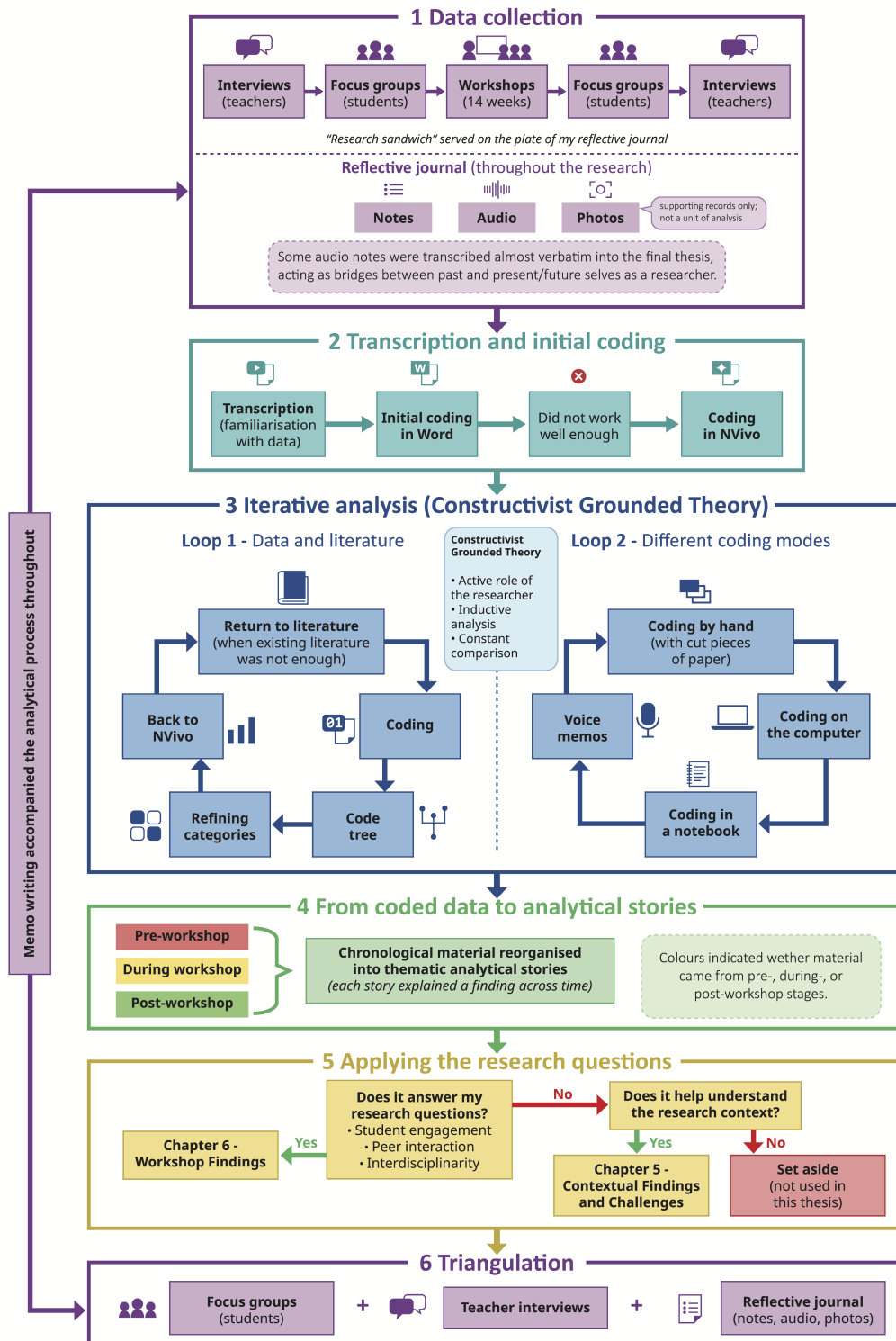
The analytical methods and techniques described in the previous sections formed an iterative process rather than a series of separate stages. Constructivist grounded theory provided the main logic for moving repeatedly between data, coding, comparison, literature, and interpretation (Charmaz, 2006, 2017). In practice, however, this movement also involved

changing the physical way in which I interacted with the research. I moved between computer screens, handwritten notes, printed material, physical sorting, and, at a later stage, spoken analytical memos. These changes in medium became part of how I processed a large qualitative dataset and maintained the iterative movement between the different elements of the analysis.

Figure 24 brings these methodological elements together visually. I came to think of the data collection structure as a “research sandwich”. The fourteen-week workshop programme sat between two rounds of focus groups, which were themselves framed by teacher interviews, while the reflective journal ran throughout the project as the “plate” on which the process was recorded (or “served”). Photographs were used as supporting records within the reflective journal rather than as a separate unit of analysis. The flowchart also shows how the analysis developed iteratively through repeated movement between data and literature, changes in the medium used for coding and interpretation, thematic reorganisation, the research questions, and triangulation.

Figure 24

How the Methodological Elements Came Together in Practice



Note. Concept and content by the author. Graphic design and production by Daniel Diehl, used with permission. The two analytical loops represent repeated movement between data and literature and changes in the medium used for coding and interpretation. Memo writing accompanied the analytical process throughout.

The process began with transcription and the first readings of the interviews and focus groups. As described in Sections 4.6.3 and 4.6.5, I initially identified codes and recurring ideas while remaining close to participants' accounts. Although the transcripts were produced and stored on the computer, I often moved away from the screen when analysing them and wrote developing codes and ideas by hand in a notebook⁵. Although handwriting might appear to slow the process, for me it often had the opposite effect. Extended work on a screen could become tiring and, at times, I reached a point where I could no longer develop an idea productively. Changing from screen to paper changed the way I interacted with the material and often allowed the analytical process to continue. Appendix T provides examples of these handwritten codes and notes.

This movement between media remained important throughout the analysis. At times, I would transcribe material on the computer, read it there, and then move to a notebook to write codes or relationships that I had identified. At other times, I printed material so that I could annotate it away from the screen. When I became saturated with one way of processing the thesis, changing the medium helped me approach the same material from another direction. This became one practical way in which I worked through periods of analytical or writing blockage without leaving the data itself.

The movement between data and literature developed in a similar way. Some recurring codes could not be adequately interpreted through the literature I had initially reviewed. When this occurred, I returned to the literature to develop a better understanding of what I was seeing and then returned to the data with this additional theoretical knowledge. The process was therefore not data, followed by literature, followed by a final interpretation. Data sometimes indicated that something was missing from my theoretical understanding, while further reading subsequently changed what I was able to recognise in the data. One example of this iterative movement occurred with the dimensions of engagement. The behavioural, cognitive, and emotional/affective dimensions that initially informed my understanding of engagement did not fully account for some patterns in the dataset. Students were participating and developing in ways that could not be adequately explained through these dimensions alone, particularly in relation to initiative and peer interaction. This led me back to the literature, where I encountered the concepts of agentic and social engagement. Once I had developed a better understanding of these additional dimensions, I returned to the data and was able to interpret aspects of the students' participation that I had already observed but had not previously been able to describe

⁵ This was not a new practice for me. During my master's research, more than half of my initial writing had been produced by hand before being transferred to the computer.

with sufficient precision. The literature therefore did not function as a predetermined coding framework. It entered into dialogue with the developing analysis, and that dialogue sometimes required another return to the data.

I subsequently worked with the developing codes and categories in NVivo, as described in Section 4.6.5. NVivo enabled me to retrieve material, compare participants and data sources, and examine developing nodes. Some codes became more significant, others were combined or renamed, and some gradually fell out of use. Not every initial idea survived the analytical process. Through comparison, codes began to form larger groupings, and those groupings increasingly suggested broader analytical stories.

This process did not occur exclusively within NVivo. As described in Section 4.6.5.1, when extended work on the computer became difficult, I again changed the medium. I printed developing codes and categories, cut them into pieces, and physically moved them to construct and reconstruct relationships between them. In this sense, I used a hands-on process to analyse a project that had itself been based on hands-on learning. I could move, touch, separate, reconnect, and reposition parts of the analysis rather than interacting with them only through a digital interface. The result was not a different dataset, but a different physical relationship with the same dataset. NVivo provided organisation and retrieval, while handwriting and physical sorting provided other ways of seeing relationships within the material.

The code tree developed through these repeated movements, but the code tree did not by itself produce the final findings. At a later stage, I had organised much of the developing analytical material temporally. Evidence from the initial focus groups and interviews, observations and reflective journal material generated during the workshops, and the final focus groups and interviews could be distinguished from one another. I also used different colours to retain these temporal distinctions. Material generated before the workshops, material generated during the workshops, and material generated after them could therefore remain visually identifiable even when sections were later moved into different analytical groupings.

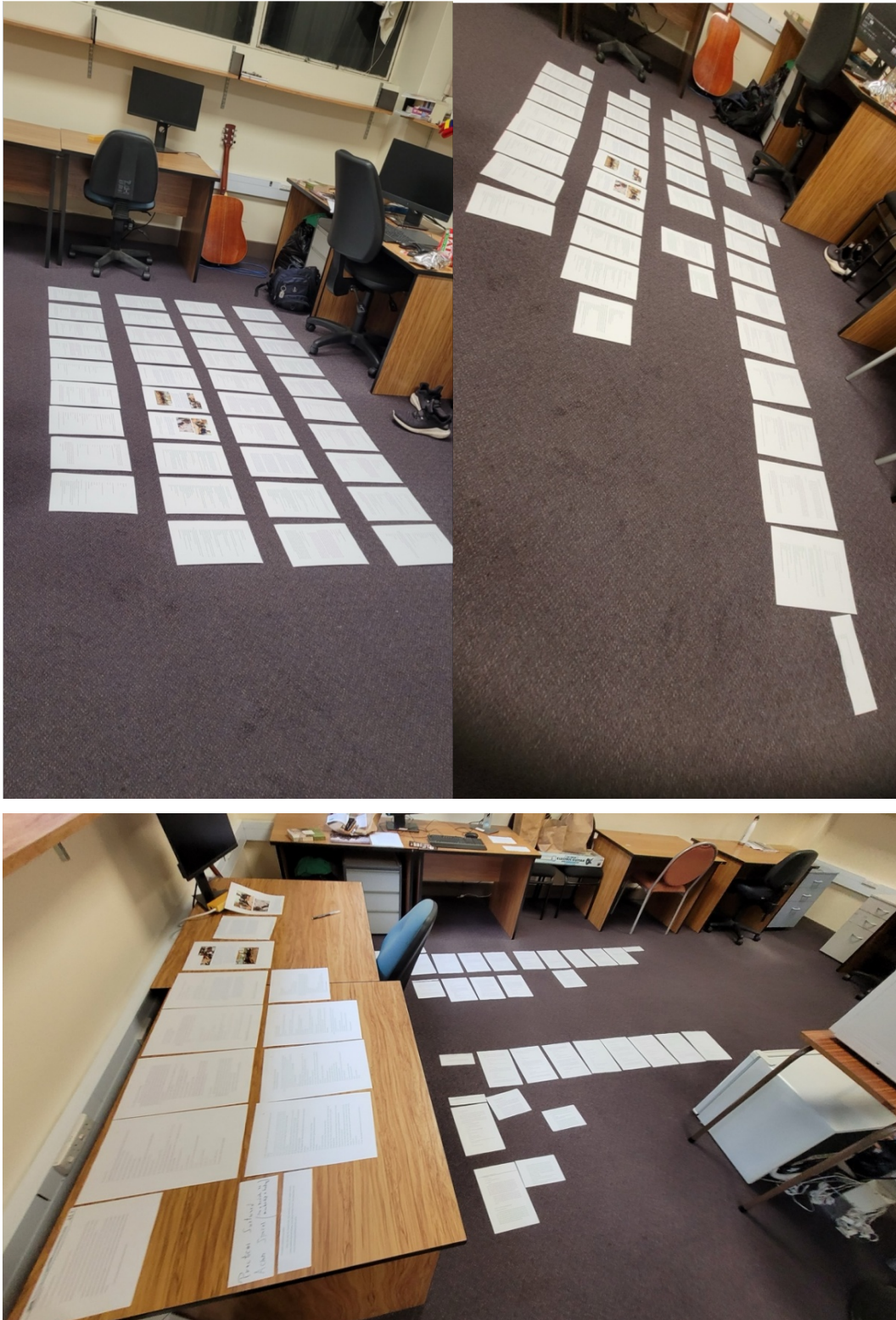
This temporal organisation gave me a story organised into categories; however, initially it was mainly a story of the intervention itself. I could see what had happened before the workshops, what had happened during them, and what had happened afterwards, with the material already grouped into developing categories. In that form, however, the material was closer to a chronological account of my time at the school than to a set of scientific findings. I had a timeline, but I did not yet have a separate analytical story showing, for example, what happened to classroom dynamics across that timeline, how peer interaction changed, or how a

particular interdisciplinary connection developed from the beginning to the end of the intervention. The next analytical step was therefore to move from a chronology of the research to thematic stories of change across that chronology.

To do this, I printed the developing analytical material and arranged the pages physically across the floor. At first, the pages retained much of their chronological organisation. I could see material from the pre-workshop interviews and focus groups, material generated during the workshops, and material from the final interviews and focus groups in relation to one another. I then began moving pages and sections of material so that evidence concerning the same developing issue could be viewed together across different moments. The colour coding was retained throughout this process so that I could still identify whether material had been generated before, during, or after the workshops, even as it was reorganised thematically. Figure 25 shows stages of this process.

Figure 25

Manual Reorganisation of Chronological Material Into Thematic Findings



Note. Printed analytical material was initially arranged to preserve the pre-, during-, and post-workshop chronology and was then physically reorganised to bring related evidence together across different stages of the project. This process supported the transition from a chronological account of the intervention to the thematic stories that became the main findings.

As with Figures Figure 21–Figure 23, Figure 25 documents the analytical process rather than serving as the readable record of the material shown on the individual pages. The thematic accounts developed through this reorganisation are presented in full as the seven main findings in Sections 6.8–6.14.

Working with the material in this way changed what I was able to see. On a computer screen, two connected pieces of an analytical story could be separated by 20, 30, or more pages. Finding the second piece required scrolling through the document, and during that movement I could lose part of the connection I had been trying to explore. With the printed material spread across the floor, the relationship did not need to be held entirely in my memory. One piece of the story could remain physically visible while I searched for another.

Over time, I began to remember approximate physical locations of material. A particular account might be located in one area of the room and another related episode several rows away. The physical arrangement became a temporary visual map of the analysis. Connections could remain partly unresolved in one area while I worked on another and then returned to them later. In this sense, the developing analysis began to resemble the construction of a larger visual composition: parts could remain in place while other parts were moved, compared, removed, or brought together. This was particularly useful with a dataset that was too large to be viewed simultaneously on a computer screen.

This physical reorganisation helped me move from a chronological account to an analytical one. The first arrangement answered the question, “What happened before, during, and after the workshops?” The later arrangements allowed me to ask a different question: “What happened to the same issue across those different moments?” This distinction was important in transforming the material into findings.

For example, material concerning group work before the workshops could be placed alongside observations of group interaction during the artistic workshops, then alongside events during the electronics workshops, and finally alongside students’ and teachers’ accounts after the intervention. Instead of four separate episodes occurring at different times, these pieces of evidence could now be read as one developing analytical story. Through this process, what had initially been chronological material became the finding concerning the movement from restricted forms of peer interaction towards more organic collaboration.

I used the same process with other developing findings. Material concerning motivation could be followed from students’ initial references to grades and external reasons for participation, through hands-on experiences during the workshops, to later expressions of

accomplishment, ownership, and intrinsic motivation. Evidence concerning interdisciplinary learning could be brought together in a similar way, as could classroom dynamics, creative troubleshooting, artistic elaboration, and practices that extended from school into students' homes and everyday lives. The physical sorting did not create these patterns independently of the data. Rather, it allowed evidence that had been generated at different times and was located in different parts of the dataset to be considered together as a developing thematic account.

The colour coding remained important during this stage because it preserved the temporal origin of the evidence after the material had been reorganised thematically. I could bring together evidence concerning the same issue while still seeing whether a particular section came from an initial interview or focus group, from my observations during the workshops, or from a final interview or focus group. In this way, thematic reorganisation did not require abandoning the temporal structure of the intervention. The two forms of organisation worked together: one showed the issue being examined, while the other showed when the evidence had been generated.

The research questions acted as boundary. I repeatedly reduced data to the questions' three central concerns: student engagement, peer interaction, and interdisciplinarity. When a developing analytical story began to take shape, I returned to these three concerns and asked whether that story contributed to answering one or more of the research questions.

This became particularly important because the dataset contained many interesting accounts. An interesting story was not automatically a finding. When a developing account contributed directly to understanding student engagement, peer interaction, or interdisciplinarity, it remained within the findings analysis. When it did not answer one of the research questions but was important for explaining the situation in which the students and workshops were located, it could contribute instead to the research context presented in Chapter 5. Material that neither contributed to the research questions nor provided necessary context was set aside. This allowed the analysis to retain boundaries rather than expanding indefinitely around every interesting aspect of the case.

Through this repeated process of coding, comparison, returning to the literature, temporal organisation, physical reorganisation, and filtering in relation to the research questions, seven broader analytical stories took shape. These became the seven main thematic findings presented in Sections 6.8 to 6.14. Each finding brought together evidence from different moments rather than representing only one workshop, one participant, or one data source.

Triangulation was important when these stories were being developed and checked. I compared students' accounts from the focus groups, teachers' perspectives from the interviews, and my own observations and reflections in the research journal. Convergence across these sources strengthened an interpretation, while differences were not automatically treated as errors. At times, differences between sources provided a more complex understanding of the same event and were therefore retained within the analysis. In this way, triangulation did not remove my position as researcher from the study. Instead, it allowed my interpretation to be considered alongside other perspectives generated within the case.

Once the seven findings had developed sufficiently, I returned again to the literature. At this stage, the purpose was not simply to find literature that confirmed what I had found. The findings were interpreted in relation to concepts that had already informed the coding as well as literature that had become relevant through the iterative analysis. At times, this theoretical interpretation prompted another return to the empirical material. A concept could make one part of a finding clearer, while a particular episode in the data could reveal that further theoretical reading was still required. The final findings therefore developed through repeated movement between empirical material and theoretical interpretation rather than through a single progression from coding to conclusion.

Changing the medium through which I worked continued into the later stages of the thesis. When I began developing the discussion of the theremin's affordances in Chapter 7, I again reached a point at which producing further written material on the computer had become difficult. I had accumulated a large amount of knowledge about the project, the findings, the literature, and the theremin through my experience as a musician, teacher, and researcher, but writing became a comparatively slow way of releasing those developing ideas. I therefore moved to spoken analytical memos.

Rather than beginning with written sentences, I recorded myself speaking through the developing interpretations and subsequently transcribed these recordings before reshaping them into academic prose.⁶ Speaking allowed ideas to be recorded at approximately the speed at which I was thinking about them, without requiring me to resolve sentence structure at the same moment as the analytical idea itself. In these memos, I articulated connections between

⁶ One group of these spoken analytical memos was recorded while I was camping. I walked around the campsite recording my developing thoughts about the theremin's affordances before later transcribing and developing them into the written discussion. Changing from writing to walking and speaking provided another way for me to work through a point at which extended screen-based writing had become unproductive.

the findings, literature, my practical knowledge of the instrument, and my experience of the workshops.

This also helps explain why parts of Chapter 7 developed through a somewhat different writing process from earlier parts of the thesis. The initial material for these sections was spoken rather than typed or handwritten. It was subsequently transcribed, edited, checked against the findings and literature, and developed into the final academic account. The change in medium did not change the evidential basis of the argument, but it changed the route through which my interpretation was initially expressed.

Taken together, the process described here was iterative both intellectually and materially. I moved between data and literature, between coding and interpretation, and between different physical ways of interacting with the same research material. Computer-based coding, handwritten analysis, NVivo, printed sorting, colour coding, physical mapping, and spoken memoing were not separate methodologies. They were different analytical practices operating within the broader constructivist grounded theory process described in Section 4.6.1.

This process also reflects the constructivist position taken in this thesis. My interpretation cannot be separated completely from my position as the researcher who designed and facilitated the workshops and then analysed the material generated through them. Rather than attempting to present myself as detached from this process, I made my analytical role visible through the reflective journal, memos, records of coding decisions, physical sorting, and repeated comparison across data sources. Reflexivity, triangulation, and a traceable movement from the initial material to the seven final findings were therefore used together to support the credibility of the analytical account.

4.7 Summary

This chapter (Chapter 4) explains how the study was designed and carried out. It starts by locating the research in Paraná, Brazil, and by explaining how access to the state school system works through SEED and the regional NRE, including the documents required and the steps needed to obtain permission to work in a school. It then describes the COVID-19 situation in Brazil and explains how it still affected the workshops in 2022, including the interruption caused when I became ill.

Next, the chapter presents the qualitative case study approach used in this research. It defines the case as the implementation of a theremin-based workshop sequence in one public school and clarifies the study boundaries (setting, participants, timeframe, and evidence

corpus), including the four Year 8 classes as embedded units within the broader case. Action research was also considered because I designed and facilitated the workshops and was actively involved in the research setting. However, the intervention was not repeatedly evaluated, redesigned, and reimplemented through successive research cycles. The main methodological iteration occurred instead in the analysis, making the qualitative case study a closer description of the research undertaken. It also explains how student engagement can be examined through different methods (focus groups, interviews, and reflective journal) to access students' and teachers' own explanations about participation, effort, emotions, and classroom dynamics. In this study, engagement was examined qualitatively rather than through a standardised scale or numerical score, using behavioural, cognitive, emotional/affective, agentic, and social engagement as interpretive lenses.

The data collection section then describes the intervention and the participants. I ran weekly 50-minute workshops over 14 weeks with participating students from four Year 8 classes (8A, 8B, 8C, and 8D), including mixed-ability groups and a small number of students who were older due to grade repetition. Students who were not participating in the research workshops remained with their regular music teacher during these sessions. Data were gathered through two rounds of focus groups with eight students from each class (before and after the workshops), two rounds of semistructured interviews with the arts and science teachers (before the initial focus groups and after the workshops), and a reflective journal kept throughout the project, supported by photographs of activities and student work.

The workshops section introduces the overall sequence and the main influences from theremin music education. It then describes the three phases of the programme: pre-electronics artistic and creative workshops (including free exploration, drawing-to-sound activities, storytelling, dialogue between theremins, and group composition), electronics workshops (safety, PCB work, etching, soldering, and peer-supported assembly), and post-electronics artistic and creative workshops (playing techniques on the optical theremin and composition using paint).

The chapter then outlines ethical procedures. It explains institutional approval, consent and assent in Portuguese, anonymity and confidentiality, and safety measures during group work and electronics sessions. It also clarifies withdrawal options and notes the ethics extension used to include an additional interview with the principal.

Finally, the chapter explains how the data were prepared and analysed. After manual transcription, I began initial coding in Word and then moved the dataset into NVivo to manage

the volume of codes and support retrieval across sources. Coding followed an iterative process that moved from initial codes to focused categories through constant comparison and memo writing. I also used manual sorting, including handwritten notes and physical category mapping, to help develop the final code tree. The analytical process did not end with the code tree. Material that had initially been organised chronologically as pre-, during-, and post-workshop evidence was later reorganised into thematic analytical stories. The research questions helped determine which developing stories contributed to the findings, which material was better placed in the research context, and which material should be set aside. Through repeated comparison, engagement with the literature, physical reorganisation, and triangulation across focus groups, teacher interviews, and the reflective journal, seven broader analytical stories developed into the seven main findings presented in Sections 6.8–6.14.

The next chapter, “Context and Challenges” (Chapter 5), examines the broader social and institutional landscape in which the research took place. It discusses the specific challenges faced by the school community and participants, providing essential background for understanding my study’s findings.

CHAPTER 5 – CONTEXT AND CHALLENGES

This chapter, Chapter 5, situates the study by describing the school environment and the conditions in which these Year 8 students lived and learned. It draws mainly on my field notes and research journal, alongside contextual material from staff interviews and focus group talk. The purpose of this chapter is to provide background that helps interpret the workshops, even though this material is not presented as findings. Unlike Chapter 6 that talks about the findings of the study, this Chapter 5 looks at the constraints that shaped students' lives and school participation before and during the project. The findings focus on change within the workshops, including shifts in students' relationships with science, art, peer collaboration, and group work.

This chapter describes the starting point and key boundary conditions of the case. Several episodes reported here were observed by me or reported by staff and students, but they could not be triangulated across the full dataset (interviews, focus groups, and research journal) in the same way as the findings. For that reason, I treat them as contextual indicators rather than analytic claims.

Many of these challenges, for example political decisions and persistent infrastructure shortages, were not resolved during the workshops. They sit outside the scope of a 14-week intervention, yet they shaped attendance, access to materials, and the forms that disengagement and resistance could take. Acknowledging what the project could not change is part of presenting the case with appropriate limits.

In this Brazilian public school, class labels such as 8A, 8B, 8C, and 8D are organisational and do not indicate streaming by ability or achievement level. Each class included a heterogeneous mix of students in academic performance, motivation, and background, and there was no formal or informal ranking between groups.

5.1 Postpandemic Impact on School and Students.

In an initial conversation with the educational coordinator⁷, I was briefed on the postpandemic challenges faced by the school. She oversaw internships and was involved in the school's academic and administrative structure. She described the institution as being a "pandemic school", noting that many students lacked access to online learning due to not having

⁷ Called pedagogue in Portuguese (*pedagoga*). A related job role in New Zealand would be the assistant principal.

devices, relying instead on printed materials. Teachers that were once known for their excellence were no longer as effective: “For [teacher’s name withheld] to lose patience or raise his voice, it means the situation has gotten very ugly,” she said. According to her, students appeared demotivated, with little interest in school or future goals. In her own words: “Simply planning finishing high school was seen as an achievement” (Research journal, May 3, 2022).

The educational coordinator told me that the students would likely become very attached to me as I was bringing something different from their routine, and they would probably not want me to leave after the workshops. She explained that most students were not violent but rather emotionally needy and deeply unmotivated. In her words, they were children without dreams and without aspirations to any profession. They remained apathetic as if they had not resumed living fully after having their lives paused by the pandemic (Educational coordinator, personal communication, May 3, 2022). In addition to the demotivation caused by the pandemic, students were also affected by a number of social and behavioural issues that shaped how they interacted with school. This matter of high-risk behaviour patterns and adverse experiences will be displayed in the Section 5.2 below.

5.2 High-Risk Behaviour and Adverse Experiences

The examples in this Section 5.2 refer to issues observed or discussed in this school and are presented as local context, not as universal estimates.

5.2.1 Marginalisation

One of the most pressing realities faced by students at this school is marginalisation, both socioeconomic and geographic. According to the arts teacher, most students are recipients of government social programmes, such as *Bolsa Família*, and live in peripheral or high-risk areas. While the school is located in a neighbourhood that also includes middle-class residents, these families typically send their children to private schools. As a result, the school draws most of its students from distant and underserved communities, which the teacher described as “the outskirts of the outskirts”. He explained that although the neighbourhood is officially considered peripheral, the student population mainly comes from even more disadvantaged areas beyond its limits. These conditions, he added, mean the school serves a group that is “very needy” with many students living in vulnerable situations and requiring additional social and educational support (Arts teacher, initial interview). Some of these tensions were also reflected in how students interacted with the school space and its resources, as in public property damage, as I account below in Section 5.2.2.

5.2.2 Public Property Damage /Vandalism

Vandalism was identified as an issue in the school, particularly in relation to the absence of mirrors in student bathrooms. During a focus group, students pointed out that only teachers' bathrooms had mirrors while student facilities did not. One student commented, "when we go to do our makeup, there's no mirror" while another pointed out, "There's no mirror in that bathroom!", which was confirmed by the rest of the class: "It's true, the mirror ..." (Year 8C, initial focus group). The students explained that mirrors had once been installed but were quickly broken, which they believed was the reason for their removal. They speculated that if mirrors were put up again, they would likely be damaged: "there was one time, but they all got broken." (Year 8C, initial focus group). Alongside the physical environment, teachers pointed to deeper emotional and behavioural patterns, especially around how early students began to take on adult roles, as reported in the following Section 5.2.3.

5.2.3 Early Adulthood

When exploring possible reasons for decreased student engagement, even during playful activities, I discussed with the science teacher the impact of early adultisation and sexualisation among children. She considered that this may have intensified during the pandemic. She noted that by the sixth grade, students were already highly sexualised and adopted adult-like behaviours, showing disinterest in anything considered childish. According to her, this is common in Brazilian public schools where children as young as four express disdain for childhood activities, seeing them as inferior. This leads to what she described as the "death of childhood" where being childish is viewed negatively (Science teacher, personal communication, May 31, 2022).

By the time these students reach high school, the teacher observed that they often attempt to compensate for this lost phase. As a result, adolescents may carry emotional gaps while displaying adult behaviour. This issue was evident in the way consent for workshop participation had to be framed. The word "child" could not be used in communications as it risked ridicule and withdrawal from the project. The term "adolescent" was adopted instead as it acknowledged their transitional identity while respecting their emotional sensitivity (Research journal, May 31, 2022).

The effect of early adulthood of Brazilian youth was reflected in one moment during the workshops as one student from class 8C informed me that she was pregnant, which raised safety concerns regarding the soldering activity as most solders in Brazil contain lead, a

substance harmful to developing babies. I explained that she could safely complete the drilling stage and participate in all other activities but should avoid soldering for health reasons (Research journal, September 8, 2022). This sense of disconnection often showed up in attendance patterns with many students coming irregularly or dropping out altogether.

5.2.4 Low Attendance and Dropout Rate

Another issue mentioned by students in the focus groups was low attendance. This was discussed during the focus groups and confirmed through informal conversations I had with teachers during coffee breaks where they shared their class stories in a more informal way. I also recorded these insights in my reflective journal. For example, some classes had 31 students enrolled, but when I asked how many usually showed up, the students responded:

S1: Some days, quite a few are absent.

S2: Usually it's around 20-something. (Year 8A, initial focus group)

When asked whether the same students were consistently absent, they replied:

S1: Hmm, it varies ...

S2: There are specific people who come, and there are people who have never come.

S3: It depends a lot. (Year 8A, initial focus group)

Despite these variations, students agreed that approximately 20 students typically attended class each day, with around 8 to 10 missing every day.

This pattern reflected a broader issue: high dropout rates throughout the school year. In some cases, classes that began with 26 to 28 students dropped to around 14 by the second semester. This dropout phenomenon is not uncommon as students leave for various reasons, including transferring to other schools, being expelled, or dropping out entirely. These dynamics significantly impact the school's ability to maintain consistent learning and progress.

The issue of school dropout was once again visible during the workshops and directly affected class composition. Although this did not compromise the project's goals, it required constant adaptation to maintain group work and engagement. In some classes with high dropout rates, we were still able to build the optical therein and carry out the activities effectively.

In the first workshop with Year 8D, some patterns stood out. A few students who had not participated in the music workshop performed very well in group settings. Though quiet, even with peers, they worked efficiently and helped guide their classmates. The dropout rate in

this class was particularly noticeable. While the group initially had 14–16 students, only eight attended this session – not due to lack of interest but because many had left the school, either through transfers or dropping out. The workshop required repeated adaptations – not because of poor planning but because of the unstable school structure.

Interestingly, this was the easiest class with which to form groups. Two well-functioning groups emerged, with some students already familiar with soldering and the steps involved. There was strong peer support. Eventually, these groups began collaborating more closely, turning isolated efforts into a collective one, as seen in Figure 26 I found this highly functional and encouraging.

Figure 26

Students Working Together Despite High Dropout Rates from School



Despite the challenges, participation remained meaningful. In spite of this, one initiative stood out as a positive alternative for students who had left school: the Youth and Adult Education programme (*EJA – Educação de Jovens e Adultos*). The science teacher noted that many students only begin to value education when they face the demands of the job market. Often, they realise too late that even entry-level jobs require at least a high school diploma. Some of them return to school through the *EJA* programme to obtain this qualification and improve their job prospects. *EJA* offers an alternative path for those who left school early, providing access to basic education and, in some cases, sparking renewed interest in learning. In the science teacher's words: "when they come back, they understand they should have taken school more seriously. Some return out of necessity, others begin to enjoy the process of learning and keep going" (Science teacher, initial interview). This ends up becoming a functional response from the state as it gives the youth a second chance at education and self-development.

The principal attributes student dropout mainly to external factors, such as drug dealing, hunger, and family vulnerability. She explains that students rarely leave school due to internal school matters. According to her, the real challenges lie outside the school gates. Many of these

issues, she noted, start or intensify inside the school environment but originate elsewhere. She acknowledges the limits of her influence: “I have no control over the family, over the drug trade, over hunger out there” (Principal interview). This external factor of drug dealing and usage became evident as it affected my workshops directly. I lost two students due to drug-related issues. I will discuss this further in the next subchapter, Section 5.2.5, and in my Findings - “Students’ learning and experiences extended beyond the workshops – Theremin the artefact as a bridge” (Chapter 6.10) – and “Shift in dynamics and students’ participation” (Chapter 6.11).

5.2.5 Drugs

This Section 5.2.5 uses specific cases and staff accounts from this school to illustrate context. In conversation with the science teacher, a concerning picture emerged of students’ disinterest in life and schooling, often linked to drug use and a sense of hopelessness. She described how one student, previously expelled from another school for using drugs, continued despite suffering seizures. When questioned, the student explained that drug use was her only source of happiness, and she saw no point in changing her lifestyle, referencing a family member who died in similar circumstances. This case shows how some students see drug trafficking not only as a more accessible path to income and social status but also as an escape from the lack of opportunities they associate with education. The pandemic intensified these issues, but the root causes are structural and deeply embedded in the social realities many students face (Research journal, May 31, 2022).

In a conversation with the school principal, the issue of substance use among students was brought to light. While most students are not involved, drug use is a significant concern in this school context. During our first meeting, I introduced the principal to the theremin, which she enthusiastically supported due to her own background in piano and guitar. She described the eighth-grade students as “unfocused, unwilling, lazy” and noted that some are easily drawn into drug use. According to her, for children who live without long-term prospects, “the moment of ecstasy from the drug is the only happiness some of these children have in their daily lives”, with some reportedly smoking “at least 10 marijuana cigarettes daily” when it comes to lighter substances. She also shared the case of a ninth-grade student who sold drugs. When she asked him, “What if they kill you while you are selling drugs?”, he responded, “What’s the point? With drugs or without drugs, what future do I have? At least by selling drugs today I can wear cool clothes or buy the sneakers and things I want” (Principal, personal communication, May 11, 2022). Beyond community challenges, political decisions and policies also shaped how education happened in this school.

5.3 Politics

5.3.1 Numbers over Learning in Public Education

Arts teachers in Brazilian public schools work with four different areas of art during the school year – dance, visual arts, drama, and music – regardless of their professional training. The majority of professionals teaching arts in the Brazilian educational system are trained in music education or visual arts education, with very few having training in dance or drama (Weingärtner et al., 2020).

Both the arts teacher and the science teacher commented on the negative impact of politics on education. The arts teacher explained that the current system prioritises students passing to the next year over genuine learning. He traced this trend to municipal-level⁸ policy, which has since spread to other educational stages, driven by a political focus on number of approvals rather than educational quality. He described the situation as “a more political methodology than an educational one”, noting that “politics works a lot based on results, based on numbers”, which has become “a very big problem for public schools” (Arts teacher, initial interview).

The arts teacher acknowledged the importance of differentiated evaluation for students with learning difficulties or psychological diagnoses but stressed that the broader system often fails to accommodate these students. Even more neglected, he added, are students facing socioeconomic hardship: “They just want the student to pass”, he said, even if no meaningful learning has occurred. In his view, the system’s emphasis on metrics acts like a bulldozer flattening students’ individual needs (Arts teacher, initial interview).

The science teacher shared similar concerns, observing how political cycles have led to long-term instability in education. Since beginning her career in 1998, she has witnessed major shifts every election cycle⁹, with new administrations replacing leadership roles and disregarding previous work. “Even if you’re doing the same thing, the name is different, so it’s a completely different process”, she explained. According to her, these frequent changes contribute to a growing sense of disconnection in schools and among teachers (Science teacher, initial interview).

⁸ A *município* in Brazil is the smallest administrative division in the country, equivalent to a municipality or township in other countries. In Brazil, *municípios* are the responsible division for management of primary schools.

⁹ Elections in Brazil are held every four years.

The science teacher also described how grades and learning have become trivialised, both for students and families. “It makes no difference if they have grades, if they learn, or if they understand the content”, she said. Academic progress is no longer clearly communicated as in the case of passing the year because the student knows the content. Retaining a student requires ongoing documentation that can be difficult to maintain in the middle of daily teaching. “Sometimes we forget, so we can’t retain the student, not because they should pass, but because the documentation wasn’t done”, she explained. Families tend to express concern only when a child risks being retained and often opt to transfer the student to another school rather than address the issue (Science teacher, initial interview).

The science teacher further reflected on how the pandemic exposed a lack of recognition for teachers’ work. Despite supporting students online – often late into the night – teachers were widely perceived as not having worked. “For the family, for society, we didn’t work during those two years,” she stated. This perception informed a federal law proposal (PEC – *Proposta de Emenda à Constituição*) to freeze service time for pensions and career advancement, effectively disregarding two years of online teaching. “It doesn’t count for retirement, it doesn’t count for steps in career salary progression, it doesn’t count as service time, nothing,” she said. Although the proposal was not voted on, she saw it as part of a broader attitude: “Society sometimes gives the impression that it unites against the teacher, when in fact, we need support – because we are the ones preparing students for the job market and for life” (Science teacher, initial interview). Teachers also mentioned the uneven distribution of resources across public schools, which directly impacted what students had access to.

5.3.2 Disparities in Public Funding Distribution

Disparities in public funding distribution were raised by the arts teacher, who described a stark contrast between his school and better resourced institutions within the same state system. Although his school is publicly funded, it does not receive the same level of investment as others. He explained that during state-sponsored training sessions, he spoke with teachers from different regions and discovered that some state schools are considered model institutions, equipped with facilities such as music and visual arts rooms. “That exists in the state,” he said, “because that teacher is there. But that’s not my reality here.” He characterised his school as peripheral – not only in terms of the student population it serves but also in how it is perceived and resourced by the state. “My reality here is peripheral in terms of the attention the government gives to this institution,” he added, pointing out that although some schools receive

specialised equipment, his school continues to face significant limitations (Arts teacher, initial interview).

5.3.3 Public Funding Shortages: Insufficient School Resources

Students described limitations in their access to computers. The use of the computer lab is generally restricted to English and occasionally Portuguese classes, and, even then, attendance is irregular due to scheduling. Out of 31 students, only around 10 can use the lab at a time as many of the devices are not working. In most cases, students are required to work in pairs or trios in activities designed for one student only, which sometimes hinders productivity. Although some reported that these groupings can work, others noted that tasks are often interrupted or abandoned due to technical issues (Year 8A, initial focus group).

Another common complaint among students was about the unreliable internet connection. Several students mentioned that the internet often cuts out during lessons, preventing them from completing activities. This recurring issue has become so normalised that students jokingly refer to it as “bakery internet” – a humorous comparison to the typically weak free Wi-Fi in local bakeries. As one student put it, “When we’re in the room, we say: ‘Oh, this bakery internet isn’t working!’” When the internet fails, students either wait idly or resort to playing the offline dinosaur game built into the Chrome browser, reinforcing the sense that online learning tools are often inaccessible (Year 8A, initial focus group).

Students from Year 8C echoed similar concerns on limited access to technology. They reported that their use of the computer lab has become sporadic and is largely limited to English classes on Fridays. Even during those sessions, students must work in pairs due to the shortage of devices. When asked if they had been using the lab recently, one student noted: “we do, but ... not really anymore”, reflecting the lab’s declining usability. Another commented, “only for accessing that ...”, referring to specific assignments or apps (Year 8C, initial focus group).

The main use of the lab is for the Paraná-English programme, which resembles language learning platforms like Duolingo. Students log in, complete language tasks, and sometimes record their voices. However, the activity is affected by group work constraints and connectivity issues. One student sarcastically remarked, “It’s going great (sarcastically)”, demonstrating frustration with the system’s limitations. Another said, “I listen and skip”, suggesting a lack of genuine engagement (Year 8C, initial focus group). Apart from digital tools, more basic infrastructure problems were also present in the school environment.

5.4 Infrastructure

From the beginning, I was met with goodwill from the school staff and workers, who demonstrated genuine commitment to education and did their best to support me throughout the research activities. However, the public school's poor infrastructure posed significant challenges. One of the rooms offered for the workshop had rainwater infiltration on the floor, broken tiles, damaged desks, dirty and painted windows (intended to prevent students from being distracted by physical education classes in the adjacent court), broken windowpanes, and security cameras (Research journal, June 2, 2022). Figure 27 shows examples of these issues. Not every classroom had all of these problems, but conditions such as partially broken desks, graffiti, and surveillance cameras were common across most rooms in the school.

Figure 27
Infrastructure and Maintenance Challenges



The surroundings of the school presented similar issues, such as walls covered in graffiti by a gang marking territory, and broken tiles on the sidewalks that made access to the school difficult during rainy days, as seen in Figure 28.

Figure 28

Graffiti and Accessibility Issues in the School Surroundings



This was the reality I observed in and around this school, and it shaped how students arrived and participated on some days. Weather conditions added another layer of difficulty for students trying to get to school, especially on rainy days.

5.4.1 Rain and Weather Affecting School Attendance

The lack of infrastructure also affects students' arrival at school. Weather can have a significant impact on student attendance in underprivileged communities. On rainy days, these conditions are worsened by the lack of proper clothing or access to transportation. This was evident during the first focus group with Year 8A. Despite arriving early and preparing snacks, recorders, and a list of questions, I found that only three of the 33 enrolled students were present in class at the beginning of the session. Four more arrived late, totalling seven students, but only two belonged to the selected group. I decided to postpone the initial focus group session as I believed an interview with only two participants would not create a comfortable environment for open discussion (Research journal, June 2, 2022).

The experience of low attendance due to rain led me to further investigate how weather conditions affect student participation. While preparing for the first thereimin presentation, which required specific light and sound conditions, I visited the classroom I would use in advance. It was a rainy day, and the educational coordinator showed me a room with only three students present. When I asked if this was common, she confirmed that attendance is usually very low on these days. She told me: "When it rains, only a handful of students show up. They come from very poor communities." She explained that most do not own umbrellas, and when they do come, the school often needs to provide a change of clothes to prevent them getting ill.

“When it rains heavily like this, the students stay at home, warm under the covers, sleeping” (Educational coordinator, personal communication, June 2, 2022).

Weather-related absences affected the early stages of my project. In one instance, during a planned session with Year 8B, the rain again led to low attendance. As stated before, many students rely on public transport or walk to school, and the lack of resources such as umbrellas often results in them choosing to stay home. As written in my notes: “This week it rained a lot, so the number of participating students was smaller. There’s not much infrastructure; they take the bus or walk, and they don’t even have money for an umbrella. So, they probably didn’t want to risk getting wet and staying soaked all day, and, as a result, very few students came to class today” (Research journal, August 17, 2022).

In one focus group with Year 8A, students shared how cold weather also impacted their motivation to attend school. One student said, “I told my mum not to send me to school on Thursday.” Another commented, “It’s too cold”, noting that her mother often lets her stay home. A third explained, “My mom says, ‘Why did I buy you a coat then?’ But it doesn’t even keep me warm ...” (Year 8A, initial focus group). Health issues also played a role in student engagement, particularly when families could not afford basic items like glasses.

5.4.2 Lack of Access to Basic Healthcare

One issue in this kind of community was the lack of access to basic items such as prescription glasses. In Brazil, a pair of glasses can cost up to half a month’s worth of minimum wage, so many families cannot afford them. This affects students’ attendance and their ability to follow classroom work. When I asked who needed glasses, one student said that her mother had signed her up, but she had not been called yet. Another asked, “Did she schedule it with the ophthalmologist?” The first responded, “She did, but ... a long time ago.” These responses display how scheduled healthcare appointments are delayed or inaccessible in these communities, leaving students with untreated visual impairments that may hinder learning (Year 8A, initial focus group). Students did not always express these challenges directly. Often, their dissatisfaction appeared through humour, silence, or sarcasm in daily interactions.

5.5 Sarcasm and Silence in School Life

The patterns described here are drawn from focus group talk in this school and from my field notes, and I treat them as contextual indicators rather than general claims. This Section 5.5 explores how students experienced and responded to tensions in their school environment. Most of them came to light through students’ sarcastic remarks, ironic humour, and critical

attitudes toward school, teachers, and peers. Together, these accounts reflect how disengagement and resistance manifested both through silence and satire in these students' everyday school life.

5.5.1 Satirical and Mocking Attitude

Initial focus groups revealed a significant level of negative responses and satirical/mocking attitudes towards academic work, classmates, the school environment, and teachers. Many students expressed dissatisfaction, often using humour and sarcasm as coping mechanisms.

5.5.1.1 *To academic work*

In the initial focus groups with Year 8 students, satirical comments about academic work were common. One student responded to a question about school satisfaction by saying, "None. I'm bad with grades and I like to talk", later adding that they usually score just enough to pass (Year 8A, initial focus group). In Year 8D, students expressed mixed feelings about science, showing interest in some topics like planets but joking about others, such as the human body. Comments also targeted the teacher, with students laughing about disliking both the subject and the person teaching it. Some noted they used to enjoy science but no longer did, criticising the teacher as a "pain" who "doesn't forgive" (Year 8D, initial focus group).

5.5.1.2 *To classmates*

During the focus group with Year 8A, one student made a positive comment about the science subject. He stated that he enjoyed the endocrine system, and another student agreed. However, after this, the tone shifted as a third student dismissed the classroom environment by saying, "Yeah, it's good, but the class is full of idiots" (Year 8A, initial focus group).

5.5.1.3 *To school*

Students from Years 8A, 8C, and 8D frequently described school life with sarcasm and criticism. In Year 8A, one student said school was "boring", and this was echoed by others in the group (Year 8A, initial focus group). When talking about a day with science classes, another student joked, "Imagine if it were science? [...] We'd kill ourselves! (laughter)" (Year 8A, initial focus group).

When I asked the students if they looked forward to coming to school, most replied with a simple "no", followed by laughter (Year 8A, initial focus group). Year 8C responses ranged from

sarcastic remarks like “Really great, really great!” to stronger criticism, such as bluntly stating that the school was “a shit”, “It’s crap, teacher”, and “a big shit” (Year 8C, initial focus group). Complaints about teachers also emerged, especially regarding maths: “I’m not at all satisfied with the maths teacher (laughter)” (Year 8C, initial focus group).

Year 8D students responded in a similar way. They answered things like “It’s a shit” and, when asked again, added: “This school? It’s shit (laughs). Just kidding”; “True”; “Not much”; “That’s true”; and “But just a little bit” (Year 8D, initial focus group). These comments were met with humour and sarcasm. They reflected the students’ shared perception of discontent with the school environment as a whole. In contrast, the arts teacher believed these attitudes masked some affection for school elements behind the “tough guy stance”, noting, “Most students like it here. Even those who say they don’t, I know they do (laughs)” (Arts teacher, initial interview).

5.5.1.4 *To teachers*

In the interview with Year 8A, there was a demonstration of negative and cynical attitudes towards teachers. When talking about their daily life at school, one student expressed frustration and disdain towards the maths teacher, using a derogatory term to describe her: “Yeah, the math teacher is crap ...”. Another student stated that she actually liked science while another student sarcastically remarked about her dislike of the science teacher: “Oh, science? Wonderful ... (with irony)” (Year 8A, initial focus group). These feelings were not shared by the whole class.

In Year 8D, negative and cynical attitudes towards teachers were displayed in the form of a joke. When asked about how they felt in relation to the subject of science, one student answered: “It’s cool, but sometimes the teacher, sort of ...”, which was replied with, “The teacher makes the class boring” by another student. This was humorously replied with: “Yeah, that’s it. We just need to leave when she leaves the room (laughs)” (Year 8D, initial focus group).

In the focus group with Year 8C, some examples of disrespectful behaviour emerged. When asked about their feelings towards science, a student expressed a general liking for the subject but described a contentious relationship with the teacher, using strong language to convey feelings of mistreatment. As in the student’s words: “I think it’s fine. I actually like it. I like it [...] The subject, right, teacher? She messes with me! [...] The teacher is a bitch to me” (Year 8C, initial focus group). The same student felt unfairly targeted and frequently sent to the principal’s office, describing the teacher as sneaky. This sentiment was echoed by other students, who supported the initial student’s claims of unfair treatment. In their words: “Oh,

anything I say, she's like, 'Go to the principal's office.' The teacher is a jerk ... – Yeah. She is! – Very much, teacher!" (Year 8C, initial focus group).

In her interview, the science teacher described frequent disrespectful behaviour among students, including swearing and lack of respect, which she believes reflects what they experience at home and in their communities. "I ignore a lot because they exhibit this kind of behaviour at home. For them, it's very normal [...] you'll hear them using swear words, in the way they treat each other is very common..." (Science teacher, initial interview).

She noted that students often show no respect for teachers, parents, or grandparents: "It's a different kind of relationship, you know? And I can't argue every time they swear in class. Sometimes I shout, 'Hey, stop that!' – 'Oh, sorry, teacher.' But soon enough, another one slips out" (Science teacher, initial interview). While she tries to reinforce classroom rules, the behaviour quickly returns: "Hey, you're not on your street or at home. Let's get back to the school environment? Back to the science class? Stop?' Okay, but soon enough, they forget (laughs). I think it's something natural for them" (Science teacher, initial interview). When asked why students behave this way, she concluded, "They insult each other for nothing" (Science teacher, initial interview).

5.6 Summary

This Chapter 5 describes the school environment and the broader structural conditions that framed student engagement before and during the study. Using contextual material from interviews, focus groups, and the research journal, it outlines the postpandemic mood of the school and the constraints that shaped participation, without treating these accounts as prevalence estimates.

It examines high-risk behaviour and adverse experiences, including marginalisation, vandalism, early adultification, and unstable attendance and dropout as factors that interfered with classroom participation. It also shows how drug trafficking, hunger, and poverty influenced students' choices and their relationship with schooling while noting EJA (*Educação de Jovens e Adultos*) as a later pathway back into education for some students.

Political instability and underfunding were recurring themes in staff accounts. Teachers described results-driven policies, frequent policy changes, and uneven distribution of resources across state schools. These conditions were visible in limited digital access, degraded facilities, and practical barriers to attendance, such as heavy rain and lack of basic healthcare items (for example, prescription glasses).

This chapter ends with students' talk about school, where sarcasm, silence, and mockery functioned as common modes of response to a system they experienced as disconnected from their lives. Together, the contextual conditions described here define the baseline and boundary conditions for interpreting the participation and peer interaction shifts reported in the Findings chapter (Chapter 6).

CHAPTER 6 – FINDINGS

This chapter, Chapter 6, reports the findings from the theremin-based workshops with four Year 8 classes in a Brazilian public school. It is organised in two parts. Sections 6.1 to 6.7 present selected workshop activities and episodes that illustrate how students initially engaged with the theremin through gesture, storytelling, composition, collaboration, and early interdisciplinary responses. These sections show moments from the workshops that help prepare the reader for the later sections of the chapter. From Section 6.8 onwards, the chapter turns to the broader analytical themes generated across the full dataset. The findings draw on pre- and post-workshop teacher interviews, student focus groups, and my reflective journal, including written notes and audio memos. In this second part, the analysis is organised thematically to show how the same intervention shaped students' engagement, peer interaction, and science–music connections across activities and phases.

The second part of the chapter is organised as seven thematic sections followed by a summary section. Section 6.8, “From Isolation to Organic Collaboration: The (Re)Emergence of Group Work,” establishes baseline conditions for collaboration and traces how pair work, group work, and help-seeking patterns shifted from the early artistic sessions to the electronics phase. Section 6.9, “Hands-On Activities Triggered Intrinsic Motivation,” examines how hands-on tasks, especially in electronics, shifted motivation by increasing expectancy of success and task value through visible progress and immediate feedback. Section 6.10, “Students' Learning and Experiences Extended Beyond the Workshops: Theremin the Artefact as a Bridge,” explores how learning travelled beyond the workshops, with the self-built theremin acting as a bridge between school and home contexts.

Section 6.11, “Shift in Dynamics and Students' Participation,” presents participation and classroom dynamics across the project timeline, including the period before the workshops, the artistic workshops, the electronics workshops, and the period after the workshops. Section 6.12, “Creative Troubleshooting and Developing Peer-to-Peer Interaction,” analyses how students managed technical obstacles during building and testing, and how peer interaction sustained problem-solving. Section 6.13, “Shift From Artistic/Creative Block to Elaboration Through Art,” returns to the artistic phase and examines how drawing, paint, and simple scaffolds helped some students move from creative block to elaboration and performance.

Section 6.14, “Interdisciplinary Connections Through STEAM Workshops,” examines how students made connections between music and science, ranging from no perceived link to

student-initiated connections using textbooks and technical language. Section 6.15 then summarises the main findings of the chapter. Where needed, I use pair work for two students and group work for three or more, while recognising that boundaries sometimes blurred as students moved between configurations.

Each section ends with a short discussion that links the empirical evidence to the study's theoretical framework and selected literature. These short discussions serve as analytic signposts and do not replace the fuller interpretation developed in Chapters 7 and 8.

6.1 Conversation between Theremins

This first part of the findings chapter presents selected workshop activities and episodes that were especially important in showing how students responded to the theremin project in practice. Rather than functioning as isolated descriptions, these sections provide concrete examples of how engagement, interaction, and interdisciplinary meaning-making began to emerge during the workshops. I begin with "Conversation between Theremins" because it illustrates, in a clear and immediate way, how the instrument supported turn-taking, listening, imitation, and dialogue through gesture and sound.

The "conversation between theremins" activity validates the artistry of the theremin as well as its uniqueness. In traditional music, there are two common routes for dialogue: (a) a written piece for two instruments with study of dynamics, tempo, and cues across rehearsals; and (b) improvisation as, for instance, in jazz, supported by years of training and a shared vocabulary. The theremin offers something more accessible: it does not require knowledge of scales or reading to play in duet. Musical dialogue becomes very close to speech because the continuous glissando and the nuance of pitch resemble human prosody. This sometimes causes estrangement but here becomes an advantage as it makes the students curious about the instrument. The response to gesture is immediate: it is the body "speaking".

I often explain it with the metaphor of a child's pointing: before speech, a child points, and this gesture produces social meaning. With the theremin, the student "points" to notes in the air and already establishes a sonic dialogue. Over time, that dialogue evolves from gestures – that grow progressively and instinctively – to a community "speech" in music, without depending on reading or a complex vocabulary. This does not invalidate later advancement; it is desirable to move on to reading and a more sophisticated repertoire, as with any instrument, and there are virtuoso composers and thereminists who are always extrapolating boundaries in

the theremin world. However, the starting point is inclusive: on the theremin, simple gestures generate meaningful sound.

In practice, one student moves a finger up and down and produces a glissando; the peer imitates the gesture and perceives sonic similarities. From this imitation, they explore nuances: one moves the hand more slowly (slower glissando); the other acts on the volume antenna to cut the glissando. Thus, the idea becomes rhythmic based. The “platform for dialogue” can shift from a predominantly melodic construction to a predominantly rhythmic one. At times, both converge (melodic ↔ melodic; rhythmic ↔ rhythmic) while, in others, they build complementary motives (melodic vs. rhythmic), like a duet of fluid functions.

This process allows us to think in more complex forms. For example, there is the idea of “theme and development” in a sonata: themes appear, undergo variation, and there is call and response between instruments. The difference is that, with the theremin, everything arises from a simple, instinctive initial input without prior musical training – something the theremin singularly enables.

Another feature that makes the theremin easy to use is how to start the note. Depending on the instrument, the very act of starting a note already requires prior training and refinement for the sound to come out intelligibly. As I said before, this does not diminish the technical refinement that great thereminists develop over time, nor does it reduce the theremin to low-quality “beeps”. The argument is about initial accessibility: the theremin offers immediate entry possibilities. In comparison, to produce a single note on a guitar or ukulele, which are easy-access instruments, a person needs to press the string at the right fret with the right pressure, position, and angle, and they need to pluck with a pick or finger in the right way. If one point of contact fails – either right or left hand – the note will sound wrong or not at all. In other examples, as with the trumpet, a correct embouchure and airflow are necessary; the same applies to the flute, whose embouchure is not trivial. On the violin, one needs the right bow pressure against the string. In short, the entry point for flute and violin is very high: without precise technique, there is no sound. On the theremin, just raising a hand in the air produces sound – produces a note. This immediacy is a strong incentive to musical experimentation.

6.2 Composition Activity and Gesture

In the example of the composition activity with alternative notation, there are many different figures, such as arrows, spirals, lines, and curves, drawn on paper. If an arrow points upwards, I move my hand upwards and the pitch rises; if there is a spiral downwards, I make a

spiral gesture and the note spirals down. On other instruments – for example, a piano, violin, or trumpet – one can do something similar, but it demands technical command. On a slide trombone, a glissando is more accessible than, say, on a keyed flute; on the piano, it is also possible, but it requires correct technique, otherwise the person can injure their fingers when sweeping across the keys. The theremin allows this glissando immediately, on first contact, with no initial technical barriers.

To play a descending vibrato (as glissando or as a scale) on a traditional instrument, one needs years of practice. On the trumpet, for example, someone studies a scale, masters it, and only then adds vibrato to play that descending scale with quality. On the theremin, to reach a similar effect, one simply rotates the hand in small circular movements, progressively moving away from the antenna, and this creates a descending spiral effect.

6.3 Drops Activity

The “drops” activity, created by Carolina Eyck (2016), works like a reverse-engineering of sound-visualisation tools, like spectrograms, equalisers, and so on. In those tools, the person feeds in the sound and receives an image; in the drops activity, it is the opposite: the image comes first and the person must produce a sound that corresponds to that visual parameter. Classic examples of visualisation include a graphic equaliser shows where the frequency is (bass, mid, treble) and the gain of each band, or a volume meter indicates intensity. In simple terms, there are unidirectional meters (only intensity) and bidirectional ones (intensity and placement in frequency). Some systems even deliver a “3D” view of sound – and it is precisely this idea that the drop activity recreates accessibly.

In the drops’ visual score, the vertical position indicates pitch (the higher on the page, the higher the pitch; the lower on the page, the lower the pitch). The size of the drop suggests dynamics (louder or softer). The thickness and sequence of drops can indicate duration and articulation (for example, many thin drops suggest staccato). Thus, the person intuitively manipulates a “3D axis” of sound: pitch–dynamics–duration. This resembles traditional notation (up = higher, down = lower) but without requiring precise intonation or a repertoire of linguistic markers – Italian terms, such as *andante*, *adagio*, *forte*, *piano*, *rallentando*, *crescendo*, or *decrescendo*. For monolingual students or those who have not yet mastered a second language, this reduced linguistic load facilitates performance: they read the image and respond with the body on the theremin. In short, the drop activity offers an instinctive, visual way to compose and perform on the theremin, articulating pitch, dynamics, and duration without terminological barriers – something that is possible on other instruments but usually demands deeper technical

command. In the workshop context, a few days were enough for students to understand and apply this visual-sonic logic on the theremin. Read through Vanderlinde's (2017) *Universal Design for Learning* lens, the visual scoring can be interpreted as an additional pathway for engagement and expression, supporting access to the task and peer interaction for students with different verbal and motor needs.

Although it looks similar to the way we compose the alternative notation, it is not the same activity. In composition, the vector is student → score: the student freely creates their own score and, at the end, there is both a process and a product — the student's composition (the visual page), and its sounding result. In the drops activity, the vector goes the other way, score → student: the score is already given, and it is a limited closed task. Limited here does not mean lower quality; it means limited in openness — it is not open ended. Precisely because the vectors are opposite (student→score vs. score→student) and because one is open while the other is closed, each activity activates different linguistic and musical questions. That difference validates both, and they are not redundant. Medvinsky (2017a) argues that technology integration is most effective when it provides a transparent scaffold within musical learning and when learner-musicians have voice and choice in designing their learning processes and in showing their musical understandings.

6.4 Effects

There are other unique theremin movements that produce sound effects without requiring advanced knowledge of sound engineering. Today, there are prompt-based production tools that generate audio from text, but they still operate in the realm of written language and rely on interpretation. On the theremin, many effects arise through the body. I go back to that idea from the start of language: before producing words, there is pointing. The adult speaks and the toddler points – the bodily response comes first. In the same way, on the theremin, people experiment and find sounds with the body long before they can formulate a complex fine motor skills prompt to “ask” for that sound.

I also detail a repertoire of embodied sound effects: “birds” (quick repeated touches at the pitch antenna); “car accelerating” (a slow ascending sweep in the low register plus a sharp descending gesture that simulates gear change); “siren” (repetition of open-closing three fingers, producing a third, plus a slow descending glissando, producing a Doppler-like effect when bringing the hand closer to the body); and “ghost” (slowly bringing up the hand closer to the volume antenna while keeping a vibrato that climbs an octave and then descends). These

are straightforward to achieve and expand students' expressive palette, even without theoretical labels.

6.5 Storytelling

Another activity that shows why the theremin differs from other instruments is “storytelling”. Storytelling allows the performer to construct a narrative while producing simultaneous sounds. Sometimes, these work as sound effects, sometimes as background music, and, at other times, as a direct response to gesture. The sound that appears is not always exactly what the person was “seeking” for that moment, but, even so, it provokes response and, in most cases, complements the story. For example, if there is an ambulance in the narrative and the person discovers that opening and closing the fingers generates a siren sound – even without knowing that it is “a third” – they can insert the ambulance into their story. This enriches the visualisation of the event (such as an accident or a chase). It is not just someone talking about an emergency vehicle; it is the storyteller producing the sound of the vehicle passing at that instant.

If the story is spooky and there is a ghost, one can add a ghost sound. This is done by first vibrating the hand while moving slightly toward the pitch antenna, then – without stopping the vibrato – slowly moving the hand away. The result is a slow rise-and-fall (up then down) vibrato that sounds “ghostly”. It is easy to achieve and enriches the narrative even if the person does not grasp the theory (for example, octave, vibrato, ascending, descending). If the person places that sound within the story, it shows musical understanding.

This means that music is accessed by the person via spoken and heard language and not first through writing, which accelerates the internalisation of musical language. That is how many jazz improvisers work: they do not begin by reading a lick on a score; they listen to the music they like, understand the harmonic context, and reproduce the phrase on the instrument, grasping the sound of each interval and note in that context. They go even deeper, and most times, analyse the relation of each individual note related to the chord that is being played at the moment. For example, if they play an F# on top of an Em7 chord, it is because they were looking to use the 9th flavour sound, not because they were accidentally playing random notes on an Em scale and ending up finding a cool sounding one (they do that at the beginning when exploring scales and ideas, but this is not the case for seasoned players). Later, they may write the phrase, and, when they read it, they know where it comes from. However, the phrase becomes part of the musician: they have ownership of that linguistic tool, just as we have ownership of words we hear and then use to form our own sentences.

With the theremin, students can absorb these “musical words” through the body in a path more instinctive than starting immediately from reading. This process is not “primitive” as in inferior; it is simply the stage prior to writing, as in language acquisition. Before writing, there is spoken words and gestures, and these gestures speak on the theremin.

6.6 Collaboration

Nevertheless, what makes the theremin special enough to make students work together? Why did they collaborate in ways that would not happen the same with other instruments? Novelty in the theremin sits in the possibility of exchange. In some instruments, it is difficult to create that exchange among experimenters due to limits of volume, ergonomics, or overlapping functions. For example, the drum kit is a loud instrument. If someone speaks while the drums are played, they will hardly be heard. Further, it is complicated for two people to play the same drum kit at the same time as designed, maintaining best-sound performance and ergonomics. Drum duos exist and are indeed amazing, but true exchange demands a lot of experience and sensitivity so that both can be heard.

With the theremin, it is different. Through alternative notation (drawings, arrows, spirals), it is possible to anticipate ideas, write, and share proposals quickly. Drawing arrows up/down/sideways means that exchange already exists. In the “conversation between theremins”, I just placed the instruments facing each other, and students began to interact: one triggered a gesture, and the other answered. In this way, peer interaction is aroused organically and immediately.

This pattern aligns with Green’s (2008) account of informal learning where cooperation and inclusion become more likely when students have genuine autonomy, and learning is organised around peer exchange rather than constant teacher direction. In the theremin workshops, that peer exchange became practical because sound and gesture were immediately public, allowing students to initiate, imitate, adjust, and respond without relying on advanced technical vocabulary. At the same time, cooperation was organised around assembling and troubleshooting a self-built artefact and coordinating access to scarce tools, which made contribution visible and kept feedback immediate. Collaboration therefore emerged from the activity itself, with students contributing at different levels within a shared structure. Read through motivational accounts of engagement, this pattern suggests a movement from disaffection towards engaged behavioural and emotional participation (Skinner et al., 2008, 2009) rather than compliance alone.

From a motivational standpoint, this peer exchange can also be read through Situated Expectancy-Value Theory (SEVT). SEVT treats students' choices, persistence, and performance as shaped by their expectancies for success and subjective task values, including intrinsic value, attainment value, utility value, and cost (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000). In my workshops, troubleshooting and immediate feedback made small competence gains visible, which raised expectancies. The shared artefact and public output also increased value, while the task structure kept costs manageable by distributing effort and tools. This helps explain why collaboration became a practical default rather than a teacher-requested behaviour.

Hallam's research syntheses suggest that making music in groups can develop prosocial and teamworking skills because it depends on shared goals, cooperation, and trust and respect between participants (Hallam, 2015; Hallam & Himonides, 2022). Read through this lens, the collaboration I observed around the theremin can be interpreted as a structured form of joint action rather than a generic preference for working with friends: the task created immediate reasons to coordinate, compare actions, and support peers.

Another facilitator is gesture visualisation. Even in singing (which links voice and body), to "see" a note go up or down means one already needs to have awareness of pitch; beginners often fail to perceive whether a short/close interval rose or fell. On the theremin, this is obvious and visible: hand nearer the pitch antenna → pitch rises; hand farther from the antenna → pitch falls. That visual clarity aids peer exchange because everyone understands what is happening musically.

This connects with the idea of reverse engineering in the drops activity: first comes the graphic (a metaphorical 3D image of sound), then the student produces the corresponding sound. The theremin operates in this sound-gesture-image triangle. This triangle provides a foundation for interaction between students and music, prepares for building the instrument (the science part), and then science feeds music back. In the end, the full cycle closes: they make music with the artefact they built.

Hence, I say that artefact, music, electronics, theremin, composition, drawing, conversation between theremins, the drop activity, and storytelling all feed each other. Without the theremin's exclusivity and unique functionality, the workshops would not have worked the same way. Could one create workshops with other instruments? Yes, but to achieve the same effect, the adaptations would be so many that it would no longer be the same project. For instance, building a synthesiser with Arduino is excellent but, to grasp it, students need to understand notes and layers of control. Even with easier inputs (magnetic tape plus a special

pen) to generate glissando, a technical limitation appears straight away: striking and holding a note in the line/tape with the pen. In this case, one needs to interact with two media (hand + pen/sensor) to imitate the theremin's ease. On the theremin, people just move their hands in the air, and I had students with hand-motor limitations who managed to produce sound without needing to hold anything due to the nature of the theremin. This broadens access.

This access is pedagogically important. Vanderlinde (2017) frames Universal Design for Learning as planning for seamless access not only to content but also to peer interaction, which helps interpret why students with motor challenges could still contribute meaningfully during both building and performance. Medvinsky (2017b) similarly suggests that music technology should be used to widen points of entry into music-making, and not only to replicate traditional tasks. In this project, flexible roles and shared troubleshooting made participation visible and legitimate across different skill profiles, which connects with Green's (2008) argument that group cooperation and inclusion can increase when pupils work in practical, self-regulating ways around shared musical goals.

Another factor was the circuit's simplicity. There are few components; with very little soldering practice, Year 8 students (with no previous electronics experience) built an instrument with melodic functionality, rhythm, and timbral variation. The result was not "instant" as they had to exert effort to make it work, but it was much quicker and more easily accessible than more common complex electronics projects, and this stimulated interaction among the students. If the circuit had been more complex, the workshops would not have worked like they did.

I also see a natural unfolding for this type of activity. This project could be the impetus to start electronics clubs at schools, much like a robotics club would, despite the two having different goals. In both cases, there is construction, hands-on work, understanding and outcome, and they can work as a starter for the love – or at least curiosity – for science in the long run.

The workshops are as useful for science as for art. They can happen in a music lesson that talks about science, or in a science lesson that talks about music – without loss of content in either of the subjects. Students learn about electronic components (resistor, capacitor, light-dependent resistor [LDR], polarity, battery, and circuit) in a hands-on way. They also consolidate pitch, rhythm, and dynamics: pitch = hand closer (higher) or farther (lower); rhythm = timing of the gesture at the volume antenna; dynamics = amplitude of the gesture. The theremin's visual –body linkage helps retain these concepts.

6.7 Interdisciplinary Science–Art Engagement

The same features that make the theremin accessible for musical exploration also support interdisciplinary work between science and arts. When students move their hand over the LDR and hear pitch change, they are experiencing in one gesture the relation between light intensity, electrical resistance, and frequency. The optical theremin makes this chain visible and audible at the same time: the exposed circuit invites questions about components while the continuous sound invites musical choices.

These activities constantly prompted students to translate across domains. They played with gesture, image, and sound without specialised vocabulary, labelled parts in plain language, drew arrows and shapes to describe what the instrument was doing, connected electronic components to circuit diagrams and textbook terms, and used music to test ideas about pitch, dynamics, and duration while also explaining how light and current were behaving in the circuit. In this sense, the theremin acted as a shared object through which students could talk about resistance, polarity, and energy while also making artistic decisions about gesture and timbre. Other electronic projects could offer similar links, but the combination of visible circuitry and highly responsive sound meant that each movement was at once a scientific event and an artistic one.

After presenting selected workshop episodes, I now turn to the broader themes generated across the full dataset. While Sections 6.1 to 6.7 illustrated concrete moments from the workshops, the following sections synthesise recurring patterns that became visible across the focus groups, interviews, and reflective journal.

6.8 From Isolation to Organic Collaboration: The (Re)Emergence of Group Work

This section begins the second part of the findings chapter. From this point onwards, the analysis moves beyond individual workshop episodes and focuses on the broader themes that emerged across the dataset. I begin with group work because the movement from isolation to more organic collaboration became one of the clearest patterns across this research and shaped many of the changes discussed in the sections that follow.

6.8.1 Findings from Interviews and Focus Groups Before the Workshops

This subchapter, Section 6.8.1, proceeds chronologically through the theremin workshops. I begin with findings from the preworkshop interviews to establish the baseline

conditions reported by students and teachers regarding group work. Nomenclature-wise, I use pair work for duos with two students and group work for three or more students. “Open groups” refers to flexible groups of three or more students with rotating roles and a group → peers → teacher help-seeking chain. Although this section narrates how students worked together, the analysis is anchored in music (gesture-sound mapping, composition) and science (circuit building/testing).

One of the most surprising moments from this research was during the focus groups when I received the information that Year 8 students had not done group work since Year 5 – in this scenario, this meant scarcity of structured group work beyond pairs. The students revealed to me that their last group activities were in 2019 and, despite returning to in-person classes in late 2021, they had not had structured group work or paired knowledge building since. This fact caught me by surprise as a researcher. This is particularly significant given the well-established role of group work in supporting social, cognitive, and emotional engagement in education. The absence of collaborative experiences, specifically structured group work beyond pairs, had a clear impact on classroom routines, as reflected in my notes:

Some students returned to school in July/August of last year (2021) – sometimes 2–3 per class, and the rest followed via Google Meet – and everyone returned in person in November 2021. So, this means they had 8 months of in-class lessons without any interaction or knowledge building in pairs! The only instances when they sit in pairs are when one of the classmates forgets their book at home or when a teacher uses the computer lab, and they have to take turns using the computer. (Research journal, June 9, 2022)

After getting this information, my initial suspicion was that students reporting not forming groups might be an exaggeration, potentially fed from their dissatisfaction with the school system. To clarify this, I decided to talk to the arts teacher, who confirmed that students not having group work was indeed true. Later interviews clarified that some collaborative tasks did occur but mostly as pair work within friendship circles. He informed me that teachers generally were not doing group work, especially with this age group. He explained that students would not work outside their friend groups, which would vary in size. If a teacher asked for a group of five people, the group of friends who were six would end up excluding one, and some would only join in pairs. The one left out might have ended up working with peers they would not usually interact with, and would remain apathetic and would not actively participate in the group. These past experiences have shaped teachers’ expectations of group work, which made teachers maintain a cautious stance on the matter. There was a consensus among teachers that

the effort required to guide students in group work was not worth the outcome, so they preferred not to conduct activities in this manner. They were usually only resuming group work in the final years of high school, when students became more pragmatic and focused directly on grades. “Unfortunately, it was not a complete exaggeration ...” (Research journal, June 9, 2022).

Most focus group students reported a lack of collaboration due to limited group work or peer problem-solving tasks. Despite returning to in-person classes, they expressed disappointment that group assignments had been infrequent and mostly absent from their recent school activities. The number of group assignments was also not equally distributed between classes. Some students reported having slightly more group assignments than others, though still a very small number. Several commented that more group work would make their educational experience “more engaging and dynamic”, while others mentioned that the last time they worked in a group was “about three years ago” or even “before the pandemic”. When prompted, some students replied, “No, the teachers don’t allow it”, and one added, “I wish we had more group projects. I think it’s cool. But we don’t; the teachers think it’s bad” (Year 8B, initial focus group).

Despite several students expressing that having more opportunities to collaborate would make school “more exciting” or “more interesting”, some noted it “wouldn’t change the school that much” because “sometimes it’s still boring”. A few students commented that the benefit of group work depended on the group itself, with one noting, “it depends on the group” (Year 8B, initial focus group).

Some students also mentioned the absence of field trips, expressing that not having these experiences further limited their opportunities for learning beyond the classroom and contributed to a sense of monotony in their school routine. As one student explained, “It would be cool if we had group projects. But also if we had field trips, like in science. Going to the planetarium, you know?” Others emphasised that they had “never had that” type of activity since joining the school (Year 8B, initial focus group). In this case, students explicitly linked collaboration to science in-field or hands-on experiences.

In the focus group with Year 8C, students reported that they had only one group project assigned over the previous two-and-a-half years: a linguistic activity about the use of slang in Portuguese. As one student commented, “Yes, in Portuguese class. In fact, this was the first group project. It was the first one in a group.” When asked about other group work, students replied that there had been “just this one so far” and confirmed that even after returning to in-person classes, “we didn’t have any group work” (Year 8C, initial focus group).

Year 8D also reported the absence of group activities within their educational experience, with students revealing that their last group work dated back to the fifth grade. Since then, opportunities for group assignments had been extremely scarce, even after the return to in-person classes. As one student remarked, “Never! We haven’t done any [group work]”, while another recalled, “The last time we did group work was in 5th grade.” When asked about pair or trio activities, students clarified that these only happened “when someone forgets the book” rather than as planned collaborative learning (Year 8D, initial focus group).

The science teacher acknowledged that students enjoyed participating in group activities when assigned, though they would engage actively in informal discussions unrelated to the subject. She also noted that their limited ability to articulate their thoughts coherently often constrained the quality of their work. When asked about student participation, she responded, “No, it’s a minority. Their participation is ... For the classroom collective, it’s great. So, if you give them group work, they’ll love it ... But the work doesn’t get done. They will sort and organise the groups and they will talk a lot” (Science teacher, initial interview). This perspective suggests that although students were eager for collaboration, transforming that motivation into productive group outcomes remained a significant challenge.

According to the science teacher, the students had a lot of content to discuss with their peers, but they struggled with writing and expressing what they understood from the class: “They have difficulty giving me information, both orally and in writing, but among themselves, they talk well” (Science teacher, initial interview). She believed that the level of formality brought by correct grammar incapacitates them to properly communicate ideas in a more academic ambient, as she continued: “So, I suppose they understand that when they speak to me, it’s something more formal. So they need to think more, and in the group, they don’t need that” (Science teacher, initial interview).

This difficulty in shifting from informal peer conversations to more formal, academic communication was reflected in the students’ own descriptions of their school experiences. Their responses were often brief, colloquial, and sometimes dismissive, with comments such as “good”, “bad”, or “a shit”, frequently accompanied by laughter. When asked about school, some replied, “It’s good because I don’t like staying at home”, while others stated, “It depends, teacher, the school is good. The classes are bad, you know?” and “It’s not the classes, it’s the teachers” (Year 8D, initial focus group). These examples illustrate that, although students communicate freely with each other, expressing themselves in a more structured or academic way remained a challenge.

At this stage of my enquiry, I understood that when “group work” happened in this year group, it largely meant working in pairs and not bigger groups (three or more students) for a continued long project. The arts teacher also discussed the dynamics of student relationships within said groups. According to him, most students generally cooperated well in group activities, although there were occasional exceptions when individual preferences or conflicts arose. He emphasised that students typically chose their groupmates based on existing affinities and friendships, preferring to maintain these relationships during collaborative tasks. He acknowledged that some students may express reluctance to work in groups, though this was not the norm. When asked about the students’ relationships with their peers and if they got along well in group activities, the arts teacher responded:

Yes, most of them do work well in groups. There will be one or two who ... But those are more specific cases, right? They are the exceptions, not the rule. The rule is that they work in groups. However, it’s the group they want. They have their affinities, and they want to maintain those affinities. (Arts teacher, initial interview)

Even with these positive responses when working in pairs of their choice, the arts teacher reported that there are still cases when some students would not work in any kind of group scenario. As he stated: “There might be one or two who say, ‘Oh, I don’t like working in groups’, you know? That can happen. But it’s the exception. The rule is that most will work together, and life goes on” (Arts teacher, initial interview).

The same challenges with rigid group formations and limited flexibility in collaborative learning environments were reported by the science teacher. She noted that, when students were allowed to choose their partners for pair work, some pairs saw one student doing most of the work while the other waited passively yet still received credit. She acknowledged that there were a few pairs who genuinely collaborated effectively, with each member contributing equally to the assigned tasks. However, she said that these instances were rare, suggesting that the majority of student pairs struggled to establish balanced and productive working relationships. When asked if the students worked well in pairs, the science teacher replied: “In pairs, if you let them choose their partners, yes. Because usually in pairs, one does the work and the other accepts it. So, there’s that person who always pairs with me, right ... So I’ll pair with So-and-So because So-and-So does everything” (Science teacher, initial interview).

This pattern was also reflected in the students’ accounts. When asked about their experiences with group work, several students said it was “easy” but often clarified that it depended on being paired with friends: “If it’s with friends, it’s easy,” and “It depends on the

group". Others mentioned that being allowed to choose their own groups made collaboration much smoother (Year 8C, initial focus group). These responses indicate that students were generally unwilling to work with peers outside their preferred circle, which limited opportunities for broader collaboration and reinforced inflexible group dynamics.

Although both students and the science teacher acknowledged that situations where one student completes all the work while the other remains passive do occur, this pattern was not found in every group. As the science teacher noted: "And there are those pairs, of course, that really work well together; one does one part, the other does another part, and it turns out well done. But, those are few" (Science teacher, initial interview).

This scenario – where collaboration was almost always restricted to pairs – was also described by students in Year 8A. They reported that group activities were limited to "two" students with only occasional exceptions when a third could join if someone was left out. Their most recent project in mathematics had followed this same structure. As the students explained, "We don't do big groups ... at most, in groups of three" (Year 8A, initial focus group).

Students explained that this restriction was due to teachers' concerns about classroom management. As one student put it, "He [the teacher] said we make a lot of noise, you know? When we work in a group, it's usually just in pairs" (Year 8A, initial focus group).

Even pair assignments were rare, with students recalling only "two or three" group projects in the year after returning from the pandemic. When asked about these assignments, students clarified that "we only do it in pairs" and, for them, group work essentially meant working with just one partner (Year 8A, initial focus group).

6.8.2 Findings From the Artistic Workshops

Up to this point, I have summarised preworkshop interviews and focus groups. From here, I report what occurred in the workshop, in chronological order, beginning with the initial artistic workshops. From the beginning, even before arriving at the school, I knew that one of the biggest challenges would be group work. When I got to the school, I discovered that students had not been having regular group activities for a long time. Most of the group work was related to working in pairs within friendship circles. This led me to ask myself: how do you work with a class that has not practised group work for years? The school system did not support group work, most teachers avoided them, and the students were not used to working together. The solution in this context was to lead the students into open groups – flexible, student-led groups where participants could choose their own partners, join or leave groups as needed, and

collaborate on shared tasks. In these open groups, each member ended up having a specific function and sought help first within the group before consulting others outside. If a problem could not be solved within the group, students then approached peers in other groups, promoting a classroom dynamic in which everyone contributed to, and benefited from, a collective pool of knowledge. This “community functionality” meant that the entire class often functioned as one large collaborative network, exchanging ideas and providing support as needed. This setup was heavily inspired by the work of Green (2008). From here, I will report on how these groups developed over the course of the workshops.

In the composing activity during the artistic workshops with Year 8D, students formed their own groups to compose their music for the theremin, and one of the elements that facilitated interaction between the students and the theremin was the absence of a rigid classroom structure, such as sitting in lines and having to be quiet while someone was trying the theremin in front of the whole class. This provided students with a platform for experimentation as they could move freely around the room and interact with the instrument at their own pace without the added pressure of performing in front of the entire class. I was initially concerned that this freedom might lead to confusion, excessive noise, or students becoming disengaged and off task – essentially, a turbulent or unruly classroom environment. However, what occurred was the opposite: the flexibility allowed students to focus on their own exploration, and small groups naturally formed to help each other with the instrument. This arrangement proved to be functional because it encouraged active participation, peer support, and creative experimentation while maintaining a productive and respectful atmosphere in the classroom. As I noted in my journal: “I feared it might become chaotic, but it turned out to be functional” (Research journal, June 22, 2022).

This setting provided them with two simultaneous activities for group work: either composing with their group – as seen in Figure 29 – or experimenting with the instrument with a colleague. This allowed the students who were not used to work in bigger groups, or who felt embarrassed and vulnerable creating art spontaneously in public, to fully participate with their peers. In some cases, this meant collaborating in some way with colleagues who were not part of their inner circle.

Figure 29
Students Working in Groups



Like the students from Year 8D, students from Year 8B also took steps towards improvised music-making during the artistic workshops. With the instrument freely accessible while they were drawing their compositions, and no preestablished rules for exploring it, the students engaged creatively with the theremin and had the opportunity to work with peers. As I noted about Years 8B and 8D: “In general, giving students free access to the instrument while they write their composition is always a good idea as they like to experiment and create music without the pressure of getting it right, just for the fun part” (Research journal, June 27, 2022).

Despite Years 8B and 8D having good participation with the more open setting, rigid student groups began to emerge in other classes (8A and 8C) during the composing activity. This lack of flexibility was so significant that when pairs were supposed to be formed for the activity, one group said that if they could not stay as a trio, they simply would not participate, and other people preferred to work alone and joined no group at all. At this point, I started to worry about the electronics workshops at the end of the project. As I noted in my journal: “They are not flexible in this regard. They don’t consider joining anyone outside their close-knit group. Some students, who performed well in the composing activity, did the work alone. I wonder how I will resolve these issues in the electronics project ...” (Research journal, June 22, 2022).

6.8.3 Findings From the Electronics Workshops

The initial resistance to group work contrasted with the dynamics in the electronics workshops where students began developing strategies to resolve problems in group settings. In Year 8A, for example, it was possible to divide them into groups with a similar number of participants, ensuring that at least one or two students who knew how to solder were in each group. There were four groups, and each had one soldering iron. Their participation in this case was quite different from the creative workshops. The students engaged more actively and efficiently in the electronics phase, showing a higher level of interest and collaboration compared to the artistic activities.

While Year 8A students were not participating well in the artistic part, they were very engaged in the electronics activities. This class was extremely difficult to get working initially; artistically, it was hard for them to work in groups, and their engagement with creative tasks was slow. Yet, with a project that was quite different from what they were used to doing in school, specifically the electronics component, they became participative. In my notes, I related that the arts element from my workshops did not bring much novelty when compared to the electronics: “Artistic production with the theremin is interesting, but it is still something familiar to them. They have art production in class, they have to produce drawings for grades, and they pass the year” (Research journal, September 23, 2022). While creating art with the theremin resembled activities they already did in regular classes, the electronics component took them far out of their usual environment and routines.

In the context of the workshops, another factor that increased student engagement and compelled them – as in a positive pressure – to work as a team included the strategic use of scarcity. By providing fewer theremins than the number of students at the beginning of the electronic workshops, the necessity to share created a positive form of competition among the students. This competition motivated them to actively participate in the construction process and engage more deeply with the activity, as seen in Figures Figure 30 and Figure 31. As I wrote in my journal: “There are 5–6 students per class, but I only provide 4 theremins. They have to share among themselves, and since there isn’t exactly one theremin for each student, they end up competing (in a positive way) to engage with the construction of the instrument” (Research journal, August 22, 2022).

Figure 30
Students Waiting for their Turn (A)



Figure 31
Students Waiting for their Turn (B)



The long period without group work significantly influenced the students' behaviour. They had not engaged in group activities for a long time, which made collaboration challenging at times. A strategy to address this was working with them in open groups – that is, flexible, student-led groups where students could choose their own partners, move between groups as needed, and take responsibility for their roles within the team. This proposal was efficient in engaging students in peer activities, allowing them to navigate troubleshooting with minimal help and support from the teacher, and made them rely more on their peers. By organising students into trios where each member had a specific role and was the first point of contact for problem solving, the open group format helped with collaboration and self-sufficiency. This approach created a dynamic where, even amid some chaos, students knew who to turn to for assistance and were able to resolve most issues independently. In this matter, I wrote:

This worked well because, despite a certain level of chaos, they clearly knew who to seek help from. So, there was a group within the larger group; sometimes it disbanded, sometimes it reformed, but even then, they were self-sufficient. I only needed to answer the occasional question, but in general, they managed to solve everything on their own, precisely because of this pregroup within the larger group. (Research journal, September 19, 2022)

As explained earlier in Section 6.8.3, I treated the entire class as a single, large group, encouraging community functionality where everyone exchanged ideas and supported each other. This strategy was also reused in the other classes. This collective approach helped them shift from an affinity-based mindset to a community-oriented one. Once this sense of community was established, it was then translated into smaller working groups, as can be seen in Figure 32, where a bigger nonchaotic group can be seen, along with a smaller one. Both groups were functional.

Figure 32
Bigger and Smaller Groups Working Simultaneously



Previously, students tended to interact only within their close friendship groups and rarely engaged with peers outside these circles. This inflexible pattern was a reflection of limited collaborative opportunities and a preference for working with familiar peers. Through the workshops, we began to move beyond these constraints, taking the first steps toward developing a sense of community and functional group dynamics.

This larger community group naturally began breaking down into smaller, more manageable cells in an organic way without the need for me as their teacher to guide them into doing it. By “organic” I mean a self-organising, student-led form of cooperation that emerges

when teachers step back: roles, leadership, and peer instruction arise within friendship groups, and the group coheres and negotiates towards a shared outcome. This concept of organic group cohesion was extracted from Green (2008) and will be explored further in the Discussion in Chapter 7. One example of this action taking place can be seen in Figure 33.

Figure 33

Bigger Group Breaking Down into Smaller Cells



The students had become self-sufficient at the final stages of the electronics workshop. They now worked in flexible groups, helping each other as needed. Most groups were nonfixed, meaning they worked among themselves and helped each other. They did not sit at desks that defined the group's space until the end of the process. Instead, they adapted based on demand. As noted in my reflective journal:

Sometimes one person in the group knows a lot, while others don't know as much, so they seek help from different people, and that's how it goes. Some classes – the ones the teachers said would be more difficult – are working very well in groups. (Research journal, September 22, 2022)

I had to do very little of the process with them; they were becoming self-sufficient. This functionality was not evenly balanced across all classes but, nonetheless, occurred in every class, as seen in Figures Figure 34 and Figure 35. In another note, I wrote: "this mutual help and community assistance are happening in all classes, despite some having a higher degree of group functionality than others" (Research journal, September 22, 2022).

Figure 34

Functional Class Group with No Determined Subdivisions (A)



Figure 35

Functional Class Group with No Determined Subdivisions (B)



Despite the long-term scarcity of structured group work beyond pairs in Year 8 classes, which significantly impacted students' ability to collaborate and engage with their peers, the workshops provided a structured yet flexible approach to reintroducing group work. In the electronics workshops, the students were initially put in groups of three and were allowed to seek help from other students in the class. As mentioned in Section 4.5.3, each person in the trio knew one part of the optical theremin's building scheme. Every student received a small package containing all the components that were needed to build the instrument, and they had to exchange information within the group to build the optical theremin. If someone forgot their part, they were to seek help from their colleagues from other groups as I told them not to come to me for help first. This encouraged more flexible working in the classroom and initiated the protocol of reaching out for help with their group first, then other students, and then me, the teacher. In some instances, students continued to work in this way. When given autonomy, students were able to rebuild their collaborative skills. Through the workshops, they transitioned from rigid, self-selected groups to open, community-based learning environments.

Reflecting on the differences between the workshops, I believe that the theremin workshop was essential for building the foundations of organic collaboration in groups. It acted as a bridge between the students' starting point – where group collaboration was minimal or, in some classes, resisted – and the more productive, collaborative environment seen in the electronics workshop. The creative activities with the theremin allowed students to gradually become comfortable with peer interaction and begin experimenting with more flexible group structures. This preparatory phase was crucial: I do not think the same outcomes could have been achieved with the electronics workshop alone as students would likely have lacked the trust and initial experience required for effective teamwork.

Furthermore, the open group approach worked noticeably better than traditional, teacher-assigned groups. Because students did not feel forced into artificial groupings and could choose their partners or move between groups, participation became more organic and self-directed. This autonomy helped reduce resistance, allowed students to take ownership of their roles, and led to higher engagement and more meaningful collaboration, especially in contexts, such as the electronics workshop, that required genuine teamwork and problem solving.

6.8.4 Discussion On: From Isolation to Organic Collaboration: The (Re)Emergence of Group Work

Initially, students were reluctant to work outside their friendship circles, with several saying group work “never happens” or that “the teachers don't allow it” (Year 8B, initial focus

group). When group work was attempted, some students described it as “cool” but added, “it depends on the group”, highlighting a preference for working only with familiar peers. This dynamic reflects Green’s (2008) research on informal music learning: when students lack opportunities for authentic, peer-led collaboration, they tend to retreat to their comfort zones, and group work becomes either passive or superficial. In Green’s (2008) study, students reported they could cooperate “because they were allowed to work with friends. Friendship was important” (p. 10), and she notes that informal learning typically happens “in groups of friends, mostly without adult guidance” (p. 3). In her study, teachers also contrasted this approach with ordinary lessons where students would “play their bit ... [and then] ... go off task and have a big fight over who’s doing what” (p. 14) whereas under her project they saw more positive teamwork.

Chu et al. (2019) emphasise that group work is central to developing student engagement. Specifically, they structure lessons so that the exploration happens in small groups, leading students to pose investigation questions and to build, refine, and evaluate shared explanatory models; modules explicitly include small group/class discussions to articulate and revise understanding. In motivational terms, they highlight hands-on activities and group discussions as routes to interest, enjoyment, and confidence (Chu et al., 2019). My findings corroborate this as the long absence of collaborative activities left students less confident and often unprepared for meaningful peer interaction, with students wishing they had more group projects (Year 8B, initial focus group). Teachers themselves acknowledged the challenge, stating that the students were not flexible in this regard and would not consider joining any other peer outside their affinity-based group (Research journal, June 22, 2022). This also resonates with Howell’s (2017) account of technology, play, and informal participation, in which flexible social arrangements make space for experimentation and shared problem-solving to emerge without tight teacher control.

The open group model implemented in the workshops was heavily inspired by the work of Green (2008) as well as the organic collaboration concept; according to her, collective tasks can yield an “organic type of group cohesion” (p. 15). In Green’s view, organic group cohesion means a self-organising, student-led form of cooperation that arises when the role of the teacher is minimised; learners group with friends, take up roles, and teach one another toward a shared product (Green, 2008). In Green’s work, the shared product was the performance of popular songs chosen by the students themselves, while in my workshops the shared product

was both the artistic production presented as their compositions and the technological apparatus, the optical theremin¹⁰.

Another connection point is, like Green's (2008) early lessons, what looked like "chaos" soon revealed its own order as students negotiated choices and entries without a teacher present. In her work, these negotiations gave rise to moments of peer agreement on who should take the lead, when to start, and how to manage tempo. In my workshops, the absence of a teacher was not possible as I was always with the students for safety reasons (soldering iron, ferric chloride). Nevertheless, their decisions on how to handle the electronic components – sharing the soldering iron, waiting for their turn for the ferric chloride, overcoming problems, troubleshooting – and most of their artistic choices when composing the songs were negotiated between themselves without my direct intervention.

Figaredo (2009) describes music workshops designed for social inclusion and notes that, when participants have a history of conflict, the group can agree by consensus on a minimal code of behaviour with the facilitator guiding but not replacing that negotiation. This is consistent with the idea that collaboration in workshops often depends on shared norms that are made explicit rather than assumed. In my workshops, routines, such as sharing scarce tools and using a peer-first, help-seeking norm, functioned as practical expectations that made joint work more manageable.

In brief, what initially could appear "chaotic" under an open-group design became workable through an interactional mechanism in both the artistic and electronics workshops. In the artistic part, the theremin's gesture-sound correspondence afforded imitation, turn-taking and dialogue, making negotiation both audible and visible. Composition used an open platform, such as drawing hand movements, and students navigated freely between both of them (testing the instrument and composing for it). In the electronics workshops, purposeful scarcity and a group → peers → teacher help-seeking norm led students to coordinate electronics choices with minimal teacher direction. This aligns with the technology and music education literature that argues tools do not produce engagement by themselves; engagement depends on how tools are situated within curriculum, culture, and everyday practice (Merrick & Joseph, 2023; Tobias, 2017; Upitis, 2001).

The shift was not accidental. Free access to the instrument without assessment (as in giving grades for it) and peer pressure in the artistic workshops, and purposeful scarcity (limited tools and theremins) in the electronics workshops, created real interdependence without raising

¹⁰ This comparative framing was developed in the review of the literature in Chapter 2.

frustration too high. The same artefact tied the work together. In terms of music learning with the theremin, students used gesture-sound (experimenting), image-sound (drops activity), image-gesture-sound (composition activity), and a feedback loop gesture-sound-gesture (conversation between theremins). In terms of science learning, they tested their printed circuit boards (PCBs), checked polarity, and traced faults. These processes moved the room from friendship pairs to a shared practice.

The theremin's affordances carried much of this work in a way that would not be able to be reproduced with another instrument. In use, manipulating pitch in a voice-like manner and visible hand motion made negotiation audible and visible. Imitation, turn taking, and quick cues came naturally. Later, portability helped the artefact travel home and sparked conversation with family. When making the optical theremin's circuit – soldering – although not initially easy for everyone, it was within reach for all. Together, these affordances explain why engagement rose most in electronics and why agency grew across both phases.

This model also enabled peer-directed learning: students manipulated parts, used gestures and sound cues, and translated explanations into what Green (2008) calls “kid language” (p. 11). In Green's work, this meant students would explain rhythmic or harmonic patterns to each other using simplified terms, clapping, or bodily demonstrations. In my workshops, a similar dynamic occurred as students explained to one another how to control pitch variation, adjust timbre, or refine their painted compositions. They described sounds as dirty or clean, referred to thinner when comparing timbres, and used gestures to demonstrate how pitch could rise or fall.

Green's (2008) open-group model created room for emergent leadership as in the accounts of Hana and Tyler coordinating the group's timing and stagecraft. Hana, another example given by Green, often initiated rehearsals, setting the tempo and prompting others to follow, while Tyler assumed responsibility during performance, signalling entries and managing dynamics. In my workshops, leadership was less formalised. Students occasionally took the initiative by guiding others when they needed help soldering or organising the components they received in their packages. These actions did not establish fixed leaders but revealed temporary roles that shifted according to the activity. This contrast is partly explained by the fact that, in my workshops, group boundaries were sometimes fluid and all groups worked in the same shared space whereas in Green's study, groups rehearsed in separate rooms and were therefore more stable.

There was a deliberate move in my groups towards agency and student autonomy, consistent with Reeve and Tseng's (2011) frameworks for agentic engagement. In these open groups, each member had a role, and the artefact was central. Building the optical theremin created roles with real interdependence; soldering was not uniformly easy but achievable for all, which elicited within-group problem-solving before escalation to peers and, only then, to me. As noted in my journal, "It's as if the entire class is one big group" (Research journal, September 19, 2022). In the using phase, the instrument's affordances – immediate gesture-sound mapping and continuous pitch – made negotiation audible and visible: students imitated and varied each other's gestures, coordinated entries, and adjusted parameters without notation. This combination of making and using the theremin enabled students to enact agency within open groups and helped shift the class from friendship-based pairs towards a community orientation. Students began to report, "it's easier when you can ask your group" and, in the electronics phase, many groups became "self-sufficient", needing little teacher intervention (Research journal, September 22, 2022).

Intervention evidence aligns with the loop reported by Cheon and Reeve (2015) that teachers that adopt autonomy-supportive strategies reduced amotivation and boosted engagement in students. In addition, effects from autonomy-supportive teacher training have been shown to endure at one-year follow-up (Cheon & Reeve, 2013). In my study, the open-group structure operationalised these same principles: by giving students roles, inviting questions and suggestions within the group first, and letting support circulate peer to peer before reaching the teacher, students' agentic moves (seeking help, proposing fixes, redistributing roles) elicited more autonomy-supportive responses from me (choice, rationale, resources), and groups became progressively "self-sufficient" with minimal teacher input (Research journal, September 19, 2022 and September 22, 2022). This created a classroom-level feedback cycle that mirrors the transactional account of agentic engagement described by Cheon and Reeve (2015). Merrick and Joseph's (2023) postpandemic snapshot also helps interpret why teachers in this school were cautious about complex collaborative tasks: when workload is high and routines are fragile, teachers tend to favour safer formats that are easier to manage. In my case, using a low-cost, tangible artefact and a clear peer-first routine reduced the practical burden of collaboration.

This pattern aligns with work showing that students' proactive contributions can coevolve with teachers' autonomy-supportive responses (Patall et al., 2019, 2022). It also links with intervention studies in which autonomy-supportive teaching reduces amotivation and is associated with higher engagement (Cheon & Reeve, 2013, 2015) and with design framings that

treat STEM as practices enacted across semiotic, physical, and social domains (Lowrie et al., 2018). In my context, open groups operationalised these mechanisms: roles, choice of partners, and peer-first troubleshooting invited students to ask, propose, and coordinate while my role shifted to offering rationales and resources on demand or, more precisely, applied to: semiotic – naming/diagramming; physical – handling tools and materials; and social – coordinating roles and mutual support.

Notably, these dynamics emerged more strongly in the electronics phase, which was helped by purposeful scarcity of theremins, thus creating interdependence, than in the arts phase that resembled familiar classroom routines. This is consistent with Lowrie et al.'s (2018) Experience–Represent–Apply (ERA) heuristic in which early sessions functioned as *Experience*; *Represent* tasks as the dialogue between theremins and composing activities that stabilised shared language; and the build/repair tasks served as *Apply*. The progress described here was gradual. The early artistic workshops gave students a low-pressure space to try out collaboration (*Experience*). Later, the electronics workshops required more cooperation and genuine interdependence, especially due to limited resources (*Apply*), aligning with a learning-by-doing tradition common to makerspaces (Lowrie et al., 2018).

As Lowrie et al. (2018) argue, this type of stepwise progression, from direct experience to joint problem-solving, is important for interdisciplinary learning and offers an alternative to superficial integration heuristics. Given the long hiatus without group work, initial resistance and friendship-based clustering were expected and found in the early stages of the workshops, and were accommodated by flexible grouping and role allocation that gradually widened participation. I suggest that hands-on experimentation plus flexible grouping can reintroduce collaboration and gradually promote agentic behaviours.

This transition also aligns with Expectancy–Value Theory (EVT; Gladstone et al., 2022; Wigfield & Eccles, 2000). When students see value and personal relevance in collaborative tasks, and when they feel competent to contribute, their motivation and engagement increase. In the workshops, the components of subjective task value were present. Intrinsic value rose with the novelty and open exploration of the theremin and with the satisfaction of making sound and later making a working circuit. Utility value was clear in electronics because students could connect the skills to real tools and a tangible product. Attainment value increased when roles, such as solderer, tester, and helper, mattered inside the group and when doing the role signalled competence to peers. Scarcity of equipment created positive interdependence because

students needed one another to progress, which raised value without raising cost beyond a manageable level.

The structure and gradual freedom introduced in the workshops raised their expectancy for success. Students themselves observed that “helping each other with the electronics was easier than in art ... [and] ... when there’s not enough equipment, we have to work together” (Research journal, August 22, 2022). These mechanisms fit the EVT account of how expectancies and values guide choice, persistence, and performance, and they also align with SEVT because the changes were situated in the specific routines and culture of the classroom (Eccles & Wigfield, 2020, 2024).

Calabrese Barton and Tan (2018) argue that sustained engagement emerges when youth occupy expanded, peer-driven roles, and the learning space operates as a community. Their equitable and consequential making principles include elevating youth voices and roles, using participatory methods, and providing multiple entry points; for example, letting students choose a role, begin with a simpler task, observe before trying, or contribute through building, testing, documenting, or presenting so that learners with different skills and confidence can join in meaningful ways (Calabrese Barton & Tan, 2018). In my workshops, this meant open groups where students chose roles, such as solderer, tester, and helper, and moved between groups as needed, helped rebuild collaboration and shift the class from rigid pairs to flexible teams.

In summary, Year 8 students reported scarcity of structured group work beyond pairs since Year 5; teachers largely avoided it due to management issues and uneven participation. When group work was held, collaboration would be achieved only by friendship-based relations. In the theremin workshops, an open-group approach, where students chose partners, moved between groups, and sought help within the group first restarted collaboration. What may have been chaotic became self-organised teamwork with rotating roles and peer teaching. Engagement rose most in electronics where purposeful scarcity, brought by having fewer theremins and solder irons than students, created interdependence and produced small wins that built confidence. Across classes, the norm shifted from fixed pairs to flexible teams and a classroom-wide community, reducing the need for teacher input, matching Green’s (2008) peer-led learning and agentic/EVT mechanisms.

6.9 Hands-On Activities Triggered Intrinsic Motivation

Authentic, hands-on activities have been shown to transform students’ attitudes towards learning, enabling them to connect abstract concepts with real-world applications and

develop a stronger sense of agency and interest (Chu et al., 2019; Lowrie et al., 2018; Tobias, 2017). According to the students I interviewed, they developed connections with different school subjects, but when learning was heavily focused on theory and grades, many began doubting their abilities and losing interest. The disconnect between subjects – that is, the lack of interdisciplinarity – and the pressure to perform made the students feel as though they were not good at certain subjects, even when this did not reflect their true potential. This Section 6.9 explores how hands-on activities can empower students by giving them opportunities to engage with learning in a meaningful way and by reducing the perceived “cost” of participation through concrete, achievable steps (Gladstone et al., 2022; Lowrie et al., 2018).

6.9.1 Motivation at the Beginning of the Workshops

Student engagement with science and the arts varied according to the teaching methods used. Across my research, I found that traditional, theory-heavy approaches often led to negative emotional responses from the students, such as frustration and disinterest. In contrast, lessons that involved practical activities with clear explanations tended to promote enjoyment and curiosity. This section demonstrates how motivation fluctuated within and across classes as a result of different pedagogical strategies. These reports were drawn mainly from the initial focus groups and interviews. I will discuss further how this related into intrinsic and extrinsic motivation in the next Section 6.9.2.

Students’ feelings, such as frustration, disinterest, or curiosity, were triggered by their experiences in the classroom. The requirements of the state-mandated curriculum, standardised tests, and lack of resources in the Brazilian public educational system led to the use of poor pedagogical practices, such as repetitive copying and an overemphasis on theoretical content, as it is rare for public schools in Brazil to have wide access to musical instruments, such as ukuleles, keyboards, and guitars. These teaching methods shaped students’ motivation and engagement with the subjects.

During my first focus group interviews with the students, they described a series of negative and frustrating emotional experiences. An example of this was found in the Year 8A reports on their arts class¹¹ where students expressed frustration, particularly with copying text from the board. One student said, “What I don’t like is studying about the paintings”, indicating lack of interest in the theoretical–philosophical aspects of art. When asked about copying, they

¹¹ As noted in Section 5.3.1, music classes are integrated into the arts curriculum. Consequently, the arts teacher is responsible for simultaneously covering four distinct disciplines: music, visual arts, dance, and drama.

clarified, “The teacher gives us a lot of things to copy.” Another student confirmed, “Yes, text on the board for us to copy into our notebooks”, and “Who wouldn’t think it’s horrible?” another student replied (Year 8A, initial focus group). These ongoing negative experiences appeared to contribute to a broader sense of disinterest and disengagement from the subject. Such outcomes from these practices – particularly those based on repetitive copying and theoretical content – can compromise students’ emotional connection to the arts.

This pattern was not limited to Year 8A. In the focus group with students from Year 8C, the same kind of disengagement was found as a disinterest in learning in the arts class. The students generally expressed a positive view of the arts class but showed a clear aversion towards the written assignments associated with it. When asked about how they felt about the arts class, the students replied:

S1: It’s good, except for the texts.

S2: Because we end up spending the whole day writing.

S3: Yeah! Why do we have to write in art class if art is supposed to evaluate things like drawing? (Year 8C, initial focus group).

Similar patterns appeared in science classes where students’ engagement often depended on their expectations, prior experiences, and the way content was presented. The science teacher’s interview revealed low self-belief among 8th-grade students regarding their potential success in science, more specifically physics and chemistry. The teacher noted a stigma associated with these subjects, where students believed they would not understand or learn the material with phrases like “I don’t know, I don’t like it, and I don’t want to know” (Science teacher, initial interview).

According to the science teacher, when a topic was identified as chemistry or physics, students often expressed surprise at how simple it was, going against their initial bias. This reflected a low sense of self-efficacy where students doubted their ability to understand and succeed in traditionally challenging subjects. In the science teacher’s own words: “So, physics and chemistry for them, they already have that stigma that it’s terrible, that they won’t understand, that they won’t learn. When I mention that this is a chemistry or physics topic, they respond, ‘Wow, so that’s what it is!’” (Science teacher, initial interview).

Despite these challenges, students’ attitudes were not uniformly negative. Many demonstrated interest and curiosity, particularly in lessons that involved hands-on activities or clearer explanations as the sense of frustration in the arts class was not generalised towards all kinds of art or the approaches to teaching it. One student remarked, “I think it’s good to learn

about the type of sound and those things. It's interesting." These students also demonstrated positive feelings towards the teacher: "He explains it well", and another echoed, "I understand too" or "I'm not good at art, but the subject is good" (Year 8A, initial focus group). This contrast suggests that their negative feelings were directed more at the teaching methods required by the curriculum (such as copying from the board) rather than at the teacher himself or the subject as a whole.

Students in all Year 8 classes shared some positive learning experiences in science. When I asked about their feelings towards science, one student noted that they "learn a lot" and another expressed outright enjoyment, saying, " I think it's good. I even like it. I enjoy it " (Year 8C, initial focus group). In Year 8A, some students enjoyed topics like the solar system: "I prefer the planetary system. It's much cooler. I just don't know how to say the name ..."; "It's the solar system, man!" another replied (Year 8A, initial focus group). The same was reported in Year 8D as a student said: "I like more about planets, nature, those things." Even though their interest in human anatomy was moderate, they still found it "interesting" (Year 8D, initial focus group). In Year 8B, one student was particularly enthusiastic about space: "I really like it, especially space, I love it" while another student replied, "I prefer learning about the human body, but also because of ... and space!" (Year 8B, initial focus group). These classes mostly agreed that science is a subject they enjoy.

Although earlier comments from students highlighted frustration and disinterest – often linked to repetitive, theory-based tasks like excessive copying – this negative sentiment was not universal. When discussing art, many students also expressed strong positive feelings, especially towards practical activities. Multiple students shared their enthusiasm for the subject with statements like "I like it", "I love it", and "Best subject!" (Year 8D, initial focus group). However, some students voiced mixed feelings about written assignments, as in: "I like drawing; I don't like it when the teacher assigns texts." This kind of task was common: "For example, the pointillism drawing, he goes there and gives us a text about pointillism, and we have to write it down, copy it." Overall, students enjoyed the drawing activities, with one enthusiastic student saying, "I'm a sketch artist!" (Year 8D, initial focus group).

What is shown is that when negative emotions towards school subjects occurred, it was more associated with traditional teaching methods – such as long text copying, theory without experiments, and excessive theory in artistic contexts – than with the subject itself. Also, the lack of comprehension would affect their enjoyment, as in one student's words: "I like the things I understand" (Year 8B, initial focus group). This shows that emotions are not separate from

motivation but shape effort, strategy use, and persistence through engagement (Pekrun & Linnenbrink Garcia, 2022; Tamura et al., 2022).

6.9.2 Extrinsic and Intrinsic Motivation

When analysing motivation in both students and teachers, I found evidence of both extrinsic motivation – which involves external rewards or avoiding social consequences – and intrinsic motivation – which comes from personal interest, curiosity, or satisfaction with the learning process. In the context of this research, however, extrinsic motives appeared mostly in students’ day-to-day school experiences. For students, their motivation in the school environment often centred around the notion of “coming out winning it” (Year 8C, initial focus group), or they perceived school more as a game or about “beating a score” than mastering content. Only a small percentage of students seemed to care about grades because they associated being a good student with high academic performance (Science teacher, initial interview). These reflect a focus on measurable outcomes, such as grades or scores, that determine whether school felt worthwhile.

During discussions with students about their motivation to attend school, the range of responses varied from outright disinterest to conditional enthusiasm. When asked, “Do you look forward to coming to school?”, their answers spanned the whole spectrum: “No”, “Yes”, “It depends”, and “More or less”. However, one student’s response stood out: “Only when I come out winning it” (Year 8C, initial focus group). This revealed a clear link between their attendance motivation and the anticipation of achieving good grades or some form of academic recognition.

The science teacher also observed that students’ motivation was primarily extrinsic, driven by the desire for high grades rather than genuine learning. She stated that: “They equate being a good student with getting top scores, and some are willing to redo activities to achieve perfect marks” (Science teacher, initial interview). For them, it was not about being dedicated to learning but about achieving the best grades. According to her: “If some score even one-tenth of a point lower than perfect, they want to redo the activity, not because they feel they didn’t learn but because they feel they need the highest score” (Science teacher, initial interview).

To encourage the students, the science teacher presents lessons and tests as part of a game. At the beginning of the school year, she introduces the concept of the school year as a “game with three stages¹²”, explaining that they must complete each stage to “finish the game” by year’s end. While students initially find this analogy engaging and respond positively to it, she

¹² The three school terms in Brazilian public education.

noted that this gamification does not change their focus. As she puts it, “They understand and say, ‘How cool is this’, but ... it doesn’t change much” (Science teacher, initial interview).

While extrinsic motivation, particularly identification with external rewards, seemed to dominate students’ approach to academic achievement, there were moments when their engagement went beyond this mindset, particularly when the learning experience was hands on and connected to real-world applications. This was evident in the students’ perception of science. In contrast to their game and/or grade-focused motivation, students in Year 8B in the final focus group expressed a genuine understanding of the relevance of science in their lives, recognising that what they learn in school can have meaningful applications outside the classroom. Their engagement was deepened further when they had the opportunity to build something tangible, such as during the electronics workshop. Here, the creation of a tangible artefact they could take home provided a powerful motivator that shifted their focus from abstract rewards like grades to the intrinsic satisfaction of hands-on learning and production.

In Year 8B, one student responded “Zero” when asked about their satisfaction at school in the initial focus group, while another student indicated that grades were a major element in his school satisfaction: “I feel satisfied when I get good grades.” This was complemented with “or when the teacher teaches something that I know, and I can speak about it. Something like that ...” Although the student perceived grades as an indicator of success, the idea of having the capacity of participating fully in class with an exchange of information was equally important to him (Year 8B, initial focus group). Initially, only a minority of Year 8A students felt that science made sense beyond school (Year 8A, initial focus group). This perception shifted during the electronics workshops.

The electronics workshop facilitated a shift in motivation as I could see from the researcher’s position – and not as the teacher only – students becoming more proactive than in the artistic workshops at the beginning. This became evident when students would gather around the table and focus on lesson instruction on topics that were not common in their school life, such as how ferric chloride could stain clothes permanently, using closed shoes and protection goggles, or the care one should have around the burning hazard of the soldering iron.

The possibility of real-life consequences of not managing the equipment correctly gave the students a different perspective on their education. They were building something beyond their writing on paper, and this building was not only aesthetic, such as a representation of a musical instrument using recyclables or a poem or drawing that would be stuck on a corridor’s wall – activities that could be a value resource on their own — but, instead, something that

would respond to their actions and work with an immediate live response to their movements and prompts, and they would pay a price if not taking care in the process. I was disappointed that I did not collect more data on this specific issue due to the limitation of my own research as I would like to have researched deeper into how these “real-life processes” can shape students’ intrinsic motivation in learning.

Building an artefact with their own hands, after a long period without tangible educational tools during the lockdowns, significantly reignited their interest in participating in class. This shift was not only observed in general student behaviour but also reflected in specific moments documented in my reflective journal, as in one case when I was extremely satisfied with the day’s work. As noted in my reflective journal: “The generation that is afraid of exposing themselves and producing really got hands on, and everyone did well. Even the more disruptive and extremely restless students, like (name suppressed), worked diligently” (Research journal, August 22, 2022).

The electronics workshop took the students further from their everyday routine than the music with the theremin did. The fact that it was something tangible facilitated their motivation and willingness to participate. This contrasts with something more abstract like music created with an exotic instrument. The students became so attached to their product that I had to give a “spoiler” and said that in the end, each of them would have their own instrument. I did this to keep them engaged as I feared that the idea of not being able to keep their own instrument could have a negative effect on their motivation and participation in the remaining sessions.

During the workshops, students had the opportunity to experiment, develop, showcase, and use skills that they did not usually use in the school environment. At least two students who were considered by other teachers as disruptive, uncooperative, or overly talkative excelled well above average when it came to doing something mechanical and hands on producing the theremin. They had skills that stood out, which are not typically emphasised in school. As noted in my reflective journal: “These are mechanical skills that are essential for building an object like this. Such mechanical skills are also necessary for a surgeon, a technician, a dentist, or any job that requires manual precision.” Some of the soldering they did was “beautiful” (Research journal, August 26, 2022). There was one solder joint that was better than mine. There were also two girls who laid out the circuit perfectly, so much so that I used their circuit as a reference. This pattern of excellence achieved by girls was found in two of the four classes. This example reinforced the motivational aspect and the inclusiveness of the workshops, including the high

level of engagement by female students in the electronics component. STEM subjects are predominantly male dominated in Brazil, so seeing girls excel in this area was very motivating, both for me and for these girls.

In the Year 8D class, there was a notable case of a girl who usually remained quiet and isolated during the workshops and did not engage much with the artistic aspects of the project. She had no interest in producing the artistic part of the theremin and would be a prime example of disengagement in various aspects. She was always holding a soccer ball, and her sports and physical abilities were excellent, but she was not very communicative. However, when we moved into the electronics phase, she became one of the most engaged participants and ended up constructing one of the best and most well-made theremins across all classes. This displayed the importance of giving students opportunities to develop or experiment with different skills as they may excel in areas not typically explored in school.

During these moments, I would make notes in my reflective journal, saying that we, as teachers, must give these students “the opportunity to test other skills, especially at this age. Sometimes they may not be very good at written tasks or copying from the board, but that doesn’t mean they aren’t good at other things that are useful in society and employable skills” (Research journal, August 26, 2022). For me, as an educator and researcher, this was also quite thought provoking. It led to results that made me leave the day satisfied, happy, and wanting to share my progress with others, saying things like: “Look at the research I did, look at the results I achieved and how they reached them!” (Research journal, August 26, 2022). In this case, the research also affected me positively. As a researcher inserted in the students’ school life, I could not come out of it untouched by the results of these practices.

The workshops showed how hands-on tasks increased students’ engagement as they were motivated by the chance to create something real. While this practical work uncovered hidden talents, especially in students seen as disruptive, difficulties emerged when they had to apply the same creativity to more structured, rule-based tasks. So, despite all the development we achieved in the workshops, the students still experienced a certain block when it came to creating art or text within a system of rules or in writing, even when this type of composing was more open and unstructured than traditional music. For example, there was a lot of spontaneous creation with the theremin, especially towards the end of the exploration activity with the optical theremin. As I noted in my reflective journal: “The students in Year 8A played a lot, explored extensively, and had fun. They struggled to compose based on the writing system. When it comes to organising knowledge and putting it into writing, they freeze up. However,

when it's time to explore, they do so eagerly" (Research journal, October 7, 2022). There was a significant blockage and little incentive to compose guided, creative work. They did not see the idea of rule-based creation as positive, and it created a considerable mental block. When it came to structured classroom creation, their creativity seemed to vanish, and they no longer wanted to expose themselves. However, when it was time to play freely with the theremin, they did so easily and freely and created interesting things. A clear example of this spontaneous creativity is exemplified through a student who showed me a new way to operate the on/off switch that I had not thought of before. This student played with the instrument by connecting and disconnecting the battery just by touching it without locking it in place.

The students' intrinsic motivation and reasons throughout the workshops were reported in the postworkshop interviews. When asked what the students thought of the workshops, the responses were mostly positive, such as: "I thought it was cool ...", "I thought it was interesting that we learned ...", "It was good", "It was wonderful, teacher", "It was something different", and "It was very good" (Year 8A, final focus group). However, these positive responses alone are not enough to grasp the depth of how much their internal motives were fuelled by the workshops. This extra layer could be found in answers that students gave when asked about their biggest fear during our classes, which was the instrument they were building not working – not because they would have some type of punishment or loss in grades but purely due to wanting to succeed in building something with their own hands.

A student reported that he was "sad when it (the theremin) didn't work the first time. But now I'm happy" (Year 8A, final focus group). Further, sometimes, this happy instance would come after trying about five times to make the instrument work as it took in his case. Others would respond to this moment after the theremin not working initially with "I was very sad", "almost cried ...", and "Wow ..." (Year 8A, final focus group). This represented a marked shift away from the extreme focus on grade from a parcel of interested students, to focus on achieving success in the task at hand, from the perspective of all the students.

After these answers, I provoked them, prompting, "Because you worked hard for that, right? We spent several classes working on it and all ...", which brought answers as "I almost cried because I managed to help others and wasn't able to make mine work at first..." and "I liked it, teacher. You know why? Because if it didn't work, I would learn a little more in the next class" (Year 8A, final focus group). This last answer, given in a context where no teacher pleasing

was needed¹³, displayed a major shift in motivation from external (fear of punishment or grades) to enjoying the school process and seeking more information without prompts (internal).

Along these intrinsic strategies, a healthy balanced measure of extrinsic motivation identification, known as tangible rewards or fear of social punishment, could be observed. When asked if they identified any challenges during the process, one student replied, saying, “Yeah, soldering, then (the components) it’s like, ‘you have to do it right’; otherwise, the teacher will come and say, ‘it’s wrong!’ (laughs). So, there’s that pressure” (Year 8A, final focus group). This pressure of fear or receiving a reprimand was, in this case, presented as a motivator for the student in trying to be as precise as possible in the soldering process.

The students reported that the soldering elements were challenging. Some found it difficult to drill the holes and remove the solder because they were very small. Others enjoyed the process, which led to the formation of pairs with classmates who had different skills. One student who was near-sighted received help from other classmates. When asked if they could remember any challenges they faced or mention anything that was difficult, the students replied:

- S1: Well, for me, at the beginning, it was soldering.
- S2: For me, it was drilling in the right spot because it was so small. And also extracting the solder when we made mistakes.
- S3: I enjoyed removing the solder.
- S2: For me, it was hard because I’m near-sighted, you know? (Year 8D, final focus group)

Another piece of feedback about the uniqueness of the instrument and its possibilities came from the students. Regarding the unusual ways of producing music that the theremin provides musicians, the students reported that this made some of them like to play for their colleagues: “Teacher, I also liked it when we came up to play in front” (Year 8B, final focus group). When asked if they liked it because they enjoyed the sound or because the instrument was very different, the unanimous response was: “It was different”, “It was different”, and “Because there’s nothing quite like that” (Year 8B, final focus group).

The arts teacher addressed the question of students’ understanding of artistic aspects after the workshops, noting that the relationship that public school students have with intonation differs from traditional Western perspectives. From the arts teacher’s perspective, I

¹³ As our student–teacher relationship evolved, the students would give more honest answers without the need of validation or fear of punishment.

worked with what he considers one of the most difficult forms of art to work on in the classroom, which is music. In his words: “because of what it involves in teaching music. You know? Music has parameters; there’s a lot to understand, right?” (Arts teacher, final interview).

The arts teacher explained that these students were accustomed to genres like Brazilian Funk, a form of RAP that involves spoken poetry over a fixed musical base where intonation is less emphasised and not as precise. In his words: “microtonalism or atonalism is much closer to public school students than to private school students. Why? Funk is atonal, Funk is microtonal. It’s part of their repertoire ...” (Arts teacher, final interview). According to him, the theremin, which can initially be played without a strict focus on intonation from a Western viewpoint, provided a unique opportunity for these students to engage with music in a way that might have been more accessible to them than a traditional instrument. According to him: “So they don’t find what would be, in quotes, ‘out of tune’ as strange as someone who learns to study Brazilian jazz, learns to study ...” (Arts teacher, final interview). This open platform provided by the theremin, and the students not trying to achieve perfect intonation from the first try due to the lack of prior music training, worked as a tool for empowering them into trying to produce music in a way that they would probably reject if presented in a formal, conservatory-style of learning.

When considering science, the main element that helped increase student engagement was the hands-on activity. However, this increase in motivation and interest was not unanimous when related to subject-specific knowledge from the curriculum. After asking students if they found science more interesting after building the theremin, the majority of answers were positive, such as: “Oh, yeah, that I did” or “Yes”, while another student responded, “For me, it didn’t change much because, for me, science is about the body and planets. To me, that’s it and nothing more” (Year 8A, final focus group). This suggests that, in some cases, the workshop was so different from students’ usual experience of science at school that they did not recognise it as part of science learning.

6.9.3 Discussion On: Hands-On Activities Triggered Intrinsic Motivation

In this Section 6.9.3, I examined how students’ engagement shifted from extrinsic to intrinsic motivation, particularly as a result of their experiences in hands-on activities like the electronics workshop. While many students initially approached learning from an external/extrinsic reward perspective – especially grades – practical tasks gave them opportunities to discover new skills, develop a sense of accomplishment, and engage more with the learning process. These activities often revealed strengths among students who had previously been disengaged in class or labelled as disruptive, enabling them to build confidence

through meaningful, tangible challenges. One of the elements present at the starting point of the workshops is echoed by reports of how school can be often seen as a “game” of points/score and progression in which some students aim for the minimum necessary to advance rather than for mastery (Hallam & Himonides, 2022). This helps explain why grade-oriented goals were initially present in these students, as reported by the science teacher.

The workshops – centred around building and exploring the theremin – served as a catalyst for this shift. By focusing on active creation instead of isolated abstract concepts or test performance, students were empowered to challenge their own perceptions of ability and take initiative in their learning. Overcoming practical difficulties and being able to see tangible results helped them persist, gain confidence, and experience ownership over their work. My observations showed a clear emotional-behavioural trajectory: initial anxiety when circuits failed, repeated attempts to diagnose faults, and satisfaction at the first sound – a trajectory that helped consolidate ownership along sessions, especially with the prospect of taking the artefact home. This sequence is consistent with academic emotions functioning as antecedents that shape engagement and persistence (Pekrun & Linnenbrink Garcia, 2022).

The shift from extrinsic, grade-oriented motivation to intrinsic engagement shows the link between dimensions of engagement (Fredricks et al., 2004; Skinner et al., 2009; Tamura et al., 2022). Emotional activation, such as curiosity, satisfaction, and a sense of achievement, overlapped with behavioural engagement (active participation), cognitive engagement (problem solving, persistence), and motivational engagement (agency, self-efficacy). This positive cycle was most visible during electronics where feedback was immediate and progress was visible and concrete. Even so, a recurring limitation concerned the move from experience to representation: some students froze when asked to encode ideas in rule-guided forms (guided composition, notation, written explanation). Viewed through the Experience–Represent–Apply lens, the pathway stalled at “Represent” for some cohorts in the early stages of the artistic workshop.

Student agency and ownership emerged in line with O’Neill’s (2015) discussion of transformative music engagement. As students constructed and experimented with the theremin, they moved beyond extrinsic drivers of grades or teacher approval and experienced the intrinsic rewards of discovery and creation. However, this process was not limited to a direct shift from extrinsic to intrinsic motivation. The ownership of a functioning artefact also gave the activity personal value, suggesting a process of internalisation in which reasons for participation moved beyond external rewards and became increasingly connected to the students

themselves. The extension of this ownership beyond the workshops, and its role in connecting school learning with students' everyday lives, is discussed further in Section 6.10.

O'Neill (2015) argues that transformative music engagement occurs when young people take agency, explore, create, and construct musical identities in contexts that amplify their voices. This is consistent with my findings of ownership over the artefact, satisfaction at the first sound, and the significance of taking the instrument home as an extension of themselves (as discussed in Section 6.10). This resonates with Expectancy-Value Theory (EVT; Gladstone et al., 2022) as motivation increased as students perceived the tasks' value and believed in their capacity to succeed. EVT claims that engagement is enhanced when learners recognise the utility of a task and deem that they can succeed. In my workshops, this was evident when the concrete utility of "building something that works" and the expectation of eventual success – sometimes even after multiple attempts – sustained persistence.

Most of the students who were often considered "disruptive" or less academically successful excelled in mechanical and technical tasks. This connects to the literature on differentiated learning and the recognition of diverse talents. Hallam (2015) synthesises evidence that active music-making can support self-belief, social cohesion, and participation, particularly for lower attaining or disaffected students (Catalano et al., 2001; Rusinek, 2008). This mirrors my data, showing students labelled as "disruptive" excelling in circuit layout and soldering, with some joints described as "better than mine", as I reported in my reflective journal. The workshops created a space where traditionally undervalued skills were recognised, strengthening students' self-concept and sense of belonging. In the electronics workshops, girls were among the most accurate builders across classes (both layout and soldering), which visibly repositioned peer expectations and broadened who was seen as competent in STEM areas.

These outcomes align strongly with research on student motivation and engagement in STEAM education. Authentic, applied learning fosters agency and conceptual understanding (Chu et al., 2019; Lowrie et al., 2018; Tobias, 2017). When classroom activities were restricted to theory-heavy or repetitive tasks, students reported frustration and disengagement (see examples reported earlier in this chapter in Section 6.9.1). In contrast, hands-on work created conditions for curiosity, persistence, and self-efficacy to flourish (Fredricks et al., 2004; Skinner et al., 2009; Tamura et al., 2022).

The workshops opened opportunities for collaborative problem-solving and peer support, conditions that Green (2008) and Calabrese Barton and Tan (2018) identify as crucial for sustaining engagement across contexts and empowering students who might otherwise

remain on the margins. In addition, the findings supported social constructivist and inquiry-based perspectives in STEAM, which position learners as active agents (Chu et al., 2019).

In summary, hands-on, interdisciplinary activities activated intrinsic motivation while creating opportunities for transformative engagement, agency, and sustained learning. My evidence reinforces the need to move beyond rote learning and external rewards, prioritising practical experiences that allow students to connect content with their identities, interests, and real-world contexts.

6.10 Students' Learning and Experiences Extended Beyond the Workshops: Theremin the Artefact as a Bridge

This Section 6.10 begins by describing reasons students came to school and how they experienced school membership, drawing on teacher interviews and early focus groups. It then clarifies a key limit in this dataset: attendance and belonging did not, by themselves, make school knowledge feel relevant or usable beyond school. The section then presents evidence that the theremin workshops created new occasions for application and explanation outside the workshops because students built an artefact they could take home, demonstrate, and talk about with family and peers. I end by noting that learning across spaces remained vulnerable to community pressures, which could disrupt participation and continuity. Although one of the research questions I set out to investigate was how the theremin could be used to improve interdisciplinarity between science and music, the data shows that the effect of the workshops went beyond this and promoted experiences extended beyond the workshops, connecting not only music and science but also school and community, including family, friends, and caregivers outside the school environment.

In Brazil, school attendance for families in need is encouraged by linking it to family support payments, a system known as *Bolsa Família*. According to the science teacher, this programme was the main reason many students attended school. After the return to face-to-face learning after the pandemic, students' relationships with peers and sometimes staff also became a key reason for coming to school, reflecting the importance of belonging and feeling part of the school community.

However, while these connections helped keep students present and provided a sense of belonging, they did not necessarily result in academic engagement or the application of school knowledge in family or community settings. The theremin workshops contributed to a shift in this dynamic. The workshops drew on students' existing relationships and sense of membership but also offered something new. By allowing students to take ownership of an instrument and

encouraging them to share and explain what they had learned at home, the workshops supported students' learning. These experiences extended beyond the workshops, with the artefact – the theremin – serving as a bridge. In other words, these activities gave students a reason to use school learning in ways that involved their families and communities. Later in this Section 6.10, I show this directly through students' accounts of taking the theremin home, demonstrating it, explaining how it worked, and using workshop language to describe the device to relatives and friends.

The arts teacher echoed this view – in relation to the role of public assistance in keeping students present at school – highlighting the critical role of public assistance programmes in keeping students engaged, particularly those from vulnerable backgrounds. He explained that many students rely on support, such as *Bolsa Família*, government-distributed food baskets, and school-provided milk. While he attributed some disengagement to the students' age and their decision-making, he acknowledged that their dependence on these programmes reflected broader issues of social vulnerability (Arts teacher, initial interview).

In the initial focus group with Year 8C, positive responses to academic work and school were found through the students' satisfaction with specific aspects of their school environment. When asked if they felt satisfied with attending school, the students' responses focused primarily on their relationships with school staff and peers. In the students' own words:

- S1: I'm very satisfied with the school aunties.
- S2: Yeah, I'm satisfied with them too.
- S3: I'm satisfied with my friends (Year 8C, initial focus group).

In this scenario, the students expressed high satisfaction with the school monitors and inspectors (school aunties and uncles, as they were called), indicating that these staff members played a significant role in their positive school experience. They mention being cared for and disciplined by these staff members, which suggests a sense of security and structure provided by the monitors, even though they are the ones who take the students to the principal's office when discipline is needed. As the students stated:

- S1: They take care of us.
- S2: They take us to the principal's office.
- S3: The other day they took me to the principal's office, the uncle (name suppressed) let me scribble on the board there.
- S4: The uncle (name suppressed) has taken (name suppressed) to the principal's office three times already (Year 8C, initial focus group).

The science teacher also reported the importance of social interaction for the students. According to her, the students' satisfaction with school was closely tied to their social experiences rather than academic content. She points out that during the pandemic, what students missed most was not learning but the opportunity to interact with their peers, suggesting that their school membership is rooted in their social connections. Here, school membership refers to students' sense of belonging and emotional connection to the school environment. In her words: "They come to school happy to meet their friends and so on. I think during this pandemic period, that's what they missed the most. It's not the school itself, the learning itself, the exchange of knowledge. No, I believe it was more the socialisation that they missed" (Science teacher, initial interview).

Students' social bonding as a major factor in school membership was also found in Year 8C. When asked if they felt excited about coming to school, a student said: "Well, the only reason to come to school is for the food and friends" (Year 8C, initial focus group), indicating that social interactions and relationships with peers were major motivators. This sentiment was echoed by another student, who added that staying at home is monotonous: "It's true, it gets annoying staying at home" (Year 8C, initial focus group), reinforcing the idea that the social environment of the school provides a welcome relief and a source of enjoyment.

The interview with the Year 8D class also outlined the significance of social bonding in students' school experiences. The students mentioned that their enthusiasm for school depended on the presence of friends. When asked if they felt excited to come to school, the students replied:

S1: It depends on the day.

S2: Yeah, it depends on the day.

R: What does "depends on the day" depend on?

S1: Oh, the classes.

S2: The friends. If my best friend doesn't come (male), or my best friend (female), I jump the school walls and go away. (laughs)

S3: It's good depending on who comes to our class.

R: So, if no one from your close group comes, you're not excited to come to school?

S2: No... (Year 8D, initial focus group).

Although relationships between students and staff, as well as between peers, and the government support policy (*Bolsa Família*) were important for attendance and a sense of

belonging, these factors did not necessarily help students connect what they learned at school with their lives outside it. In other words, while social connections made students feel part of the school community, they did not automatically make academic knowledge feel relevant or practical. As a result, much of what was taught at school continued to feel abstract and disconnected from the students' everyday experiences. This suggests that social bonds alone, even when strong, were not enough to support the transfer or use of academic knowledge beyond the school environment. In this sense, social bonds were available as a pathway, but the trigger for school-to-home talk was the artefact and the applied activity, not social bonding by itself. It was only when students had opportunities to apply and share their learning – such as through the therein workshops – that this bridge between school and community began to form.

On this matter, the science teacher reported that, in the view of her students, science “is not necessary” and that for them it “doesn’t matter at all”. According to her, the students’ perspective was that they “won’t use it anywhere” (Science teacher, initial interview). As a way to generate student engagement and create an effective approach necessary for the progress of the classes, the strategy of encouraging students to study to pass that specific year was used without necessarily making a link to its application in real life. “When we talk about chemistry, right? ‘Where am I going to use this?’ I don’t know what your future holds, but, at this moment, you need to understand because it is part of the curriculum. I always repeat this” (Science teacher, initial interview).

This perception of school knowledge as irrelevant was reinforced by the local and family contexts of some students. Their parents and caregivers often reflected this view by successfully fulfilling their social roles despite not having completed their education. According to the science teacher, this led students to deliberately withhold effort, resulting in a passive attitude towards the school system. The science teacher explained that when she encouraged these students to pay attention to new concepts, saying, “No, but you need this, you need to have an education, because life goes on, you’ll work ...”, the students often replied, “My mother didn’t do any of that and we live well” (Science teacher, initial interview). In her view, the trivialisation of education and school extends far beyond the classroom.

When asked about the students’ engagement with the school in general, the science teacher reported that the school was a place they attended out of obligation but without being emotionally engaged. According to the teacher: “The school is a place where they ‘go’. That’s it. They go to school” (Science teacher, initial interview). In her words, “I always ask this question

at the beginning of the year, 'Which subject do you like the most?' – 'None', 'What motivates you to come to school?' – 'My mother tells me to come.'" (Science teacher, initial interview).

It was not typical for students to struggle to work with peers. Most were willing to collaborate but usually within familiar friendship groups, and only a small number consistently avoided group work. In the initial artistic workshops, I observed a few students working alone because they did not want to collaborate at all. For example, during the composing activity, one girl preferred to work alone to avoid sharing ideas or the A1 poster board with classmates. More commonly, students formed fixed groups in the early stages of artistic creation with the theremin, working within established social circles and avoiding unfamiliar peers. Although these groups allowed students to complete tasks, they limited broader peer interaction and creative exchange. As a teacher-researcher, one of my goals was to loosen this pattern in a nonforceful way.

Despite their rigidity, these students remained engaged and productive within their chosen groups, as I noted: "I didn't have students working alone this class. Most groups worked well. They like to gather in groups and tend to produce well this way" (Research journal, June 27, 2022). However, from a pedagogical perspective, the type of group work remained too inflexible, limiting the development of new peer connections and collaborative skills. This rigidity was something that would be broken only in the later stages of the workshops, a shift I considered both necessary and beneficial.

The students were highly interested in the electronics workshop. One reason for this interest was that the artistic workshops had provided a meaningful transition into science. Because they had already explored and played the instrument during the artistic phase, they clearly understood what they were building and why. So even though they had weeks of construction ahead, the final product was not abstract to them. They had a solid and concrete mental image of the instrument and could visualise how their actions during the electronics process would take shape. One example of this was during the first electronics workshop with Year 8A. It was a very cold morning with a temperature of 2°C¹⁴. I thought almost no one would show up; however, to my surprise, the class was almost full. I knew the weather could have an adverse effect on attendance as it did earlier in the research process when I arrived at the school on a rainy day to conduct the initial focus groups and only four out of 30 students were present.

On that cold morning, students were eager to participate, as seen in Figure 36, as they were told beforehand that they would start building their own instrument. As noted in my

¹⁴ This temperature would be considered really cold by Brazilian standards.

journal: “The students were very participative. They were very interested in the process and enjoyed getting hands on. Since the workshop’s structure changed, there was a renewal in the students’ interest” (Research journal, August 19, 2022).

Figure 36

Students Looking Forward to Building Their Theremin on a Cold Morning



The workshops provided several opportunities for students to extend their learning beyond the school environment, creating new points of contact between school and community. For example, many students shared the theremin they built with family members, explained how it worked at home, or received feedback from relatives – whether positive or sceptical. These interactions show that school learning did not remain confined to the classroom but was brought into students’ everyday lives, encouraging conversation and involvement among family and friends. In this sense, the workshops acted as a bridge, allowing knowledge and experiences from school to cross into community spaces.

However, these school-to-community connections were not always positive. Community factors also influenced the workshops and could interrupt attendance, disrupt group continuity, and limit how long “learning across spaces” could be sustained. I include the following incident as a boundary condition for extended learning in this setting. Although this episode reflects ongoing community challenges rather than an effect of the workshops themselves, it clarifies the limits and possibilities of this context.

One student, Ana¹⁵, who was considered disengaged by the teachers and produced one of the best theremins in 8C, was expelled for drug trafficking. Although I was part of this environment as a teacher, I assumed the role of researcher when processing my data. In those moments, I would remind myself that “everything is data”, whether things went well or not, because I was also an observer. By “observer” I mean someone who could move between roles, from active teacher to note-taker, with the observer aligned more closely to the note-taking end of the spectrum. However, this situation affected me deeply. It was painful to witness the progress of a previously disengaged student being cut short due to a criminal offence. As I reported in my journal: “This was a very happy case for me because she was a disengaged student who was excelling in the electronics workshop, was expelled because illicit drugs were found in her backpack” (Research journal, September 8, 2022). I felt both sadness and disappointment as I had seen the positive impact the workshop was having on her life. She was undergoing a genuine process of reengagement, and I believed it was a shame that she was removed from the school.

Ana’s case shows that, while the workshops created positive opportunities for students to share and apply knowledge beyond school, broader social issues such as drug involvement could still interrupt or limit these extended experiences and learning. Drug dealing had long been a harmful link between school and community in this setting, well before the workshops began. This context shows the workshops’ contrast, which introduced more constructive and positive forms of connection between school and community. The incident involving Ana was not an isolated case. Drug trafficking affected the school environment, disrupting attendance and participation, especially among students who were showing progress in the workshops. Students caught selling drugs by the principal or monitors were expelled from school and transferred to another institution. Despite this, the workshops continued to function. Although they did not eliminate these challenges, the workshops introduced new, constructive approaches into students’ routines.

When a student was expelled, their absence was often compensated for by the participation of other students stepping in to support the disrupted groups. For instance, when Rafael, Stella’s friend, was expelled for drug trafficking, her teammates and other groups stepped in to help her now-dismantled group, ensuring that the affected group could continue participating in the workshop. In relation to this case, I noted in my journal that I heard “One of the saddest phrases of the workshops”. It came from Stella, a girl in the eighth grade on a Friday morning. She was part of a quartet, and her class – Year 8A – had formed their groups well. Stella

¹⁵ Note: All student names used in this thesis are pseudonyms to protect participants’ identities.

was sad and even a little embarrassed when she said to me: “Teacher, I don’t know if I’ll be able to keep participating in the workshop.” She was not a disengaged student; she was very interested in these activities and participated in the workshops. I asked, “Did something happen? Why don’t you want to continue?” to which Stella replied: “No, it’s because Rafael, the boy in my team who is responsible for the soldering, was caught with drugs, and he was expelled from school ...” (Research journal, September 30, 2022). She was sad because she had lost her friend.

Stella was not a drug user, and she was a good student, but she got along well with Rafael. She was also sad because she thought she would not be able to participate any more since the part of her group that knew how to solder had been expelled for trafficking. I told Stella: “No, no, you can still participate. I’ll give you a hand here.” Other classmates and groups helped as well; they were very supportive. However, as already stated, I also felt sad. As noted in my journal: “It was very sad for the child, a teenager, to be worried that she couldn’t participate because she didn’t have a partner to solder with. And it wasn’t her fault because her partner was caught for a very serious issue in the school environment” (Research journal, September 30, 2022). These incidents illustrate that, even as new connections between school and community were emerging, long-established challenges from the wider community continued to shape students’ engagement and the sustainability of these experiences. More details on these cases of drug dealing and expulsion will be discussed in Section 6.11.

Despite these cases of drug-related expulsions, there were also moments of genuine enthusiasm and connection. One student, for example, was so happy when he found out he would keep his theremin that he hugged me. This student, who I later discovered was considered quite disruptive by teachers during morning tea conversations and “indeed gave me some trouble in the workshops”, was not necessarily disengaged (Research journal, September 30, 2022). He participated enthusiastically in the activities even if his behaviour was sometimes challenging. Receiving ownership of the artefact he built had a significant emotional impact on him.

This positive social relation with some peers and school staff was extended to their communities, as one of the main positive elements of giving the students the ownership of their instrument – or self-built, hands-on artefact to be more precise – was students’ learning and experiences extended beyond the workshops. When they took the theremin they built themselves home, the students received various reactions from their families. Some family members found it interesting, others were curious, and some were bothered by the sound, and

this all became part of their membership with school and built a bridge between school and community¹⁶. When I asked the students if they took the theremin home to show their families, one of the students replied:

S1: My mom wanted to put it away because I use that thing every day. She wanted to put it away, and I told her, "Hey mom, I brought an instrument to wake you up." Because before, I used to wake her up with a pan. Then she woke me up the other day with that thing. I shouldn't have said anything. I should have hidden this thing (laughs) (Year 8A, final focus group).

While other students also replied with their experiences, they were all seen in a positive light, even when the interaction moment between the artefact and the community had some negative elements:

S1: My cousins freaked out when I showed it to them, "Let me see, let me see, let me do this." So, "Don't touch my stuff!" I shouldn't have shown it. (laughs)

S2: My grandma came in her own way and said, "Wow, how cool!" Then she took it and put it away in my wardrobe.

S3: My stepfather said, "Now we know what profession you'll have if you don't become an actress."

S4: I showed it to my mom, and she said, "how cool", then I showed it to my dad, and he liked it too. Then I hid it in my wardrobe so no one would wake me up with it. (Year 8A, final focus group)

In some cases, the device they built was informationally disruptive to the community they live in, prompting one of the mothers to ask where her child stole the theremin from, as the artefact would not be considered as something they would ever be able to build by someone from their community, even more when considering their age. When asked about their families' reactions to the theremin, the students in Year 8B answered:

S1: My mom asked where I stole it from. (laughs)

S2: Ooh, she called you a thief straight to your face.

R: But then what did you tell her?

S1: I told her, "No, I made it," then she said, "I doubt it." She didn't believe me. (Year 8B, final focus group)

¹⁶ In this context, community refers to family members and other individuals with whom students have regular contact outside school..

In this episode, the theremin became a catalyst for family interaction. Although S1's mother's reaction may seem negative, S1 was quite proud of his work as he was eager to present the theremin to his family.

Even when the relationship between the presentation of their artefact to their community was not optimal, this element sustained across spaces was achieved. In Year 8B, when prompted further on what their families thought, the students replied:

- S1: My brother thought it was interesting, and my mom just said, "Cool, congratulations." It's just sitting there. My mom doesn't care, teacher.
- S2: My mom didn't even let me turn it on. Only my aunt thought it was cool.
- S3: No, no, teacher. I kept that "beep" in her ear just to annoy her. Then she said, "Oh girl, turn that crap off." Then I said, "Wow mom, are you really going to say that about my work?"
- S4: My family thought it was good. (laughs)
- S5: I showed it to my cousin (3 years old). She wanted to keep doing it, messing with it...
- S6: My family thought it was interesting. (Year 8B, final focus group)

In this class – Year 8B – another positive element emerged from the theremin existing across spaces, which was a student being able to recall technical information from the workshops and presenting it to his family in a way that this data would make sense to the community. This was not an isolated case. As the student said:

- S1: I showed it, I was ... in the dark, teacher, it's really noisy. Then I told my mom how it was, explained it all properly. Then she thought it was really cool. But after I did it so much, she found it annoying. So, I put it away. (Year 8B, final focus group)

Among the various reactions the students' families had to the theremin, one was particularly different: one student sold their creation to an acquaintance. When asked what their families thought of the instrument, students from Year 8D answered:

- S1: Good.
- S2: My mom found it really annoying.
- S3: My mom liked it. My mom went around showing it to everyone.
- S4: My mom liked it.
- S5: I sold it for R\$5. (laughs)

- R: Who did you sell it to?
- S5: My friend.
- R: Did he like it?
- S5: Uh-huh. (laughs). (Year 8D, final focus group)

The examples of practice sustained across physical spaces were not only present in showing the optical theremin to family members but also in teaching the content learned at school to people outside of school, as shown earlier in this section. This was exemplified by the exchange of information where a student was able to discuss elements of physics with her older brother, who was 30. When asked how it was to teach and learn with a peer, she replied: “I taught my brother ... he does these little chemistry/physics things, so I taught him” (Year 8B, final focus group).

Previously, the *Bolsa Família* programme positively influenced student attendance and presence in school. However, the act of taking the theremin they built home brought about other kinds of incentives for school participation. Now, there was not just a monetary incentive for students to attend but also an element of connection through shared spaces where the community was involved in the school system. This system presented itself to them as practical, visible, and tangible science. The student learns something at school, confirms their learning for themselves by building the artefact, and then shows to the external community that what is being learned at school is not only useful but also interesting and applicable, taking what is being learned out of the realm of the intangible and into the concrete. In this case, it is possible to see, touch, and hear the knowledge learned in the classroom.

6.10.1 Discussion On: Students’ Learning and Experiences Extended Beyond the Workshops

The theremin workshops led to students’ learning and experiences being extended beyond the classroom, connecting school experiences with students’ homes, social groups, and everyday environments. This extension of learning beyond school connects with place-based arguments about linking classrooms and communities (Sobel, 2004). It is also consistent with the work of Calabrese Barton and Tan (2018), who state that STEM learning becomes more inclusive when students take active roles in design and construction, participating in tasks that continue across different areas of their lives. Calabrese Barton and Tan (2018) show youth moving self-made artefacts, such as toy cars and a racetrack, from the making room into shared community spaces, which expanded the scale of activity, generated social recognition, and positioned older youth as community maker-mentors who hosted workshops for younger peers.

The authors also stress sustaining participation across spaces and over time through consistent access and multiple entry points. In my case, the theremin performs a parallel role: by circulating between school and home, it links contexts and makes classroom learning consequential in everyday life. It functioned as a relevant tool that allowed students to share their school learning in family settings and peer interactions, going beyond what is typically expected in conventional school activities, a pattern Calabrese Barton and Tan (2018) call practices “sustained across spaces” (p. 158). Being able to take the instrument home was only achievable because the optical theremins are small and battery powered, thus making the size of the instrument play a major role in the success of the school → community bridge.

This discussion argues that the workshops strengthened school-to-home transfer by giving students a take-home artefact they could demonstrate, explain, and repurpose in everyday settings. The key shift was not simply being present at school but making learning concrete and shareable beyond the workshops. I then consider constraints on sustaining these connections over time, including disruptions linked to community pressures. This kind of connection between classroom activity and local settings aligns with place-based education approaches that connect learning to communities and can increase engagement and attendance (Sobel, 2004).

Initially, the motivation to attend school for most students and, thus, a form of connection between school and community was established through the *Bolsa Família*, which ties financial support to school attendance. Although *Bolsa Família* could be considered primarily a motivation finding, I keep this account here because it provides a baseline form of school-to-home linkage that is structural and attendance driven, which helps distinguish it from the learning-focused linkage created through the theremin artefact. This system links family income to participation in school-related activities and compliance with educational requirements, creating an extrinsic motivational structure that influences behavioural engagement (Fredricks et al., 2004; Tamura et al., 2022). Tamura et al. (2022) argue that extrinsic reasons (like attending because of *Bolsa Família*) sustain nonautonomous participation. According to the science teacher, this was a major reason why students attended school. Although this conditionality creates a link between school and home, it does not directly promote the transfer of school learning into everyday life; instead, it positions the school as a gatekeeper to essential family resources, centring on structural rather than educational connections between these spaces.

In contrast, the workshops opened opportunities for the active use and sharing of learning across contexts, offering a more educationally meaningful form of connection, such as building and owning a functioning artefact; applying physics/music concepts with one's hands; explaining how it works in plain language; maintaining collaboration when groups were disrupted; retrieving technical information to answer family questions; and shifting from an extrinsic, attendance-driven link to interest-driven participation. Later, through the workshops, students were able to build additional connections between school and community by bringing their theremins home and involving family members in their learning. When students took their theremins home, further opportunities arose: to demonstrate and perform; to spark family talk and curiosity (and, at times, annoyance); to teach siblings and caregivers; to explain phenomena, such as the instrument being louder in the dark; to negotiate storage and safekeeping; and even to sell the artefact to a friend – concrete signs that practice was extended beyond the workshops. The theremin shifted the picture by enabling students to become authors of a functional object they could touch, hear, and explain, making school learning concrete.

My comparison in this case is not “*Bolsa Família* vs. theremin” as two equivalent attendance motivators. Instead, I treat *Bolsa Família* as a structural reason for being at school, while the theremin is analysed as a mechanism for making learning usable and shareable beyond school. In other words, the workshops provided one opportunity to change the quality and direction of the school-to-home connection. The cold morning episode is included as a limited indicator of willingness to attend a specific workshop session, not as evidence of a general shift in school attendance.

After the pandemic, many students returned to school not for academic reasons but to reconnect socially. As the science teacher observed, what students missed most was peer interaction, not learning, indicating that their sense of school membership was rooted in relationships rather than formal education. While this emotional and social engagement supported school attendance (Fredricks, 2022), it did not translate into cognitive engagement. Fredricks (2022) explicitly treats emotional/affective engagement as students' feelings of belonging and relationships with peers/teachers and behavioural engagement as observable participation such as attendance; however, in this scenario, social reconnection (emotional/affective) supported showing up (behavioural) without, by itself, producing cognitive engagement. School content continued to feel disconnected from their lived experiences, limiting the potential for learning to be sustained across settings. This distinction also helps interpret why teacher–student relationships matter: beyond peer belonging,

relationship quality with teachers has been linked to adolescents' engagement and adjustment over time (Hofkens & Pianta, 2022).

Despite social bonds and external incentives like the *Bolsa Família*, students often viewed school knowledge as abstract and irrelevant. This reflects Tobias's (2017) critique of educational practices that fail to contextualise learning in everyday life and reinforces the idea that engagement requires more than presence. It requires relevance. Tobias (2017) critiques technicist approaches that treat technology as tools detached from social, cultural, and musical contexts, urging educators to reconceptualise curriculum and resituate technology toward social issues. This is relevant to my finding that students explicitly framed science as "not necessary" and "not used anywhere". Tobias helps me interpret that stance is a problem of decontextualised practice where school tasks do not connect to students' everyday concerns or social worlds.

Tobias (2017) contrasts "assimilation" (using tuning apps, notation software, and automated assessment without altering practice) with "integration" (such as iPad sound processing yet remaining compartmentalised) and "distinction" (such as designing instruments with sensors and circuits, taking on multiple musical roles, and linking music with science and community), arguing that relevance emerges when technology mediates inquiry and experience rather than reproducing the status quo. In my data, the optical theremin aligns most closely with "distinction" because students built a device with sensors and circuits, then used it to demonstrate and explain ideas to family and peers. This mattered because it turned "school knowledge" into something that could be shown, discussed, and tested in everyday settings, which is the kind of socially situated relevance for which Tobias (2017) argues. The knowledge gained in class, in the postpandemic context, appeared detached from the communities it served from the students' point of view.

The workshops began from this point of disconnection. Initially, students showed rigidity in group work, revealing the absence of a collaborative learning culture. The opportunity to engage with both creative and technical components led to greater enthusiasm and participation. This was evident when, at the start of electronics, students arrived keen to begin building. The class was almost full on a 2 °C morning; they stayed on task, asked questions while soldering, and helped peers, which were all signs of renewed, hands-on participation. As Tamura et al. (2022) explain, hands-on and personally meaningful activities can reignite motivation, particularly when students experience a sense of ownership over their learning. Although the detailed "hands-on motivation" finding is developed in Section 6.9, I refer to this concept here

because hands-on ownership is also a precondition for school-to-home transfer. Without a student-owned artefact and confidence in using it, there is less reason and fewer opportunities to demonstrate, explain, or extend learning beyond the workshop. According to Tamura et al. (2022), autonomous forms of self-regulation are supported when curiosity and intrinsic motives connect affective aspects of learning with motivation. Under such conditions, hands-on work that gives students a sense of ownership tends to reignite engagement.

The combination of music and the arts, as proposed by Chu et al. (2019), created an interdisciplinary experience that supported both cognitive and emotional engagement. Students' willingness to participate, even in unfavourable conditions, demonstrated their investment and highlighted the potential for reestablishing learning as a meaningful, connected practice. This indicator was evidence that the prior artistic phase had already framed construction as meaningful (Research journal, August 19, 2022; see Figure 36).

Students were eager to show their instruments to family members, whether by demonstrating how they worked, explaining their purpose, or using them in humorous or casual ways. As in the examples cited previously, a student used it to wake his mother; cousins crowded round to "have a go"; a stepfather linked it to a possible future job; one student hid it to avoid being woken by others; another's mother initially thought it was stolen; siblings played with it; and one student sold it for R\$5. These actions illustrate what Lowrie et al. (2018) describe as learning that moves across symbolic, physical, and social domains. Their ERA model emphasises how learning should begin in lived experiences, progress through reflection or symbolic understanding, and culminate in socially relevant applications. The progression observed in the workshops – from experimentation to explanation and sharing – follows this sequence closely, suggesting that the theremin supported learning that was both situated and transferable. In ERA terms, students first experienced the theremin through playful exploration and performance in the artistic phase; then represented ideas symbolically as, for example, drawing/composition on A1 posters and putting "how it works" into plain language; and finally applied their learning by demonstrating, teaching, negotiating storage/safekeeping, and even selling the artefact at home and in the community. Lowrie et al.'s ERA likewise cycles from lived experience to symbolic representation to application with families/community, providing an explicit template for such movement across domains.

Similarly, Zhai et al. (2018) observed that when students use technology on their own outside school hours, their understanding and motivation increase. Specifically, they report that after-school remediating activities (student-initiated use outside class) are positively correlated

with physics achievement, whereas teacher-assigned activities show no significant correlation and learning-aid activities are negatively correlated. They further note that who initiates the use matters for its impact. This pattern was seen in the workshops as students took initiative with the theremin beyond the classroom. This kind of student-led use aligns with higher levels of technology integration (Zhai et al., 2018). These levels of technology integration are linked to deeper engagement, especially when students voluntarily adapt technology to meet their own learning needs. Even when students “repurposed” the artefact at home (as a playful object, to tease family members, or even to sell), this indicated flexibility of meaning and showed that what was learned at school had acquired practical significance in different environments, suggesting a shift toward real-world applicability and empowerment through action.

The observations also support Tan et al. (2013), who show that interest in science can grow in several settings – not only in formal lessons, but also in informal spaces and at home. The authors explicitly analyse science classrooms, after-school science clubs, and family/peer settings, and argue that girls “craft an interest in science” (Tan et al., 2013, p. 1146) through out-of-school figured worlds (for example, cooking club, Saturday family science), which then shape participation back in school; these nonschool contexts provide resources and positioning for engagement. In this study, some students explained technical elements of the instrument to siblings or other family members, showing that school learning was being reinforced and used across contexts — for instance, a student explained to his mother that the theremin sounded louder in the dark, and another taught an older brother “how it works”. The act of explaining the artefact or repurposing the instrument suggests that some students began to take on roles not typically assigned to them in formal education settings, positioning themselves as knowledgeable and capable. For students with a history of low academic confidence, these moves were especially significant, suggesting a shift in positioning from uncertain participants in formal lessons to confident users and interpreters of technical knowledge.

Although some family members were sceptical about the theremin, students proudly presented their work, indicating that the project contributed to a sense of achievement and belonging. For example, students demonstrated the artefact to mothers, cousins, grandmothers, and stepfathers, and one student noted that his mother “went around showing it to everyone”. This aligns with O’Neill’s (2015) view of transformative engagement where students connect school learning to personal experience. O’Neill frames “transformative music engagement” as beginning with learner-centred, reflective inquiry into “issues that interest and matter to them” (O’Neill, 2015, p. 389), leading to action and empowerment in real-world contexts. The workshops prompted meaningful interactions at home – even in cases of playful

“beeping” pranks that annoyed (and amused) caregivers, and mothers insisting the device be put away. As Tamura et al. (2022) suggest, when students feel ownership over their learning, their motivation increases as they show engagement organised around autonomous self-regulation, with curiosity and intrinsic reasons bridging affect and motivation. This pattern is consistent with the sense of ownership observed in the workshops – a pattern evident as students explained and demonstrated their devices beyond the classroom.

In short, relationships and social interest were the first reasons many students took part in the project. According to the science teacher’s initial interview and the students in the initial focus groups for Years 8C/8D who repeatedly said they came for “food and friends”, signalling socially driven participation rather than academic motives, the type of activity — involving building, experimenting, and sharing — helped expand their interest and thinking. As the workshops progressed, students began to apply what they had learned in their daily lives. This kind of movement suggests that certain types of projects can help school learning continue in everyday experiences.

The learning experiences described in this chapter also connect to the structure of student engagement presented in my theoretical framework. The theremin’s movement between school and home, and the students’ willingness to demonstrate, explain, or even commercialise it, displayed agentic engagement where students actively influenced their learning process. This was visible when students took initiative to share their knowledge outside school, acted independently in exploring the instrument further, and shaped how their peers or family members related to the workshops. According to Reeve (2012), such behaviours reflect a student’s perception of autonomy and self-direction, which are essential for sustained participation. Reeve characterises agentic engagement as students’ constructive contributions to the flow of instruction, such as asking questions, expressing preferences, and offering suggestions, and treats it as a proactive, transactional way students shape their learning environment. He also shows that early agentic engagement predicts later increases in perceived autonomy support, indicating that students’ initiatives can open teachers’ motivational responsiveness and help sustain participation through autonomy. Seen this way, the theremin’s movement between school and home supports a view of engagement as a dynamic developmental process, shaped through ongoing transactions across contexts such as school and family (Wang et al., 2019).

Uptis (2001) similarly frames music education through the linked influences of heritage and technology while keeping social participation at the centre of what music does in people’s

lives. She argues that technology is not only an “add-on” because some tools can enhance and even transform inherited musical customs. Read this way, the theremin can be treated as a technological artefact that carries participation with it. Students’ willingness to share it, explain it, and demonstrate it beyond the workshop can therefore be read as participation in music-making and meaning-making rather than as an “extra” activity outside the project.

In summary, the theremin workshops created new connections between school, home, and community, and helped students see themselves as capable of using and sharing their learning beyond the classroom. In effect, the workshops did more than connect these spaces; they converted classroom knowledge into lived practice by placing a self-built artefact in students’ hands, prompting performance, explanation, teaching, and even a sale at home, thereby strengthening relevance, agency, and continuity of participation. Drug-related expulsions interrupted promising trajectories and dismantled groups, yet peers were able to redistribute tasks to sustain continuity. The drugs issue produced a negative vector of community → school, intruding into their education and undermining participation, whereas the workshops generated the inverted vector of school → community in a positive way as students carried a self-built optical theremin into their homes, explained it, and put school learning to work with family and friends.

6.11 Shift in Dynamics and Students’ Participation

This Section 6.11 examines how classroom dynamics shaped students’ participation across the project and how these patterns changed over time. In this Section 6.11, “dynamics” refers to recurring patterns of interaction that influenced engagement during the workshops, including how students responded to task demands, how peer groups formed and operated, and how teacher support and workshop structure shaped participation.

I describe these dynamics in terms of adaptive and maladaptive behaviours. Here, adaptive behaviours align with positive dynamics because they supported engagement and progress, such as persistence, help seeking, collaboration, and reentry into tasks after difficulty. Maladaptive behaviours align with negative dynamics because they constrained participation or disrupted learning, such as withdrawal, avoidance, resistance, and disruptive conduct.

To make the progression clear, I present the evidence in a timeline: before the workshops, artistic workshops, electronics workshops, and after the workshops. The “before the workshops” subsection (Section 6.11.1) provides a brief baseline for interpreting later changes.

The main focus of this section is the shift in participation during the artistic and electronics phases, and how teachers described those changes after the project.

It is also important to clarify that the issues of disengagement and disruptive behaviour discussed here were not representative of the whole cohort. According to the teachers' estimates, only a small proportion of students, approximately 10% across Year 8, were consistently disaffected or disengaged. Most students showed typical patterns of participation during regular classes and the workshops.

6.11.1 Before the Workshops

This Section 6.11.1 provides a baseline for understanding later changes in participation during the workshops. Positive dynamics were evident in the preworkshop interview with Year 8B, mostly relating to mastery-goal orientation in the arts. When students were asked how they felt about art as a subject, their answers ranged from "I like it. The drawings", "I like it when the teacher gives us drawings to do", and "I prefer when the teacher gives us the drawing. Because it's easier" to "Then we try harder, we want to improve in drawing, to get better" (Year 8B, initial focus group). These responses indicate that some students viewed improving their drawing skills as a clear objective they were motivated to achieve. However, this effort was not something constant as, according to one student, it would depend on what they were drawing. Another commented that "For me, it doesn't (make sense)" (Year 8B, initial focus group).

An element of adaptive dynamics from the students' out-of-school environment was shown in the form of an openness to musical forms or genres that were not common in these students' daily lives. According to the arts teacher, the students "come from a marginalised culture ... so they end up having a less prejudiced view than people from a different social environment who appreciate other types of music. So, they end up offering a greater openness" (Arts teacher, initial interview). He noted that this openness may reflect a form of cultural resilience in a marginalised school context, which supported experimentation with unfamiliar musical genres.

The science teacher reported that a crucial factor for adaptive dynamics in the classroom was the students' out-of-school experience. For example, when a student had a family member who worked in a trade related to electricity or electronics, this student would become more participative in science classes that discussed resistance or related elements. According to the science teacher: "Sometimes there is a student who, you know, you talked about resistance, whose father works with those things, and sometimes he helps. So sometimes they say some

things. When we approach this kind of content, that student participates more” (Science teacher, initial interview). However, this was not the case for most of the students for whom subjects like electricity and electronics were beyond their lived experience.

From the science teacher’s perspective, one factor that kept students who were less engaged with academic content coming to school was the opportunity to socialise with their peers: “So, they come to school, but for them, school is a place where they can socialise¹⁷” (Science teacher, initial interview). However, as she mentioned, they were not the whole representation of students. “Of course, I am generalising. There are those students who really come to study, and they are the ones who motivate us to continue ‘fighting’”¹⁸ (Science teacher, initial interview).

On the other hand, the baseline context prior to the workshops also involved negative dynamics. These included difficulty understanding abstract musical concepts, difficulty retaining knowledge, learned helplessness, and uneven participation where some students were engaged while others were disengaged. Maladaptive behavioural engagement was also part of this context. In this chapter, I use “maladaptive” to refer specifically to negative patterns of behavioural engagement, such as resistance, disruptive conduct, and withdrawal, that constrained participation or escalated conflict.

A baseline issue raised by the arts teacher was uneven engagement across the room. He described a common classroom pattern: “a student in the back, right, doesn’t do as much as the student in the front, but I know that sometimes he ends up putting in more effort to do the little he does than the student who ends up doing everything” (Arts teacher, initial interview). He also noted that when looking at the class as a whole, “There will be students who do (the activity), and students who don’t ...” (Arts teacher, initial interview).

The difficulty in understanding and retaining abstract concepts was raised by both teachers prior to the workshops. When asked about students’ understanding of music, the arts teacher said music was the most difficult area he taught because it required grasping abstract sound concepts. He asked, “what do they understand by music?” and explained that students often linked “music” only with poetry and struggled to separate lyrics from sound: “for them to dissociate the spoken part from the sound part, that’s already a revolution” (Arts teacher, initial

¹⁷ More on this matter was discussed in Section 6.10 – Students’ learning and experiences extended beyond the workshops – Therein the artefact as a bridge.

¹⁸ The teacher uses “fighting” metaphorically to describe their ongoing effort and dedication to teaching and supporting students, even when faced with obstacles such as student disinterest and attendance issues.

interview). He added, “not that they can’t, of course, they can, but you have to insist a lot” (Arts teacher, initial interview).

This difficulty with abstract concepts also affected project work in the arts. For example, the arts teacher described building a Pythagorean monochord to address frequency, notes, and octaves, and said that although students could build it, “They did it for fun, but they didn’t understand practically anything about what was being done” (Arts teacher, initial interview). He felt students did not grasp terms or the musical meaning of diatonic and chromatic relationships.

The science teacher linked difficulty with technical terminology to broader difficulty with text interpretation, and suggested students relied heavily on visual supports. She described how external evaluations without images made comprehension harder: students “get lost in the text. When you bring an image, it makes it easier, but external evaluations don’t come with images” (Science teacher, initial interview).

Limited retention was also described as affecting classroom participation. The arts teacher said that when teaching music, he had to repeatedly revisit basic elements: “Melody, harmony, and so on ... And they never remember!” (Arts teacher, initial interview). Although difficulties with abstract musical concepts can occur in many contexts, they appeared more pronounced in this cohort based on my prior experience running similar creative workshops with students of the same age before the pandemic.

Regarding maladaptive behaviour, when asked about how well disaffected students understood the role of school, the science teacher explained that these students often actively resisted teacher instructions and behaved disruptively, which could lead to suspension. She noted that “sometimes, they gather all this anger, all this lack of understanding, and throw it at the teacher” (Science teacher, initial interview). These behaviours could escalate to the point where another staff member needs to step in. She explained: “So, sometimes they challenge us, sometimes they make comments about others, and unfortunately, in some situations, we have to bring it to the pedagogical team” (Science teacher, initial interview).

Maladaptive behaviours were also observed by the students. The situation of behavioural disruption was mentioned in the focus group with Year 8C, where some students complained about the method used by the teacher to retain knowledge, which, in their point of view, did not correspond to how they would be evaluated: “Yeah! Why do we have to write in art, if art is a subject that will evaluate, uh, like drawing!” (Year 8C, initial focus group). This student was reminded by their peers that they were writing a lot because that was a discipline action for talking too much in class:

- S1: Because we're being punished because we didn't stay quiet.
- S2: Ah, you're the one who doesn't stay quiet!
- R: So the punishment for you not staying quiet is for you to write?
- S3: Mmm (positive affirmation). (Year 8C, initial focus group).

Manifestations of maladaptive behaviour were also described in relation to boundaries, discipline, and family and school pressures. The science teacher linked some disruptive and sometimes aggressive behaviour to weak or contested boundaries at home, and to parental fear of child protection involvement. In her account, these pressures reduced some parents' willingness to impose limits and contributed to the school taking on a "shock absorber" role in managing conflict (Science teacher, initial interview).

Students adverse to the school system were identified by both teachers. When asked whether they identified disaffected students among their classes, both teachers indicated that they did but not in a number necessarily greater than expected in a general population. According to the arts teacher, "Yes, definitely, there are some. There are a few, but there are some" (Arts teacher, initial interview), which was similar to the science teacher: "Let me think class by class ... Let's say out of all the 8th grade classes ... Let's say about 10% ... combining all of them" (Science teacher, initial interview).

The science teacher also provided additional information regarding her overall perspective of the participant students in the classroom, which were not the other 90% who were not disaffected. According to the literature used for this work, participation is not necessarily the opposite of disaffection. In this case, participation and engagement have a duality¹⁹ with disengagement, not disaffection. When asked about the number of engaged students, she responded that: "If we look at a classroom, 5 or 6. Depending on the class, 1 or 2. Out of 20-30 students" (Science teacher, initial interview).

This challenge of overall participation among students was also mentioned by the arts teacher. In addition, although there was a variation in the percentage of students who engaged in the arts and science classes, there was still a percentage of students who were not necessarily disaffected but were not engaged and did not produce much. About the percentage of participant students in his class, the arts teacher stated: "In general, you will have these disparities. There's nothing that can be done about it; that's just how it is. But let's say, about 60% of the students are engaged ... 60-70%, you have a higher adherence, and then there are

¹⁹ Duality as in two contrasting parts that are understood as antitheses of one another, or opposite poles of the same issue/concept.

those 20–30% who don't produce much, you know" (Arts teacher, initial interview). It is important to note that these figures reflect the teacher's own perception and are not based on formal measurement or quantitative research but, rather, on his day-to-day classroom experience.

A sense of learned helplessness was found in Year 8B. The students shared that they often found enjoyment in having vacant classes – *aula vaga* – that happens when a teacher does not come to school. As a student mentioned: "I like it when there's a vacant class" (Year 8B, initial focus group). Vacant classes occurred frequently because teachers were absent, such as for medical reasons, and there was no relief teacher system as in New Zealand. If, for any reason, a teacher could not attend, students simply did not have that class. For instance, one student mentioned having only one class out of five on a Thursday, with the remaining four periods left vacant due to the absence of mathematics and Portuguese teachers. During these times, if no activities were assigned, students were left with nothing to do, often spending their time outside or engaging in idle play. When asked if there was no assignment or anything left by the teacher, what did they do during the vacant class, the students replied:

S1: Nothing.

S2: We stay outside.

S3: Playing.

S4: Sometimes, because there are people who stay inside reading. Like (suppressed name) and (suppressed name).

S5: Nothing much.

S4: We stay there, bothering each other, running around, because we have to run around as they (other students) bother us... (Year 8B, initial focus group).

This pattern of behaviour exemplifies learned helplessness as students repeatedly experience situations where they have little control or agency over their learning environment. The frequent vacant classes and lack of assigned activities leads students to become passive, disengaged, or resigned as they learn that their actions have little impact on the outcome. Rather than being a reflection of student apathy or lack of motivation, this dynamic is largely a consequence of structural issues, such as inconsistent teacher attendance, scheduling challenges, and a lack of contingency planning for teacher absences, within the Brazilian public education system. As a result, students adapt by seeking distraction or simply waiting for time to pass, reinforcing a sense of powerlessness over their educational experience.

6.11.2 Artistic Workshops

During the artistic workshops, I noticed uneven classroom dynamics. This was found in the initial free production without preestablished rules. There were students who engaged well in the drawing activity; however, there was also a considerable number of students who did not like to draw freely or had a profound lack of interest in doing so. Some of these students had blocks, fear, laziness, or a lack of interest or creativity in producing any kind of artistic work. As per a note in my reflective journal: "Children who do not like to draw freely catch my attention as this would be one of the most basic forms of expression" (Research journal, June 27, 2022). Even when given the chance to produce art without predetermined rules, they were apathetic about drawing.

Research in developmental psychology has documented that, around ages 12–13, young people often become increasingly self-conscious and concerned about peer judgement, which can lead them to avoid activities that might expose them to criticism (Elkind, 1967). In the context of artistic activities, studies have shown that children at this age tend to become highly self-critical of their drawings, frequently erasing and expressing dissatisfaction with their work, and often feeling embarrassed to draw in front of others (Lowenfeld & Brittain, 2000; Mortensen, 1984; Skybo et al., 2007). However, the number of drawings and how interested the students were in making them was significantly lower than in my prepandemic workshops with students of the same age in other schools, suggesting that contextual factors, such as pandemic-related disruptions, may have further reduced students' willingness or ability to engage in creative artistic activities.

Although progress became visible later in the artistic phase, it was uneven. By the later sessions, more students were willing to try short performances, volunteer brief contributions, and accept scaffolds that reduced performance pressure, but spontaneous storytelling still triggered reluctance for many students. In the Year 8D class, the students were hesitant and initially unwilling to participate, even after I explained the activity and gave examples of how they could approach it. To make the students feel more at ease, I offered to share the task with them – telling the story while they created the sounds, or vice versa. For those who still felt uncomfortable telling stories, I suggested, "Come here, I'll show you some general gestures and cool possibilities with the theremin" (Research journal, July 6, 2022). They accepted and were able to participate once the demands of the activity were reduced. Other students, who had been more active since the beginning of the workshops, engaged fully and created their own stories.

However, the overall participation of the class was much lower in this spontaneous creation activity. At that moment, I could perceive how much the stance of being the passive content absorber for two years was affecting them: “They look at and live completely immersed in the digital world and have lost their creative capacity ... These are children who struggle even with spontaneous storytelling and play, so I feel a bit sorry for them” (Research journal, July 6, 2022) as this instance illustrated their reluctance to actively engage in creative processes.

The initial refusal to engage was not due to a lack of ability. Some students who were initially withdrawn eventually gave in to their curiosity, tried the instrument, and produced satisfactory creative results. In one specific case in Year 8A in the theremin conversation activity – an exercise where students were invited to create a “musical dialogue” using the theremin, responding to each other’s sounds as if having a conversation – only three students participated, and, of those three, two engaged in a very interesting conversation. They responded musically rather than reacting at random. One of the participants even found it very “cool” (their own words) to play. This person had not played any instrument before and was initially reluctant to try it out, but when they did, they played well. They “played well” in the sense that they used turn-taking, responded to each other’s gestures with intentional changes in pitch and dynamics, and sustained a coherent back-and-forth exchange rather than producing random sounds. As I noted in my journal: “This shows that they are capable of creating, of making artistic creations, of doing something creative very well. And the reason they didn’t do it wasn’t a lack of ability, but rather an aversion to creation” (Research journal, August 5, 2022). These students were in the position of content absorbers, not creators. I recognised the need for the students to reclaim their creative potential. At this stage, I remembered something I heard from their coordinator, right before the workshops. She told me they were dreamless children, and I made this note: “So, when the coordinator told me they are children without dreams, it’s also in this sense – children who don’t have the desire or energy to tap into their creative potential” (Research journal, August 5, 2022), which, in this scenario, was proven to be true.

Student behaviour gradually became more adaptive as the artistic workshops progressed, reaching its peak during the electronics component as initial reluctance gave way to active participation. This shift was noticeable during the final drawing activity when the introduction of the “drops” activity inspired by Carolina Eyck (2016) helped the group loosen up and engage more fully. The drops activity is a music education game on the theremin in which students interpret different-sized water drops, represented by marks on paper, using musical gestures on the instrument.

One of the main reasons this activity was effective is that it provided a highly concrete and visual way for students to understand and perform basic musical elements. In the drops activity, students were presented with drawings of water drops of varying sizes and positions on the page. The size of each drop indicated the intensity of the note to be played – a large drop was to be interpreted as a loud (strong) note, while a small drop represented a softer (quiet) note. Additionally, the vertical position of the drop on the page corresponded to pitch: the higher the drop, the higher the pitch, and the lower the drop, the lower the pitch. This visual mapping allowed students to grasp abstract concepts such as dynamics and pitch in a tangible way, making it easier for them to understand and reproduce these elements on the theremin.

This example could be found in my field notes. On the day of the final drawing activity with Year 8D, the class was quiet, and my impression was that they had been reprimanded by many educators on that day. Their drawings would always be returned to me at the end of the classes, so I knew that they would not get lost. I returned their drawings so they could finish and present them to their peers. As I wrote in my reflective journal: “To add a bit of refinement to the playing, I decided to do Carolina Eyck’s drops activity. Two of the more active students in the class decided to participate. As they started the activity, the group began to loosen up” (Research journal, June 29, 2022).

Flexible planning was essential for making necessary adjustments as the workshops progressed. This flexibility in the process facilitated student participation. By being able to adapt activities, like having students reproduce drawings based on the sound-visual output of the theremin, I could address their reluctance and encourage active engagement. For example, in Year 8D, during the activity that involved playing their drawing for the class, most of the students did not want to play or show their drawings to the class. So, I proposed that the owner of the drawing play their piece while another student, unable to see the drawing, should reproduce the artwork on the board based solely on the sound-visual result of the theremin, as seen in Figure 37. This playful element broke the author’s block about showing the drawing for some students, and they did not mind revealing it to the class to compare it with what was done on the board. “By becoming part of the process and not just the end result, these students became participative and active” (Research journal, June 29, 2022).

Figure 37

Students Playing their Own and Each Other's Music



Even so, participation was not always as fluid in the artistic workshops as it was in the electronics sessions. For instance, although I initially planned for students to create their own music and play each other's compositions individually – something that had worked well in previous workshops – this approach was less effective here. To encourage involvement, I instead grouped students and had them play each other's pieces within their own groups, which fostered a greater sense of belonging and collaboration. As I reflected: "When you work in a group, you have a sense of belonging, right? So, you're no longer alone. You become part of a group, part of a set of people doing the same thing" (Research journal, July 4, 2022).

In this scenario, I figured intergroup exchanges would not work because sometimes even forming the groups was challenging. Occasionally, there were individuals, pairs, or even quintets, so the group sizes varied a lot. Reflecting on this, I wrote in my research journal: "What mattered to me was that they functioned and produced something with a peer" (Research journal, July 4, 2022).

During the artistic workshops, even when students were allowed to choose their own groups and group sizes during the drawing activity, passivity was still present. Despite having autonomy and encouragement to play and engage with the instrument, active participation remained limited. In my experience, this passivity seemed to stem from the lockdown period when students became accustomed to the online format of education – primarily watching and receiving information rather than actively participating. To try to counter the students' lack of engagement, I shifted the focus of the workshops to include fewer passive activities – sit and watch – to more hands-on, interactive experiences. As noted in my reflective journal: "Even though the instrument is interesting, why would I give them another thing to watch [...] if I can give them more things to do?" (Research journal, July 4, 2022).

Understandably, at certain times, the students wanted me to play. They would ask: “Teacher, play a song for us to hear how it sounds, play a different song” (Research journal, July 4, 2022). In those times, I played a song that I had already prepared. However, whenever I could, I left much more time for them to play, experiment, and explore the instrument in an active way rather than letting them passively watch.

Even with an emphasis on making them participate more by playing the instrument, not all sessions proceeded smoothly. Despite offering my assistance, it was difficult to get them to engage at times. The students’ engagement and behaviour were variable, which sometimes hindered the completion of the activities. For example, one day, Year 8C were extremely disruptive and unmanageable, and they were unable to complete the workshop activities that I had planned. They did not want to participate in the activities, even with encouragement to pair up or “do half the work – telling the story while the teacher played, or vice versa” (Research journal, August 1, 2022). Of the 22 students present, only four participated, and those who did participate were bothered by the behaviour of their classmates as some laughed and shouted or hit each other – kicks and punches – in attempts to be humorous.

6.11.3 Electronics Workshop

The pattern of maladaptive behaviour was broken only in the electronics workshops. During this phase of the research, students worked in groups to build an optical theremin, which required collaboration, hands-on problem solving, and active participation. Across all the Year 8 workshops, students who typically lacked interest in school – students who could not sit still, did not want to participate, or were aggressive with peers – engaged at some point in the process, stepping up to develop the skill of building the instrument. During the electronics workshops, two patterns of behaviour stood out to me: students who were typically described by teachers as disengaged became highly involved in building tasks, and girls participated actively in the STEM activities. Interestingly, in Year 8C, for example, these patterns converged in a single individual. This student, Ana, who usually showed little interest in school and tended to avoid academic subjects, demonstrated significant engagement and curiosity during the construction process. As observed and reported in my reflective journal: “With the 8C class, I encountered the same “event” as in previous years. Ana, who is disengaged and tends to avoid school subjects was very participative and curious about the construction process. This has transitioned from isolated cases to a pattern” (Research journal, August 29, 2022).

In one episode, Ana from 8C, who stood out in the electronics stage, was seen outside her class and wandering around other classrooms because she did not want to go to science

class, which is one of the main topics covered in the electronics workshops, even with the teacher calling her in. Ana eventually entered the class after being evasive and saying she needed to wash her hands, causing some trouble for the teacher to make her go inside. Although written science would distance Ana from school and the classroom, practical science, where something tangible is built, integrated her and made her participative (Research journal, August 29, 2022).

I could see Ana moving from disaffection towards learning and demonstrating greater engagement and achievement in the workshops. Unfortunately, she was expelled due to drug dealing soon after. This case illustrates both the potential for positive change within the workshop context and the ongoing challenges faced by students outside the classroom. As documented in my notes: "Apparently, the only place Ana was doing well was in my workshop, which is interesting data" (Research journal, September 19, 2022).

The idea that everything is data was one of my guiding principles as a teacher-researcher during the process. When things did not go as planned, I could write and report about it and continue with the research. As a researcher, I treated this episode as data about the limits of school-based change in a high-pressure context. At the same time, as a teacher, I found it difficult to stay emotionally distant because I wanted her engagement to be supported beyond the workshop. About this, I wrote: "It's interesting because it shows Ana was being rescued, but it's sad because she was relocated to another school in the middle of this rescue process. We end up losing a student who could have been fully rescued" (Research journal, September 19, 2022).

This event showed that the workshops were successful in engaging a student who was disaffected and uninterested in school. However, while the workshops are an excellent tool, they are only part of the solution. A student like Ana needs to be supported in multiple ways. Although this intervention was not enough to fully support her, it served as a starting point. Ana began to reengage with school. Another loss was the valuable insights she could have shared at the end:

Ana was part of the focus group, so she would have had a more in-depth discussion later. Unfortunately, it didn't come to that. Although this outcome is valid data for understanding the limits of a classroom-based intervention in this context, it saddened me because I was happy with her progress in the workshops. (Research journal, September 19, 2022)

Unfortunately, this was not just one isolated instance. Another student from a different class, Rafael, was also expelled. His situation was quite similar to Ana as he was also expelled for drug dealing. Both were doing very well in the workshops, interested in the electronics part, and working with enthusiasm. Rafael had a family history of drug dealing as his mother and grandmother had been arrested for the same issue and had been recently released from prison before this episode. Like Ana, Rafael, from the Year 8A class, was also doing very well in the workshops before he was expelled. Rafael was interested in the electronics workshops and had been working with enthusiasm.

6.11.4 After the Workshops

The postworkshop interviews with the arts and science teachers supported the observation I had made about the change in student behaviour during the workshops. When asked how the students' engagement in arts classes evolved during the workshop process, the arts teacher replied positively, saying that "There was an improvement in the sense that they became more participative, in some way" (Arts teacher, final interview). In his account, this does not mean they "became 'good' students. 'Good' in quotes, within the idea of the system. Within the idea of all that is expected of a student inside the school system" (Arts teacher, final interview) but good in the meaning that they became more active.

For the arts teacher, this activeness made a profound difference when considering completely disengaged students. As he told me: "Like, some of them, in particular, really didn't produce anything in the classroom" (Arts teacher, final interview) before participating in the workshops. He gave me a specific example of a disaffected student who did not produce anything at all in the classroom but, after the electronics component, he started doing "something" in the teacher's own words. According to him, that student "still doesn't follow through from start to finish, but at least he picks up his notebook and starts working. And that's a big deal because he didn't do that before" (Arts teacher, final interview).

The previous behaviour pattern that this student presented was of resistance, saying things like "Oh, I'm too lazy" or "Oh, I don't know..." and, despite his incomplete participation in the classroom, the arts teacher says that: "I have some basis to justify a grade for him. You know? It's something. I can get something out of him" (Arts teacher, final interview).

Following this line of thought of improvement in the arts subject, the major difference observed by the arts teacher was not in the classes that were already perceived as having a higher level of participation but in the ones that the majority of the teachers considered more

disruptive and with more challenging students. In his report, the arts teacher said: “Not that the other classes didn’t also improve. The other classes did too, of course, but they were already more focused, so their day to day didn’t change as much as it did for these other two classes, which are more challenging” (Arts teacher, final interview).

One of the major differences observed by the arts teacher was when students needed to follow a step-by-step process or instructions. According to him, the steps required to build the theremin were responsible for this improvement. As he said: “I noticed that this quality became more pronounced in them. Especially in listening to what we say. Following instructions. That was much more difficult before. Now I notice that ... particularly in step-by-step processes, there’s been a significant improvement” (Arts teacher, final interview).

6.11.5 Discussion On: Shift in Dynamics and Student Participation

The findings presented in this Section 6.11 show that students’ engagement and behaviours are shaped by their individual characteristics and classroom structures as well as by broader sociocultural factors. This pattern is consistent with the multidimensional model of engagement described by Fredricks et al. (2004) and further developed by Griffiths et al. (2022), which emphasises that behavioural, cognitive, and emotional aspects of engagement are influenced by both personal and contextual variables, and treats participation as shaped by classroom practice, tasks, peers, and wider school structures and routines. In this cohort, teachers described a small minority of students as consistently disaffected, a small subset as strongly participative, and a sizeable middle group as showing low, but not oppositional, engagement.

Before the workshops, persistent challenges with understanding abstract concepts, retaining content, and passive learning echoed concerns raised by Tobias (2017), who highlights the disconnection between school knowledge and students’ lived realities in underresourced educational systems. Tobias criticises decontextualised, techné-only (skill-based) approaches and invites music educators to consider digitally mediated musical engagement “within the contexts of curriculum as experience and as social reconstruction” (2017, p. 292). Tobias contrasts assimilation, which extends existing practices and maintains the status quo, with distinction, which emphasises what technology uniquely affords and can reshape curriculum, pedagogy, and musical engagement (2017, pp. 293–294).

The difficulty students experienced with grasping abstract concepts and the tendency toward rote participation align with Skinner et al. (2009), who note that engagement can

become superficial when learners are unable to see relevance or meaning in the material. Similarly, the presence of learned helplessness and disengagement, particularly in response to structural issues, such as vacant classes, resonates with findings from Henry et al. (2012) on how inconsistent support and unstable routines contribute to passivity and disaffection. Henry et al. show that early school disengagement, such as poor attendance, suspensions, and course failure, predicts later dropout/risk, reinforcing the role of reliable school structures. In this study, the recurring vacant class episodes illustrate how routine instability can normalise passivity and weaken participation over time. Taken together, this points less to students' ability and more to the conditions around learning: tasks that felt meaningful, continuity from one lesson to the next, and stable routines that made participation easier to sustain. Dropout is often conceptualised as a cumulative process of disengagement rather than a single decision (Rumberger & Lim, 2008).

Finn's (1989) participation identification model helps interpret this pattern by treating participation in school activities as a key pathway through which students may develop identification with school, including belonging and valuing school-related goals. The model also frames withdrawal as a process that can begin with low participation and develop over time. In my data, participation was visible in small actions, such as taking a role, persisting, and helping a peer, rather than in abstract statements about valuing school.

The change in behaviour I observed through this research centred on a shift to hands-on, interdisciplinary work with clear roles and stepwise tasks. As Tamura et al. (2022) argue, hands-on, personally meaningful tasks that afford a sense of ownership support autonomous self-regulation. In this scenario, curiosity and intrinsic reasons helped connect affective engagement to sustained effort and persistence. My hands-on workshops repeatedly elicited curiosity during troubleshooting and led the students to pursue mastery/enjoyment in the task. The combination of music and the arts with science (Chu et al., 2019) provided contexts in which students could test ideas concretely and then articulate them. The "drops" activity functioned as a scaffold that bridged abstract musical concepts through a visual-kinetic mapping, aligning with Lowrie et al.'s (2018) ERA model.

Behaviourally, this design corresponded with observable improvements: students who had previously been passive or disruptive followed instructions more readily, contributed to group tasks, and persisted through difficulties. One example of this was after the electronics phase, when the arts teacher noted a "significant improvement" in following step-by-step instructions. In his account, a student who usually produced "nothing" began to open the

notebook and work. Another example was the scaffolding brought by the drops activity and small-group formats that enabled hesitant students to participate and complete tasks. Girls' active participation in the electronics build was notable, as was the engagement of students previously described as disengaged. For example, girls repeatedly took central roles in precise layout and soldering; in Year 8C, Ana, who was typically evasive in written science, was "very participative and curious" during construction; Rafael likewise worked with enthusiasm throughout electronics. For some, written science pushed them away whereas practical science drew them in, highlighting the role of tangible tasks, peer roles, and visible progress.

Interpreted through the theoretical lens, these patterns include clear instances of agentic engagement (Reeve, 2012): students made constructive contributions to the flow of activity, asked for roles, assisted peers, and proposed next steps. Following Fredricks (2022), this marks a distinction between social/affective energy that gets students in the room (attendance, belonging) and cognitive engagement that develops when students work with concepts, represent ideas, and explain "how it works". Tamura et al.'s (2022) network perspective helps explain the sustainability of these shifts by linking curiosity and intrinsic reasons to autonomy-supportive engagement.

At the same time, there were limits to what the design could overcome. Structural factors like staff absences and routine instability, and community pressures sometimes interrupted promising trajectories and blunted continuity of participation. For instance, Year 8B reported only one of five periods running on a Thursday with the other four being vacant classes; one Year 8C workshop became hard to motivate with only 4 of 22 participating despite pairing/scaffolds; and Ana and Rafael – both highly engaged in electronics – were expelled for drug dealing, abruptly halting their participation. These constraints remind us that classroom design can catalyse change, but ongoing structures beyond the classroom mediate whether change is sustained. These constraints shifted the balance between demands and resources around the workshops, and they also shaped how students interpreted what school was offering them.

Griffiths et al. (2022) argue that engagement research is incomplete if it focuses only on academic behaviours or scholastic incentives because students' beliefs and perceptions about school shape how they interpret and respond to classroom demands, especially when disengagement is entangled with high-risk or troubling behaviours. In parallel, Salmela-Aro et al. (2022) distinguish between a motivational process, in which resources support engagement and well-being, and an energy-depleting process, in which high demands contribute to wearing out

and burnout. In this study, the workshops temporarily increased local resources inside the lesson (materials, peer support, clear steps), but vacant classes, absent students, and expulsions reduced continuity and increased demands at the school level.

In summary, the shift documented in this Section 6.11 suggests that patterns of participation were not fixed. Students who resisted abstract, theory-heavy work often became more participative when tasks were hands on, social, and scaffolded, showing that context and task design mattered for classroom dynamics. This pattern supports my claim that dynamics changed because participation became organised around clearer task demands, visible progress, and peer-supported work, even while broader structural and community constraints continued to limit continuity for some students.

6.12 Creative Troubleshooting and Developing Peer-to-Peer Interaction

During the electronics workshops, creative troubleshooting created situations of practical interdependence, and these situations prompted peer-to-peer interaction. In turn, peer-to-peer interaction supported problem-solving and helped pairs persist through setbacks. In this Section 6.12, I focus on peer-to-peer interaction as collaboration that occurs while students troubleshoot technical problems. This is different from the “group work” theme in Section 6.8, which focuses on whether students worked in groups, how groups formed, and why group work was often avoided. It is also different from the previous theme of “dynamics and participation” (Section 6.11), which traces broader shifts in participation across phases. Here in Section 6.12, the unit of analysis is the troubleshooting episode: how students coordinated actions, shared strategies, and assisted peers while building and testing the optical therein.

The key finding is that technical constraints in the electronics phase required coordination in ways that were not typical of regular classroom group work. Students had to solve concrete problems that had immediate feedback. These tasks made contribution visible and encouraged short cycles of attempt, feedback, and adjustment that peers could observe and support. Some students who struggled with fine motor control or with understanding the steps were still able to contribute because peers redistributed roles and coregulated the task. In other words, participation increased here through practical teamwork.

As background, group work was often avoided in regular classes because teachers anticipated conflict and uneven contribution. For example, the science teacher noted: “I avoid group activities ... Generally, the most I do is pairs because when we put 3 or 4 together ... the

arguments between them are very frequent. They generally can't accept each other's ideas" (Science teacher, initial interview).

Another reason the science teacher, along with other teachers from the school, avoided groupwork was due to the difficulty of assessment. The science teacher stated that group work usually caused confusion and situations such as students telling her: "So-and-so didn't do anything to help; I did everything alone". She continued: "But sometimes that's not exactly what happened. It was the fact that they didn't accept the other's idea, and they did it their own way" (Science teacher, initial interview). This situation then led her to avoid group work.

When I asked how they resolved conflicts during group work, I found that students had very little training in peer conflict resolution, if any. When group problems arose, their responses, such as crying or shouting in frustration, suggested a lack of effective strategies to manage conflicts constructively. When asked how they usually handled these problems, students replied: "One cries and the other ... (laughs)" and "Well, I get angry and start yelling" (Year 8A, initial focus group). These responses revealed an environment where collaboration was more a source of stress than a learning opportunity.

The development of peer interaction was seen more clearly during the electronics workshop. Students who had previously been disengaged showed signs of cognitive and agentic engagement by developing strategies and taking initiative in collaborative problem-solving. Several tasks in the electronics workshop required good fine motor control as, for example, drilling the circuit board.

In Year 8B, students with physical challenges creatively solved the issue by collaborating. Initially, I was worried about this group as some of the students selected for this stage did not have good motor coordination for drilling the circuit, and this could greatly impact the final result. One step required piercing holes in a PCB, and precision mattered because a deviation of a few millimetres could jeopardise the whole circuit. One student had a congenital hand disability. She and her partner worked out an efficient division of roles: she focused on accuracy by locating the marks and stabilising the PCB while her partner applied force and drilled the holes using both hands (see Figure 38). I made a note about this case in my journal: "In no time, the two were making the circuit much faster than I could do alone, and with admirable precision! I was very pleased with the problem-solving quality they demonstrated in class" (Research journal, August 29, 2022). A boy, who had a fine-motor control limitation, picked up on the girls' idea, and he and his partner also managed to drill the board well and with satisfactory speed.

The hands-on and creative nature of these tasks allowed students to rely on one another and reposition themselves as competent contributors.

Figure 38

Students Helping Each Other Building the Theremin



Across the classes, students persisted through the challenges that came with building the theremin. Even after early failures, none quit during the electronics workshop. One example of this was during the final construction of the optical theremin when some students felt frustrated when their instruments did not work at first. In that moment, working in groups played a key role in building resilience. The students who had completed their theremins supported the ones who were still struggling, and this assistance helped keep everyone engaged. In the last electronics workshop for Years 8B and 8C, I saw students who had been extremely frustrated become excited when they finally got their theremin to work. This was a moment when I adopted the insider role, which allowed me to address their frustration and show that not everything in the electronics workshop would be easy. Seeing their happy faces when they succeeded made the moment worthwhile. Taking this point of view, I wrote: “So, no one gave up. I was happy about that. No one quit because it didn’t work out. They helped each other a lot, and I was pleased with that” (Research journal, October 3, 2022). Those who had their theremin ready helped those who did not, as seen in Figure 39. For me as a researcher, this was both reassuring and heartening, as it suggested that this care for one another had become part of their daily lives. As I noted in my journal: “They were concerned about their classmates. It was really nice in that regard. Really nice indeed” (Research journal, October 3, 2022).

Figure 39

Students Supporting Each Other in the Final Stages of the Optical Theremin Workshop



6.12.1 Discussion On: Creative Troubleshooting and Developing Peer-to-Peer Interaction

This section 6.12.1 argues that creative troubleshooting in the electronics workshops structured peer-to-peer interaction, supporting both problem-solving and teamwork. Unlike the previous discussion on participation shifts across phases in Section 6.11, the focus here in Section 6.12 is the mechanism: how students coordinated actions, negotiated roles, and helped each other while diagnosing and fixing technical faults. This mechanism helps explain the broader participation shift described in the previous section because the task incorporated interdependence in ways that reduced avoidance and made contribution visible.

The electronics workshops challenged students to work beyond their comfort zones, facing technical difficulties that could not be solved through rote procedures or copying from the board. Instead, students were required to experiment, adapt, and negotiate solutions – sometimes independently, but often collaboratively. The electronics workshops changed classroom interactions. Group work was usually avoided by teachers because of conflict and concerns about assessment fairness, and by students who preferred to produce “each one in a

corner”. Hands-on tasks with real outcomes gave collaboration a clear purpose. Rather than reproducing uneven participation, students coordinated effort around a shared object (the circuit), with interdependence embedded in the task.

These findings resonate with primary-source accounts of how shared, coordinated activity can reorganise peer relations and cooperative behaviour. Green (2008) documents peer-directed small-group work that can support cooperation, peer leadership, and inclusion, especially of students identified as disaffected. In music classrooms serving students at risk of disaffection, Burnard (2008) argues that community building in music classrooms depends on respect, recognition, and shared power in pedagogic relations. In her account, this can allow students to “cast off their negative reputations” and “reinvent themselves” through “democratic learning” (p. 68), while musical respect is also described as something developed through “negotiating boundaries” in pedagogic relations (p. 72). In my data, this kind of repositioning was evident when peer status shifted through practical contribution during troubleshooting rather than through compliance or teacher direction. In experimental work, Kirschner and Tomasello (2010) show that brief episodes of joint music-making increased subsequent cooperative and helpful behaviour in four-year-old children compared with a closely matched nonmusical control group, suggesting that coordinated, collective activity can strengthen prosocial orientations beyond talk and copresence alone. Relatedly, Hove and Risen (2009) experimentally demonstrate a causal link between interpersonal synchrony and affiliation with higher likeability ratings following synchronous coordination than in a nontapping control condition. Together, these sources help interpret why peer interaction during the electronics workshops shifted from avoidance and conflict towards more cooperative troubleshooting. This broader pattern is consistent with intervention studies indicating that group-based music-making can reduce aggression and support self-esteem among school-aged participants (Choi et al., 2010).

For instance, one student often labelled a distraction in class became the “go-to person” for helping others with soldering, which aligns with Burnard’s (2008) emphasis on how peer status can be renegotiated through participation that earns respect and recognition rather than through compliance alone. While Burnard (2008) and Kirschner and Tomasello (2010) focus on music contexts, my data suggest that similar mechanisms can operate in STEAM making when coordination and shared responsibility are organised around an artefact with real consequences. This shift was visible in Year 8B: a student with a congenital hand impairment paired with a peer to drill holes in the PCB; one stabilised the board while the other operated the tool, and they completed the stage with speed and precision (see Figure 38). A boy with motor-coordination

difficulties then copied the same strategy with his partner. This episode aligns with VanderLinde's (2017) inclusion argument that applying Universal Design for Learning involves reducing barriers by offering multiple pathways for participation, including "seamless access" not only to the curriculum and tools but also to peer interaction. In practical terms, the paired drilling strategy created an accessible role structure that allowed both students to participate fully despite differences in fine motor control.

In the final sessions (see Figure 39), students who had finished stepped into supporting roles, such as testing joints, tracing faults, and encouraging peers through repeated failures, until each device worked. Across classes, no one gave up during the electronics workshop; instead, frustration was channelled into active troubleshooting. These moments prompted cognitive engagement (strategy use, persistence) along with social and agentic engagement (initiative, help-seeking, and help-giving).

This peer collaboration supported social, agentic, and cognitive engagement dimensions (Fredricks et al., 2004; Tamura et al., 2022). As students worked together to resolve challenges – like stabilising the PCB while a peer drilled, testing solder joints, tracing faults, and suggesting reflow/lead swaps until each device worked – they displayed agency and ownership over their learning process. These collaborative episodes were often marked by mutual encouragement and resource sharing, reinforcing Calabrese Barton and Tan's (2018) view that sustained engagement in STEM-rich activities relies on the formation of trust and shared responsibility – or, as they describe, "equitable and consequential making" (p. 160) – with distributed roles, peer teaching, and shared authority/responsibility around artefacts. These collaborations were made easier by the task's affordances: the small, hand-held circuit board could be stabilised by one student while another drilled or soldered, and the theremin's on/off sound made faults immediately visible, giving pairs a concrete problem to work on together. In this sense, the task structured repeated moments of interpersonal coordination, which aligns with evidence that synchronised coordination can increase affiliation (Hove & Risen, 2009).

The findings regarding students' creative troubleshooting and development of new skills during the workshops reinforce the importance of inquiry-based, student-centred learning. Throughout the workshops, students experimented, adapted, and solved problems when faced with challenges such as assembling or debugging the theremin. This aligns with inquiry-rich STEAM accounts that emphasise experimentation, iterative refinement, and communicating models through shared activity (Chu et al., 2019) and with Calabrese Barton and Tan's (2018) emphasis on youth being positioned as designers and leaders rather than passive recipients. In

the workshops, students not only engaged with scientific and artistic concepts but also developed transferable skills, such as collaboration, and perseverance. The choice of materials for the task also mattered. Electronics provided immediate feedback: joints either held or failed; a misplaced component produced silence; and a corrected connection produced sound. This reduced peer friction that had hindered earlier group tasks (crying, shouting, stalemates) and created focus for negotiation (“let’s reflow this joint” and “swap these leads”). In this sense, the artefact functioned as a mediating object that promoted collaboration and reduced the need for teacher mediation.

The data show that when students were given autonomy to experiment with different approaches, their sense of ownership and agency increased. Many challenges were overcome collaboratively, with students exchanging ideas, offering help, and pooling their strengths. Such interactions built a sense of community and mutual support, echoing Green’s (2008) and Calabrese Barton and Tan’s (2018) emphasis on peer collaboration and shared responsibility in STEM-rich making contexts.

Jakobsen et al. (2016), in their study of the Hitmachine platform, argue that tangible and open-ended musical technologies can empower children to collectively make expressive music without the need for prior musical skills because the artefact invites constructive play and iterative experimentation. They emphasise that the platform’s design supports cooperation and shared ownership of the musical outcome. This frames the theremin build phase in my data, where the shared circuit and instrument created a concrete focus for joint diagnosis and repair, making technical troubleshooting a visible form of collaboration.

Interdisciplinary framing supported student participation. As students moved between assembling circuits and performing with the theremin, they enacted what Chu et al. (2019) describe as inquiry-rich STEAM: inquiry-based, collaborative exploration and model-building/communication. The work also resonates with Lowrie et al.’s (2018) movement across physical, symbolic, and social domains: manipulating components (physical), naming/diagnosing faults (symbolic), and teaching peers (social). Over time, these appeared to stabilise more equitable participation in art after the electronics than in the initial arts-only sessions. Due to peer explanation and peer teaching in the workshops, the interdisciplinary movement is directly relevant here, not only to “integration” as a curriculum goal but to how peer interaction was sustained during troubleshooting.

In addition, these findings support O’Neill’s (2015) perspective on transformative engagement: when students are positioned as cocreators of knowledge, music and STEM tasks

become vehicles for agency and empowerment. For example, several groups celebrated their success together when their theremin finally produced sound, with students expressing pride not only in their own work but in helping classmates achieve the same result. Taken together, the findings suggest that creative troubleshooting can act as a bridge between individual competence and collective practice. When feedback is immediate and ownership is real (a device to take home), peer interaction becomes a resource for learning rather than a source of conflict. This kind of situated, agentic engagement is what the thesis framework anticipates: engagement that is emergent, relational, and sustained by the interplay of hands-on inquiry and shared responsibility.

From an Expectancy-Value Theory perspective (Gladstone et al., 2022), the satisfaction students gained from overcoming technical problems – especially when success was shared – appeared to enhance both their perceived competence and the value they attached to the activity. As their focus shifted from simply “getting it right” for a grade to achieving a real, tangible goal as a team, students’ motivation became more intrinsic and sustainable.

In summary, the evidence suggests that creative troubleshooting and hands-on experimentation can act as catalysts for the development of new skills, agency, and meaningful engagement with peer work operating as the mechanism that made persistence and problem-solving sustainable in practice (help-seeking, help-giving, role negotiation, peer teaching, and shared responsibility for debugging). Designing classroom experiences around authentic, collaborative problem-solving is crucial for promoting engagement, agency, and the formation of supportive peer relationships. Such approaches offer diverse entry points for students to experience success, contribute to their communities, and develop identities as competent, resourceful learners.

6.13 Shift From Artistic/Creative Block to Elaboration Through Art

In my research, I noticed that some students seemed unsure about engaging in creative activities, expressing hesitation or even believing they were not “good enough” at art to try — as some of them told me. This Section 6.13 looks at how these creative blocks affected students and how simple activities helped them regain confidence and enjoy making art.

During the artistic workshops, the activity of composing using drawings provided a valuable avenue for students engaging in creative artistic composition. It offered students a fresh perspective on producing freehand drawings and composing visual manifestations, helping them rebuild confidence and explore new artistic avenues. In Year 8D, for example, I noticed

students responded to the activity in two different ways. The first one was to address the activity as it was planned. Students would get their pencil cases, their notes from their notebooks – that they were just waiting for an opportunity to draw somewhere – and create their arts and try to make a link between what was drawn and the sound the theremin makes. The other strategy was to place oneself in a shutdown position to the classroom environment, just waiting for the class time to end so they could sneak out of the activity without having to exert effort into it. This was exacerbated in some students that experienced a block when it came time to create their sheet music. They did not know what to do, and I could grasp from our conversations that they felt inferior or unworthy of producing something artistically. I worked with these students slowly, using very basic concepts of visual composition. I started with things like, “Choose if you want a line or a curve. Now choose if you want to go from there to another line or a geometric drawing ...”. In some cases, the production was simply a copy of a drawing found on their cell phones (Research journal, June 22, 2022).

The transition of students who had never interacted with the instrument – and had limited social and creative activities during the lockdowns – to communicating in a purely musical language was seen in one of the classes during the artistic workshops. Initially shy, the students quickly adapted to the “conversation between theremins” activity, moving from verbal communication to musical dialogue. Their interactions were expressed through sounds instead of words. This took place in the Year 8B class. They were a bit timid, but they worked well in pairs. This shyness was something I noted down many times in my journal. For example: “It’s still new to me to see teenagers having so much shame or aversion to exploring something interesting, exotic, and outside their daily routine” (Research journal, August 1, 2022).

They completed the storytelling task to a satisfactory level, but they enjoyed the conversation between theremins activity even more where they quickly moved from communicating in the Portuguese language to communicating through music. Here, the questions and answers no longer had a direct connection to words in our language but became musical events, as seen in Figure 40. Some examples of these musical events could be an ascending note ending abruptly and the other student responding with two ascending notes, or two quick staccato notes being responded by the same initial note and a descending one. The participation was so fluid that we finished early, and I gave them some “free time” to chat and relax. Naturally, some students came to test the instrument since there were no pressures or judging eyes on them.

Figure 40

Students Engaged in the “Conversation Between Theremins” Activity



In one workshop, the students used paint to create graphic scores. Although using paint was not the main focus of the workshop, it was very popular with the students. Several of them mentioned it as something they enjoyed when reflecting on their workshop experience. This is especially relevant to one of the goals of STEAM: using art to support science learning. Paint – initially seen as a minor element – turned out to be one of the most engaging aspects for students. This event with the paint served as one of the most effective platforms for them to create in my workshops, especially when compared to the initial reception the students had to the drawings at the beginning.

The platform of painting music to be played on the theremin was designed to enrich artistic experiences and improve school engagement. However, it ultimately became such a profound artistic experience that some of the students could not focus on creating the music. The opportunity for artistic creation overshadowed the original task, creating significant informational noise in the process of producing the art. While a few students followed the instructions correctly, most did not. Their enthusiasm for working with paint, a medium many had not used since kindergarten, absorbed their attention and effort. Despite this, I had some positive response in their artistic spontaneity, as seen in Figure 41, and reported in my reflective journal: “Year 8C – their creativity flowed remarkably well, deeply” (Research journal, October 10, 2022).

Figure 41
Students Engaging with Paint



This experience with the paint was one of the moments that I had to remember to put myself in the place of the researcher and not only as a teacher as I felt quite sorry for them. Some students were eager to use paint and engage in theatrical play, apparently having missed an entire childhood of playing with brushes and colours. This is grounded in what students told me directly in conversations during and after the workshops and captured in my reflective journal. In these discussions, several students described having little or no contact with paint, brushes, or open-ended art making across primary school, and they framed the activity as something they had not done since early childhood. This was a very saddening factor for me – the fact that they went through elementary school without this artistic manifestation. I believe that this could be one of the reasons for their hesitancy with creativity. When I brought the paint to the workshops, they painted their faces, arms, and made moustaches, as seen in Figure 42.

Figure 42
Students Playing with Paint



Despite the initial euphoria with the colours, some students were able to compose music on the theremin using the expected musical elements, such as those shown in Figure 43, where lines or figures move up and down or circles are easy to visualise and execute on the theremin, and a musical text is written. Other students recreated similar musical ideas in a more abstract way, moving further from traditional music notation while still retaining some conventional elements, such as note heads and ascending/descending lines. These representations could still be perceived as musical and translated to the instrument with a little bit of extra interpretation, as shown in Figure 44.

Figure 43

Music Scores with the Expected Elements of an Alternative Notation Written for the Theremin

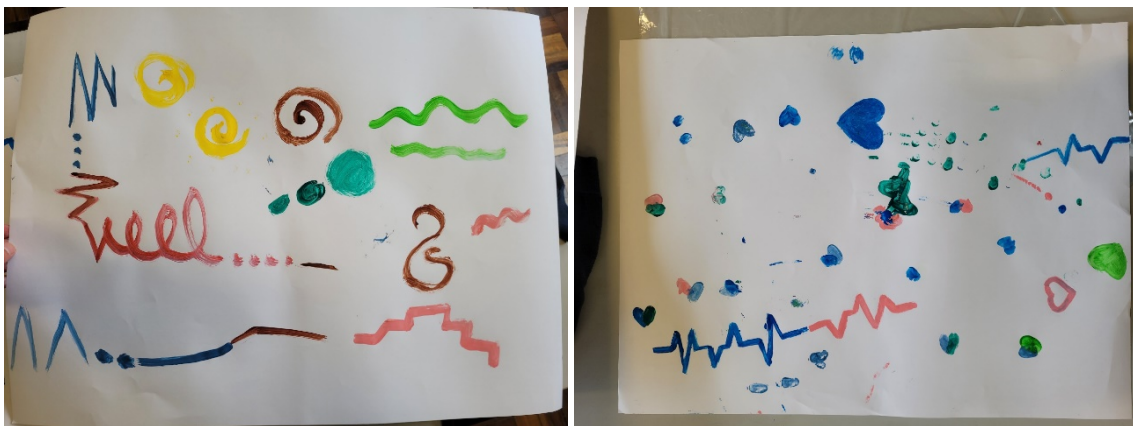
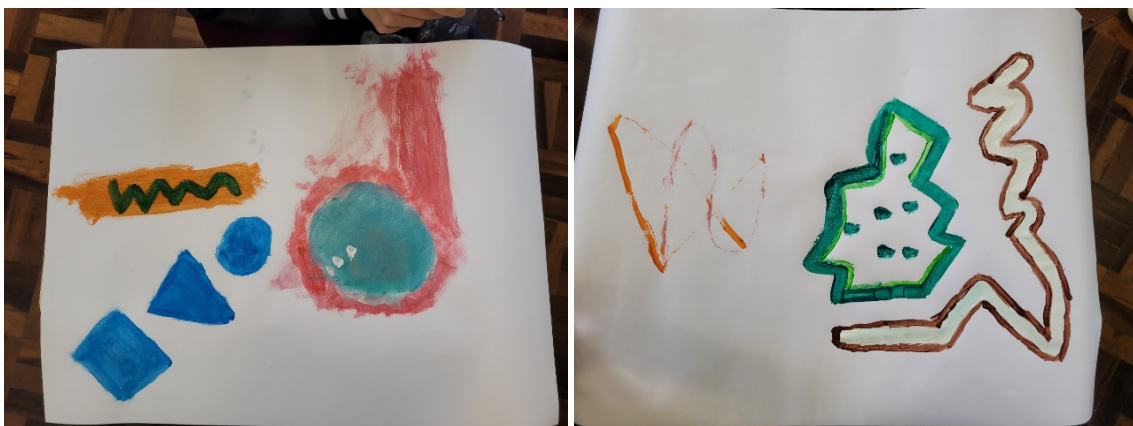


Figure 44

Abstract Music Scores Incorporating Traditional Elements



For most participants, the use of paint became so central to their work that the musical aspect took a backseat, as shown in Figure 45. Musical elements were replaced by painted hands, political signs²⁰, flowers, butterflies, major clothing brands, a tree, or a sunset. These are all elements that, while possible to depict on the theremin, would be more challenging to

²⁰ For example, "Bozo", which is a slanderous way of calling the former Brazilian president, Bolsonaro.

represent musically. It is likely that these images were not initially conceived with music in mind; rather, they were expressions of the students' desire to manifest themselves artistically through a medium outside of their usual school environment tools.

Figure 45

Examples of Music Scores where the Use of Paint Overshadowed the Original Musical Prompt for the Activity



It became clear that the visual aspect provided by the paint gave them new ways to express ideas. When only pencil and paper were available, their work was slow and hesitant, though they still produced pieces. Once paint was introduced, most students created work quickly. As I noted in my reflective journal: "In half an hour, everyone created something, and some even made a connection with the musical aspect. In this regard, I see a great victory" (Research journal, October 10, 2022). In these cases, despite missing the target for that activity in that group, the paint served as a platform for elaboration of personal experiences, one of the major things that I, as a music teacher, aim to reach through art.

6.13.1 Discussion On: Shift from Artistic/Creative Block to Elaboration Through Art

The findings from this Section 6.13 indicate that the movement from creative block to elaboration depended on task design that reduced evaluation pressure and supported emotional safety, rather than on talent or technique alone. This aligns with work on emotional engagement, which shows that emotions, such as embarrassment, anxiety, and shame, can raise the perceived cost of participation and lead to avoidance, while curiosity and pride can support persistence once students experience early success (Fredricks et al., 2004; Pekrun & Linnenbrink-Garcia, 2022).

As students moved from reluctance and shame to participation and creative expression, it became evident that giving them autonomy and alternative modes of artistic engagement with multiple entry points (drawing, painting, gesture, and sonic exploration) lowered the barrier to experimenting and was a key factor in their progress. The task of drawing and then playing offered an action pathway. The line on the paper already suggested the gesture on the theremin, and the gesture already produced sound, so the student did not have to invent everything from scratch in order to start. At the same time, the activities still required small, deliberate scaffolds, which aligns with the idea that open-ended tasks depend on pedagogical judgement and support in everyday school settings (Strat et al., 2024; Sturrock et al., 2025; Xu et al., 2024). This combination of multiple entry points and small scaffolds can also be read as a design choice about access.

Vanderlinde (2017) frames Universal Design for Learning as planning for seamless access to the classroom environment, the music curriculum, and peer interaction. This Design can also be viewed as presenting and engaging with content in varied and flexible ways so students can engage with it and express what they know through multiple avenues for applying and assessing understanding. Read through this lens, offering multiple entry points into making and performing, alongside small scaffolds, can be treated as an access-oriented design choice: it reduces barriers to participation without reducing the conceptual demand of the task.

From this access lens, this process reflects Green's (2008) insights into informal learning where student-led and low-pressure environments encourage experimentation and risk taking as students perceive learning as more "fun" and get more immersed in the flow of the tasks. The findings also echo the importance of emotional engagement in learning, as articulated by Fredricks et al. (2004), with students initially displaying negative emotions, such as embarrassment or anxiety about sharing creative ideas, but gradually developing curiosity and pride as they experienced success and support from their peers and teachers. In this Section

6.13, the key point is not simply that students participated more but that the design made creative risk-taking more likely by lowering emotional costs and providing clear starting moves. Examples could be found in Year 8B with shyness giving way to the “conversation between theremins” without judging eyes (see Figure 40); in Year 8D with minimal scaffolds where “line or curve ... connect to a shape” unlocked production; and with paint when students showed curiosity and quick output (see Figures Figure 41 to Figure 45). Emotional safety (“I won’t be judged”) preceded behavioural participation (trying, sharing), which, in turn, enabled cognitive work (symbolising sound and linking gesture to pitch and dynamics).

Howell (2017) cautions that it is easy to be dazzled by new music technologies but that learning depends on how the tool sits within musical and social practices because humans, not machines, make music. He also argues that technology-linked music learning often draws on play, improvisation, and informal exploration, which can sit in tension with tightly regulated school routines. This is consistent with the way low-pressure exploration with the theremin reduced avoidance and gave students a way to start without having to invent a finished product.

Evidence of this trajectory appeared in multiple moments of the artistic workshops. In Year 8D, responses split between engaging as planned (bringing pencil cases and linking drawings to the theremin’s sound) and “shutting down” to wait out the class. To help blocked students, I scaffolded with very basic visual choices (like the “line or curve ... now connect to a geometric figure” as noted above) and, in some cases, they copied images from their phones (Research journal, June 22, 2022). In Year 8B, initially shy students embraced the conversation between theremins, shifting from verbal to musical dialogue (see Figure 40). In ERA terms (Lowrie et al., 2018), students moved from playful exploration on the theremin (Experience), to externalising ideas in drawings/painted scores (Represent), and then to performing or explaining those scores (Apply). This Experience–Represent–Apply arc helps explain why the activities reduced creative block: students were not asked to produce a finished artwork immediately but to translate small representational choices into sound and refine them through doing.

Although painting was not the main focus, it quickly became a powerful entry point: enthusiasm for colour and texture accelerated production, sometimes eclipsing the musical brief. Some students wrote playable alternative notations or hybrid abstract-conventional scores while others centred their work on imagery — hands, political signs, brands, flowers, and sunsets. Consistent access and multiple entry points helped stabilise participation for reluctant students, aligning with Calabrese Barton and Tan’s (2018) call for equity designs that ensure consistent, frequent access to tools and materials and engagement through multiple entry

points. In our workshops, paint provided a low-threshold entry point that stabilised participation; many students had not used it since early schooling. Even when the musical aim was partially displaced, the activity widened participation and reactivated creative intent. Additionally, paint provided immediate tactile feedback and visible artefacts that acted as identity texts and moments of peer recognition. It supported elaboration because it enabled students to externalise ideas quickly, revisit them, and take aesthetic risks with low fear of “getting it wrong”. When paint overshadowed the musical prompt, the representational link to performance required later refocusing; however, the affective/identity gains (belonging, pride, willingness to share) were clear.

The workshop design encouraged student initiative. In this Section 6.13, peer interaction matters as a condition for creative elaboration, not as “teamwork” in itself (as working in groups was already discussed in section 6.8). Students wanted to test the instrument during free time and proposed simple drawing rules to get started. These student-initiated contributions qualify as agentic engagement (Reeve & Tseng, 2012) – that is, students shaping the activity rather than merely complying. Peers also operated as a low-stakes audience and a source of ideas, which reduced the risk of embarrassment and made trying out sounds and images feel safer. From an Expectancy-Value Theory perspective (Gladstone et al., 2022), higher perceived competence and utility (making something that works) turned avoidance into sustained participation and reduced disaffection.

In summary, overcoming artistic and creative blocks required more than teaching technique; it depended on a classroom climate that prioritised process over product, emotional safety, and flexible routes into making. The Represent → Apply bridge in this design turned avoidance into elaboration, especially for students who arrived saying “I’m not good at art”. This was reinforced by sustained multiple entry points and consistent access to materials that raised expectancies/values and lowered emotional costs, supporting the bridge. In this scenario, free painting was translated to playable notation/gestures that connected representation with application without suppressing spontaneity.

6.14 Interdisciplinary Connections Through STEAM Workshops

During the final focus groups, the students displayed varying abilities to make conceptual connections between the workshops, and music and science. In some cases, the connection was achieved through external facilitation, where I, as the teacher, had to “manually” build this connection by explaining how the concepts we worked on fit into the context of their subjects. In other cases, the connection was automatic, with students bringing

me their physics book and, without any external prompt, observing that what we did was represented in the textbook. Lastly, there were cases where no connection was made between what was studied in their regular classes and what we did in the workshops.

When Year 8A was asked about the connection between the workshops and their school subjects, they had an “aha” moment. This realisation occurred as we began discussing how the workshops overlapped with what they learnt in class. When asked if they understood the connection between what we did in the workshop and the school subjects, the quickest answer was a direct “I didn’t understand” (Year 8A, final focus group). However, when I explained that the workshops were part of the science curriculum, covering electronics, electricity, energy, and related topics, while the artistic activities, including music and drawing, belonged to the arts subject, they reflected and recognised that everything was an extension of their school subjects. This led to more comprehensive and relevant responses, such as “Because then the teacher drew the designs on the board for us to make with the instrument, right?” and “Yeah, it was related to music and drawing too” (Year 8A, final focus group).

In Year 8C, students connected their school subject to the long-term planning and actions involved in the workshops, applying resilience strategies for long-term work. When asked if anyone could relate our activities to the arts subject, despite some negative responses, one student answered: “We dedicate a lot of time to things. We spent more than a day working on that instrument. It’s the same with art. Sometimes we see the results days later. It’s the same with school” (Year 8C, final focus group).

Some students were able to make this connection without external support. When asked if they were able to see any connection between the workshops and the school subjects, some “Hmm...” and “No” answers came out easily, until a student offered a response:

S4: The thing with light.

S5: Current ...

S4: Electric current!

S3: Protons ... electrons ... Those things.

S1: Atom, atom ... (Year 8D, final focus group).

These discussions, in which students were prompted to reflect on their learning, helped them realise that what they were studying was related to the circuit they had built. As one student mentioned, their science book showed a circuit with similar elements to the one we made: “It also shows up in the circuit we made, you know?” (Year 8D, final focus group). With this, another student rushed while saying: “I’ll get it! (the book),” and their colleagues replied

with: “It’s like the circuit there” and “Yeah, it shows the negative and positive things” (Year 8D, final focus group).

One of my main goals during the workshops was to develop creative and engaging ways to teach STEAM, enhancing interdisciplinary collaboration between science and art. Throughout the workshops, the connection between subjects became evident, and students began to understand how concepts from both disciplines were intertwined. These interdisciplinary connections were not discussed explicitly during the workshops. The decision was made to observe whether students would be able to recognise and articulate these links independently without direct prompting. At one point during the final focus groups, some students recognised that our activities went beyond isolated subjects, acknowledging the integration of science and art. During a discussion about the artistic prompt intended to trigger a response from the artefact they built, they commented:

S1: Yeah, then it becomes an extra science class too.

S2: And arts.

S3: But we didn’t know any of this before. (Year 8D, final focus group)

This insight took longer to be grasped by some students since we were not using traditional instruments or conventional sheet music. They found it challenging to grasp the concept, particularly due to the abstract nature of the activity. As one student remarked: “it just wasn’t what I expected ... you said you were going to do something related to music ... like making us play instruments and stuff. But it wasn’t what I thought” (Year 8A, final focus group). This sentiment was echoed by other students who were surprised by the unconventional nature of the workshops. They had anticipated more typical music classes, with one student humorously adding: “I thought we were going to form a band” (Year 8A, final focus group). Despite the initial confusion, students generally responded positively to the experience, often expressing that they enjoyed these classes.

Using a hands-on pedagogy provided students with an additional opportunity to connect their learning to personal experiences—an effective cognitive strategy. For example, a Year 8B student related the workshop activities to their previous experience with sanding in a metal workshop, stating: “I liked the sanding part the most. I enjoyed it. I loved it. I enjoyed it because I’ve worked with sanding before” (Year 8B, final focus group).

Although my research shows that the students learned and benefited from the workshops, some perceived them as something separate from the school system. The hands-on approach led some students to see the workshops and school subjects as disconnected. When

asked if they could see any connection between our workshops and their school subjects, one student responded: “I didn’t see any connection at all” (Year 8B, final focus group). Later, a student said that it was “interesting to step away from the subject a bit (laughs)” (Year 8B, final focus group) and justified this to the workshops having the hands-on element. The active process of building something, like a technological apparatus, was too unconventional compared to their daily school life. In this case, they perceived it as something separate from their school subjects.

Despite this, the connection between school and the workshops for Year 8B was observed by the science teacher. She noted a noticeable difference between students who participated in the workshops and those who did not²¹. This was illustrated by a case where students proudly presented their newly constructed theremin circuit and successfully linked the physics content to the scientific apparatus they had built themselves. According to the teacher, some of the students showed her the project when she started talking about circuits, which prompted her to ask them: “‘Do you know this? The resistor, do you know what it is?’ Then one girl took it out of her bag and said, ‘Look, teacher, we made this! It has this, this, and this,’ and she showed me the parts and everything” (Science teacher, final interview).

The science teacher also reported that another class actively shared their experiences with her. Whenever they completed a new stage of construction, they would come and show her their progress. At the end, they returned once more to present her with the final product. She considered the workshops valuable, particularly due to the soldering activity. As she stated: “Sometimes they would tell me what they had learned, what they had done. ‘Oh, we did this thing this week.’” In cases when she had a class right after the electronics workshop, like with Year 8C, she noted that some students would return to the classroom and eagerly show her, saying: “Look, teacher, what we did.” She told me she could see that this experience was very meaningful to them, adding: “This situation is something different, working with soldering ... it was something very different for them. That’s what we noticed” (Science teacher, final interview).

After establishing the connection between the optical theremin built in the workshops and the science content, Year 8D students actively sought additional information about the physics concepts. When the students brought me their book with a circuit drawn on it, we were able to find other more complex structures. When I pointed and said, “Look, a resistor!”, a student reacted with “Yeah. I don’t know what that is, but you’re right”, which was then

²¹ The workshops were conducted with all Year 8 classes; however, some students were not authorised by their parents to participate.

remembered by a colleague that it was one of the components we soldered into the circuits, thus igniting her memory back to the workshops:

S1: It's the one we put in the circuit.

S2: Oh, yeah! Tha's true, tha's true. We know it (Year 8D, final focus group).

After this initial search in their book, another student asked: "Did you see the direction (flow of electrons)?", which I then answered and continued, "Oh, yeah. The direction of the current. Do you know what defines the positive and negative in the circuit?" They initially replied: "No." However, when I explained that it was the black wire and the red wire, the students responded: "Wooooow" in one epiphany of connection between the workshops and school (Year 8D, final focus group).

This led them to further discuss the subject as the students were not sure which one was positive or negative as they answered the "wow" with:

S1: Oh, that's right! Because black is negative ... No, red is negative if I'm not mistaken. If I'm not mistaken, red is negative.

S2: No, red is positive. (Year 8D, final focus group)

This prompted them to look further on Google to check which information was correct. This prompt was not initiated by me but came automatically and naturally from the students themselves. The answer came after a while with a student saying, "Red: positive, black: negative" (Year 8D, final focus group). This search also facilitated me explaining to them that instead of producing light, we produced sound with the circuit we built.

These moments, described in the previous paragraphs, were crucial for connecting the workshops to the science subject. Without them, the hands-on activities would have remained disconnected from classroom concepts, reducing their relevance to the student's broader academic experience. The students' active engagement and curiosity were essential in linking the workshops to their school subjects. Without this integration, the workshops might have been dismissed as mere recreational activities, lacking the educational purpose needed to create meaningful interdisciplinary learning experiences.

According to the arts teacher, one reason why this type of interaction was effective was the introduction of new elements into the school system, which had a noticeable impact on his classes. He reported: "You being the novelty, that's something that helps a lot. Your presence was already something new, and that already provided something new for them" (Arts teacher, final interview). He also described the theremin as a blend between a conductor and a DJ: "You

have to conduct the instrument itself, but you also create sound effects like a DJ” (Arts teacher, initial interview). This analogy points to the way the theremin invited some students to try it out by giving them this novelty aspect in their learning. Students were encouraged to try this unexpected element, making their learning experience more engaging.

This approach also allowed STEM to enhance musical skills, which is the reverse of STEAM where the arts enhance science. It promoted positive change through collaborative, active, and transformative forms of music engagement. Regarding the student’s understanding of sound and musical aspects after the workshops, the arts teacher observed that they became more sensitive to musical parameters and curious about the sound process. As he stated: “they ended up developing a greater identification with music because of this connection they have with this atonal and microtonal stuff” (Arts teacher, final interview).

By referring to microtonalism, the teacher was alluding to Brazilian Funk, a music genre characterised by poetry sung or spoken over a simple music track, often produced by marginalised groups in Brazilian society. Precise intonation is not typically a priority in this style. As he noted: “it’s an interesting sound for them; it’s a sound they ended up identifying with and thinking is cool, you know. It’s something they can do in a very spontaneous way” (Arts teacher, final interview).

The teacher noted that one factor aiding this comprehension is the absence of a need for fine motor control to begin playing the theremin, unlike forming a C Major chord on the guitar. As the arts teacher explained: “to play a C chord, you have to press here, here, and here. Okay, C chord. Now let’s play this C chord somewhere else (laughs).” He then compares this to the mechanics of the theremin:

I remember that day when you showed the theremin and said, ‘Come here, do this. Now here, you move away, you increase the volume, here you increase the note ...’, and they did it. They didn’t think about notes; they went by the feeling, which is what they already do when they listen to music. (Arts teacher, final interview)

The teacher further explained that students found the theremin intriguing, partly because of its microtonal nature, allowing them to explore sound nuances without the constraints of traditional music theory. From his perspective, this experience with the theremin enhanced their sensitivity to music.

6.14.1 Discussion On: Interdisciplinary Connections Through STEAM Workshops

The findings in Section 6.14 demonstrate that the interdisciplinary approach adopted in the therein workshops created opportunities for students to connect knowledge and practices across science and the arts. Through circuit-building, sound experimentation, and creative expression, students moved from initial difficulties with group work to coordinated, productive collaboration. The hands-on, open-ended design activated cognitive strategies – problem-solving and persistence – and shifted motivation from external rewards to intrinsic interest as students saw tangible results of their efforts and ownership over artefacts. By blending technical skills with artistic exploration, the workshops supported both academic understanding and personal engagement, transforming classroom dynamics.

The final focus groups revealed two pathways for making cross-subject links. The first one was that it mediated connections when I explicitly named how electronics, energy, and sound related to science and arts. The other one was spontaneous connections when students brought the science textbook, identified circuit symbols, and even checked wire polarity on Google. Mediated connections were more frequent in Year 8A, and spontaneous connections were stronger in Year 8D – a class initially considered the most difficult one to deal with according to the teachers. It is relevant to note that these connections were possible due to the artefact displaying its components in an open and recognisable way (red/black wires, resistor, light-dependent resistor [LDR], battery connection), which afforded immediate pairing with the diagrams in the book. If the instrument had been closed or a “black box”, this direct reading would not have occurred.

Hodson (1992) argues that integration does not happen simply by combining content and emphasises that coherent integrated courses depend on explicit integrating principles that structure meaning across contexts, themes, teaching and learning methods, and assessment. This supports the distinction between mediated connections, where I named how concepts related across science and music as an explicit integrating element, and spontaneous connections, where students generated links themselves, because the tasks alone did not guarantee that cross-subject meaning would be articulated.

These findings echo core arguments in the STEAM literature. Effective STEAM education, as described by Chu et al. (2019), is inquiry based, collaborative, and creative. These qualities were cultivated as students moved fluidly between scientific and artistic domains. One example can be found in Year 8D where students brought the science textbook, matched circuit symbols/diagrams to the built device, and verified polarity on Google – “Red = positive; black =

negative.” Peters (2017) notes that technologies have reshaped how people learn and participate in music, including through participatory spaces in which learning and sharing can extend beyond formal lesson time. In this finding, quick searches, such as checking polarity, functioned as part of how some students constructed the cross-subject link in the moment rather than as an add-on to the workshop.

Another example was found in Year 8A where students recognised overlap once electronics/energy (science) and music/drawing (arts) were named. The last example was mentioned by the arts teacher, who said that the workshops developed heightened sensitivity to sound parameters and exploratory performance in the students after they had contact with the theremin. In all these cases, the configuration of the theremin (a visible circuit that transforms gesture into sound) functioned as translation across subjects: the same object could be read as an “instrument” in the arts class and as an “electrical assembly” in the science class.

The design of the theremin workshops allowed students to build conceptual bridges between disciplines, aligning with the Experience–Represent–Apply model (Lowrie et al., 2018), visible when the students referenced circuits in their science textbooks and shared technical language across contexts. In ERA terms: Experience (exploring/playing the theremin) → Represent (drawing/symbolic notation, plain-language explanations) → Apply (relating book diagrams to the built circuit, naming components and functions). The fact that the artefact was portable and battery powered also enabled this “Apply” stage because students could physically take it to the science teacher and say, “we made this”, using the object as evidence of their achievement.

Moreover, Tobias (2017) argues that authentic integration of technology and the arts transforms learning only when it generates genuinely new and meaningful experiences – beyond superficial add-ons to current practices. The fact that students identified and discussed scientific principles, such as electric current, polarity, and circuit, while engaging in a musical and creative context demonstrates the permeability of boundaries between subjects when learning is grounded in concrete practice. The unconventional nature of the theremin challenged students’ expectations and expanded creative boundaries, illustrating Gil-Curiel and de la Garza’s (2019) claim that meaningful interdisciplinarity is problem/issue centred. Rexhepi et al. (2024) report that integrating digital technologies in music education can support student learning and engagement while also identifying implementation constraints, such as technical problems and the need for practical support. This aligns with the broader point that technology-rich music

learning depends on how tools are introduced and sustained in everyday classrooms, not only on their novelty.

Medvinsky (2017a) argues that technology can be integral to music learning when it supports learners to listen, perform, create, improvise, and reflect, rather than acting as an add-on to conventional tasks. He emphasises these processes as connected and iterative, with technology serving as a medium for musical thinking and collaboration. In a related piece, Medvinsky (2017b) warns that using technology only to do old tasks in new ways can leave existing limits untouched, and he suggests that technology-rich practice can prompt educators to reconsider what counts as musicianship. In my workshops, the theremin and circuit were not decorative; they were the medium through which students made links between gesture, signal, and sound.

A particularly significant observation was the emergence of self-directed inquiry. On some occasions, students initiated their own searches for information, such as checking technical details on Google, without prompting. This behaviour reflects agentic and cognitive engagement as learners assume active responsibility for their understanding (Fredricks et al., 2004; Reeve, 2012). The motivation to seek out answers independently indicates growing autonomy and ownership over learning, which are drivers of sustained engagement in interdisciplinary contexts (Tamura et al., 2022). Patall et al. (2019) report that students' agentic engagement can predict increases in perceived autonomy support over time, suggesting that student initiative can also shape the conditions of the classroom. Patall et al. (2022) extend this by showing reciprocal relations between students' agentic mindset, agentic engagement, and perceived teacher autonomy support and control over time. In this finding, student-initiated searches, questions, and proposed solutions can therefore be read as actions that shaped the learning conditions in the room, not only as outcomes of interest.

Another important finding is that interdisciplinary connections did not only flow in one direction. While the STEAM literature often highlights the arts making science more accessible, the activities here also showed the reverse: STEM concepts and practices enhanced students' musical skills and understanding. By learning about electricity, circuitry, and sound production, students deepened their engagement with music and became more sensitive to musical processes and possibilities. One example was when students mapped gesture → light → signal → sound while visualising and naming components, such as the LDR or the 9V battery plug, and, with it, adjusted performance decisions (pitch/volume). This bidirectional dynamic illustrates

that meaningful integration allows science to enrich the arts as much as the arts can illuminate science (Chu et al., 2019; Gil-Curiel & de la Garza, 2019).

De la Garza and Travis (2019) similarly emphasise two-way integration. They argue that science can be strengthened by philosophical, ethical, and aesthetic perspectives, and that the arts can be energised by scientific understandings of dynamic processes and by technological innovations, creating shared spaces for exploration and discovery. This framing fits the workshops when students moved between circuit building, sound experimentation, and artistic composition, and when they used language from both subjects to explain what they were doing.

Lines (2022) helps clarify why the interdisciplinarity in this study mattered educationally rather than functioning as a superficial combination of subjects. He argues that a contemporary aesthetics in music education should work not only at the level of personal musical experience, but also at a transdisciplinary level where music reaches into other places, spaces, and forms of knowledge. Read against my findings, this helps explain why the theremin supported more than musical activity alone. It became a shared artefact through which students could connect sound, gesture, drawing, electronics, and scientific ideas in ways that made music stand visibly alongside science. In this sense, the interdisciplinary strength of the project did not come from simply placing two subjects next to each other, but from creating tasks in which aesthetic experience, making, and conceptual understanding operated together.

Teachers' observations corroborate these findings, and the accessibility of the instrument amplified them. The science teacher noted that students who participated in the workshops connected classroom theory to the physical artefacts they constructed, demonstrating cognitive engagement and a sense of ownership (Fredricks et al., 2004; Hodson, 1992). Similarly, the arts teacher highlighted how the theremin encouraged students to explore musical ideas in new ways due to the instrument's novelty, and the no-fine-motor barrier (unlike a guitar C chord in his own words) enabled "playing by feeling" as well as how students "conducted" the theremin like a maestro/DJ. In line with Green (2008), and with the syntheses of music participation in Hallam (2015) and Hallam and Himonides (2022), the theremin's low-entry threshold – requiring little prior skill and aligning with culturally familiar practices – lowered barriers to participation, democratised access, and encouraged creative risk-taking.

Not all students, however, perceived the workshops as an extension of school subjects. Some experienced them as separate from regular lessons, often due to the unconventional, hands-on approach to building and performing with the theremin. In the students' words: "I didn't see any connection at all" and "interesting to step away from the subject" (Year 8B); "it

wasn't what I expected ... I thought we'd form a band" (Year 8A); initial "Hmm/No" in Year 8D before bringing the book and verifying polarity on Google. These reactions reflected the challenge identified by Tobias (2017): true integration requires moving beyond surface-level connections to create meaningful experiences.

Overall, the STEAM-based workshops provided a space for students to bridge disciplinary boundaries, develop new ways of thinking, and experience learning as an interconnected process. Integration was not simply a matter of adding one subject to another but of enabling a learning environment in which students could see the relevance and value of both fields in their academic and personal lives. As the literature suggests, effective interdisciplinarity is constructed through student agency, hands-on inquiry, and opportunities to transfer understanding across contexts (Chu et al., 2019; Lowrie et al., 2018; Tamura et al., 2022). The findings from these workshops illustrate the transformative potential of such an approach.

6.15 Summary of the Findings

In summary, the findings from this Chapter 6 show that the theremin workshops produced meaningful shifts in student engagement, motivation, and participation. The analysis spans the four Year 8 classes and was triangulated through the focus groups and teacher interviews that I held, and my reflective journal entries (both written and recorded in audio). Group work moved from isolation to more organic collaboration after years with little or no group work. Open groups and purposeful scarcity (fewer theremins/soldering irons) fostered positive interdependence, rotating roles, and peer teaching.

Hands-on activities shifted motivation from extrinsic to intrinsic factors, with the electronics phase showing the strongest gains owing to immediate feedback and tangible outcomes that raised expectancy of success and task value. Crucially, some of these outcomes were enabled by the artefact itself. Being small and portable with visible components, it offered immediate entry possibilities and few initial technical barriers: many early steps relied on simple, achievable hand actions (identifying parts, matching leads, positioning components, and testing connections) rather than sustained fine dexterity, before students moved into higher precision actions, such as drilling and soldering. This accessibility made it easy for students to show it at home, to map it onto textbook circuits, and to treat the same object as both "music" and "science".

Students' learning extended beyond the classroom. The therein acted as a bridge between school, home, and community as students demonstrated, explained, and even sold their devices, sparking family dialogue and recognition. Participation increased across the project as many students overcame initial resistance to collaborate and engage more fully.

The data also show significant challenges, including creative blocks, social and economic vulnerabilities, and external disruptions like drug-related expulsions that interrupted promising trajectories. Despite these obstacles, students demonstrated resilience, initiative, and agency, particularly in practical tasks. Learners often labelled "disruptive" excelled in mechanical and technical work, and girls showed notable precision and leadership in STEM-oriented tasks.

In the artistic phase, multiple entry points (drawing, paint, gesture, and sonic exploration), supported by small scaffolds, helped some students move from creative block to elaboration and performance. Interdisciplinary connections varied from students reporting no perceived connections to student-initiated links that used textbook terms and technical language to explain circuit behaviour and sound.

The workshops supported the emergence of new skills, strengthened peer relationships, and encouraged students to connect academic content with real-life contexts while rebuilding collaborative norms and linking science and music through a single meaningful artefact. The durability of these gains beyond the workshop period remains an open question. Practical implications include open-group structures, a peer-first help rule, rotating roles, and visual or gestural scaffolds to support representative tasks.

These findings provide a foundation for the subsequent discussion in Chapter 7 where they are examined in relation to my research questions. The discussion highlights the need for explicit scaffolds that help students convert practical experience into written or rule-based representations, and frames the results across behavioural, emotional, cognitive, and agentic dimensions of engagement.

CHAPTER 7 – DISCUSSION

Throughout this Chapter 7, I interpret the findings by connecting them to the literature reviewed in Chapter 2 and to the conceptual lenses in Chapter 3. The discussion is organised around the research questions and the key strands from the literature review. My aim is to explain what changed, why it changed, and what this case adds to existing work on engagement, music technology, and STEAM.

In this chapter, I interpret the relevance of the previous chapter's (Chapter 6) findings while answering the three research questions of this study. These questions are: (1) In what ways does using the theremin improve student engagement in science and music?; (2) In what ways can the theremin be used to improve interdisciplinarity across science and music in Brazilian schools?; and (3) In what ways can a theremin-based teaching and learning project enhance peer interaction in science and music? I discuss these questions using the frameworks outlined in Chapters 2 and 3. I focus on what changed in classrooms, how those changes happened, and why the theremin's affordances matter.

Chapters 2 and 3 also frame technology as a situated practice rather than a neutral tool that automatically raises engagement. Tobias (2017) argues that the key issue is how technologies reshape what is learned and whose musical practices are valued. In addition, Hayles's (2012) notion of technogenesis helps describe this codevelopment of people, tools, and ways of thinking. Read through this lens, the theremin mattered because it changed the conditions for participation by offering a gesture-based interface and multiple ways to represent ideas. This aligns with Peters' (2017) argument that the question is not whether technology should be included but how and why it is used, and with Vanderlinde's (2017) Universal Design for Learning framing of planning for seamless access to the classroom environment, curriculum, and peer interaction.

This interpretation also aligns with Merrick's (2020) argument that technology-mediated music teaching works best when teachers rethink learning design, assessment, and the ways students demonstrate understanding, rather than simply transferring older routines into a new format. In my study, the theremin project did not depend on digital abundance, but it did depend on adaptive task design, multiple entry points, and opportunities for students to show understanding through gesture, sound, drawing, building, and explanation. Merrick and Joseph (2023) offer a complementary perspective by showing that increased use of information and communication technology (ICT) and music technology among Australian music teachers

after COVID-19 was closely tied to confidence, professional learning, access, and pedagogical purpose. Read against my findings, these studies help explain why the theremin supported engagement in this case: not because technology itself produced change, but because the project combined a meaningful artefact with explicit structuring, teacher judgement, and accessible pathways into participation.

Pierard and Lines (2022) help sharpen this point because they argue that technology-based music learning should not be forced into conventional curricular sequences when students are working through multimodal, exploratory, and often self-directed forms of musical practice. Their constructivist account of DAW learning is relevant to my study because the theremin also opened a space where students could enter through sound, gesture, experimentation, and creative decision making rather than through prior fluency in notation or instrumental technique. In this sense, the theremin did not just add a new device to the classroom. It supported a different pedagogical relationship to music learning, one that made room for varied identities, multiple entry points, and more flexible demonstrations of understanding.

Three lenses guide my discussion. First, student engagement is treated as multidimensional: behavioural, cognitive, emotional/affective, and agentic. Second, the Situated Expectancy-Value Theory (SEVT) perspective helps explain shifts in value, expectations, and perceived costs. Third, the Experience-Represent-Apply (ERA) sequence grounds how students move from action to explanation and then to use. This multidimensional definition follows Fredricks et al.'s (2004) behavioural, emotional, and cognitive framing and treats engagement as malleable and responsive to contextual features. Following Reeve and Tseng (2011), I also treat agentic engagement as students' constructive contribution to the flow of instruction, including when they ask questions, suggest options, and shape how an activity proceeds. In addition, I distinguish engagement from disaffection, where withdrawal and frustration can cooccur with participation because engagement involves behavioural and emotional participation that can fluctuate across tasks and moments (Skinner et al., 2008, 2009). In line with Reschly and Christenson (2012, 2022), I treat engagement as a metaconstruct that has evolved across disciplines and provides a bridge between participation, belonging, and learning. Finally, I draw on Griffiths et al. (2022) to interpret why small shifts in participation and peer connection can matter in settings where a minority of students display troubling or high-risk behaviours.

Academic emotions provide a process explanation for why troubleshooting sometimes resulted in persistence and sometimes in withdrawal. Pekrun and Linnenbrink-Garcia (2022) describe academic emotions as achievement, epistemic, topic, and social emotions. They argue that these emotions shape motivation, concentration, and learning strategies, and that engagement mediates the effects of emotions on achievement (Pekrun & Linnenbrink-Garcia, 2022). Read with Tamura et al.'s (2022) motivational engagement model, the same episodes can be understood as shifts in affective experiences, expectancy beliefs, and values that change the intensity and persistence of effort.

This chapter has three main parts. I first explain why the theremin matters in this study by describing its affordances (Section 7.1). I then address each research question in turn. Research Question 1 examines changes in engagement (Section 7.2); Research Question 2 shows how interdisciplinarity grew when tasks required students to translate ideas between science and music rather than run in parallel (Section 7.3); and Research Question 3 describes how peer interaction shifted from fixed pairs to flexible, purposeful collaboration (Section 7.4). I close the chapter (Section 7.5) by summarising the original contribution, transferability, limits, and practical implications for teachers and departments.

Scope and limits are stated clearly in my research design. The evidence is qualitative and comes from one school with scarce resources and sporadic attendance. The teacher–researcher role brings both access and risks to interpretation of data. These limits were addressed by triangulation and through a long process of coding (and recoding). I separate what depends on the theremin (for example, gesture–sound connection) from what depends on the lesson design (for example, planned interdependence) so the links between artefacts can be seen when other similar research is carried out as well as the unique influences of individual schools.

Taken together, the answers to the three research questions point in the same direction: engagement increased, interdisciplinary links became more regular, and peer interaction became more stable. The same framework appears in each case: immediate make-test feedback, planned interdependence, flexible roles, and the ERA sequence anchored by a shared artefact. I close the chapter by drawing these answers together and pointing to what a similar school would need to run the sequence with confidence.

7.1 Why the Theremin?

The originality of my work is the interdisciplinary engagement with music and science through the use of the theremin. The theremin drove my workshops, and connected music and

science and led students to engage, build peer relationships, and develop interdisciplinary practice. The theremin was the fuel, the medium, and the factor that propelled students to engage.

Read through Tobias's (2017) distinction lens, the theremin is not simply added to existing routines. It reorganises participation because students can explore pitch, timbre, and dynamics through embodied gesture before formal notation, and they can communicate those ideas through drawings and movement. This also resonates with Medvinsky's (2017b) view that technology best serves music education when it supports reimagining musicianship and offers multiple points of entry rather than using tools to do the same tasks in a different format. In this study, the low-entry interface and flexible representations supported voice and choice in how students participated and showed understanding (Medvinsky, 2017a). It also aligns with Vanderlinde's (2017) argument that inclusive design involves flexible ways for learners to engage and express what they know, including through peer interaction.

The workshop had three phases. The first was an artistic workshop with the electromagnetic-field theremin with pitch and volume antennae; the second was an electronics workshop in which students built their own optical theremin with an LDR; and in the third, they composed and performed pieces on the instrument they had built, giving closure to the art-science-art cycle with the theremin as the bridge.

A key question is how students exchanged musical ideas once the optical theremins were ready after the electronics phase. What I observed is that they sat side by side and tested the instrument together. For example, one student placed their hand over the optical sensor and changed the pitch; the peer responded, commenting how the register was altered (from high to low pitch). Sometimes, the other student's interest was more rhythmic, and they replied with a rhythmic idea, showing how, by connecting and disconnecting the 9-volt battery, it is possible to create variations of note and silence length: with long battery removal, there were long pauses; with quick insertions, there were short notes; and with intermediate timings, medium-length notes. In this way, a progressive rhythmic modulation emerged in response to their peers' glissando.

This is something the theremin enables immediately. To produce a clear glissando on other instruments, like a guitar, one needs training: pressing the string at the right fret, keeping pressure, and sliding without letting the note fade. With a synthesiser's glide (portamento) function, although it is easier than on a guitar, there is still a degree of coordinated mechanics: the player must hold the first key while pressing the next, and the synthesiser then moves

between the two pitches over the preset glide time. There is also the option to enable an always-glide setting, but that requires knowledge in navigating the synthesiser's interface. In contrast, on the theremin, the glissando is built in and natural: without needing prior theory or particular skills, the person moves a hand through space and stops where the ear demands it to stop; they can prolong it, reverse direction (high ↔ low), or turn it into a non-stopping wide, slow vibrato. The direct and intuitive relationship between body movement and sound control apply both to the optical and to the electromagnetic theremins. From Hayles's (2012) technogenesis perspective, these interactions can be interpreted as coevolution, where repeated gesture-sound adjustments are associated with shifts in students' attentional focus and in the meanings they attached to musical control and electronics.

7.2 Research Question 1: In What Ways does Using the Theremin Improve Student Engagement in Science and Music?

Using the theremin – together with the workshop design – increased engagement across behavioural, cognitive, emotional/affective, and agentic dimensions. The clearest change appeared in the electronics phase. No student gave up, even after early failures. When a circuit did not work, classmates who had already finished went over to test it, resolder joints, and help trace errors. This kept everyone on task. At the same time, the classroom stopped operating as separate islands and began to act like a network. Groups were flexible. Students moved between work cells and became increasingly independent, with less teacher intervention and with decisions about who to ask for help coming from the students themselves. This interpretation draws on the multidimensional engagement framework outlined in Chapter 3, especially Section 3.2 (Fredricks et al., 2004; Reschly & Christenson, 2012, 2022). It also aligns with Skinner et al.'s (2008, 2009) claim that engagement is visible as behavioural and emotional participation in ongoing classroom activity, and that task conditions can make engagement more likely to emerge and be sustained.

This pattern supports Tobias's (2017) critique of technological determinism. The gains were not a general tool effect but outcomes of how the artefact and tasks were situated in classroom relationships, norms, and expectations. Hayles's (2012) notion of technogenesis offers a compatible description: as students learned to build and play the theremin, their skills and learning identities codeveloped with the artefact and with the social arrangements around it. This also connects with postpandemic accounts of increased reliance on ICT in music education and the associated need for teacher confidence and professional learning (Merrick & Joseph, 2023). Rexhepi et al. (2024) report, in a higher education study, that structured

interventions can produce measurable gains when design is explicit and the learning process is analysed. My findings extend this logic to lower secondary STEAM by showing that clear make-test cycles and planned interdependence can support sustained participation without assuming that technology alone will produce engagement.

Figaredo (2009) describes music workshops for young people at risk of exclusion in which engagement grows when participants experience achievable success within a supportive collective. He links this to commitment and a sense of belonging in a group that the students feel is protective rather than hierarchical (Figaredo, 2009). My electronics phase specifies one mechanism for that shift. The binary feedback of a circuit that works or fails created clear, shared problems to solve, which made peer help timely and visible and kept students on task without constant teacher direction.

Cognitive engagement was visible in authentic troubleshooting and in students' own searches for information. In Year 8D, students brought the science textbook to compare circuit symbols and discussed current direction and polarity (red for positive and black for negative). They linked what they had soldered to the formal content. This was not an isolated episode. The science teacher reported that students showed their boards in her lesson and named components when the class worked on circuits. That behaviour had not been common before the workshops.

Emotional engagement shifted from fear of losing marks to fear that the instrument might not work after all their effort. Several described frustration when the instrument failed and joy when it finally sounded, even after repeating the process several times. Some were close to tears. Students became happy to have helped classmates and for having learned more after correcting mistakes. This points to a shift in focus – away from grades and towards success in the task and a felt sense of learning.

In these electronics sessions, frustration, relief, and pride functioned as short-cycle feedback signals. Pekrun and Linnenbrink-Garcia (2022) argue that students' emotions can shape the direction, intensity, and persistence of motivation, and can change the effort students invest. This framing helps interpret why repeated circuit failure sometimes increased effort and peer help rather than ending participation. When repairs produced sound, relief and pride signalled progress and supported continued work.

This process view also aligns with Tamura et al.'s (2022) account of motivational engagement as a network of values, expectancy beliefs, affective experiences, perceived autonomy, and social relations. Read this way, the emotions reported in my workshops can be

treated as part of a broader motivational system that supports self-regulation and sustained effort during repeated make-test cycles.

This pattern also aligns with Figaredo's (2009) argument that workshop settings can redirect students' emotions away from institutional pressures and towards the experience of making, listening, and achieving within the group. Figaredo further proposes that public sharing can reduce fear and strengthen self-esteem when it is framed as a collective experience. In my data, the emotional centre of gravity moved from marks to whether the artefact would sound, and the strongest affect was attached to repeated cycles of failure, repair, and eventual success.

Agentic engagement grew as the workshop progressed. The classes moved from fixed pairs that resisted group work to a community of practice. Students chose roles, moved between groups as needed, and taught other peers specific steps. There were practical examples of inclusion. One pair with a motor challenge divided the drilling task: one student stabilised the board, and the other operated the drill. The result was precise and quick, which repositioned who was seen as competent in the room. There were identity shifts as well. Girls stood out in layout and soldering. In one case, the circuit made by two girls became a reference for the class. A quiet student who had been less involved in the artistic phase became one of the most engaged in electronics and produced one of the best theremins. These shifts reflect agentic engagement as students' constructive contribution into the flow of instruction and activity, including making suggestions, requesting help, offering explanations, and influencing how the task unfolds (Reeve & Tseng, 2011).

The reach beyond the classroom reinforced this picture. The artefact travelled between school, home, and peers. Students explained how it works to family members. They negotiated who would keep the device, and, in one case, a student sold a unit for five reals (R\$5). This circulation made science visible, tangible, and audible in daily life, and gave social recognition to what is learned at school. This pattern aligns with equitable and consequential making, where artefacts and explanations move across settings and generate recognition that helps sustain participation (Calabrese Barton & Tan, 2018). This process can be read as students rehearsing narrated and embodied identities as competent makers across school and home contexts (Tan et al., 2013).

Why did this work? Three elements appear consistently. First, there was immediate feedback from making. A circuit either works or it does not. That clarity focuses attention, produces small step-by-step gains, and sustains persistence. Second, there was planned interdependence. Scarcity by design and the division of stages – printing the board, etching, and

soldering – require cooperation and create points of contact among students with different levels of skill. Third, there was the tangible artefact that goes home. Learning is not just words or talk. In this situation, it became an object that people could show, discuss, and use. This raises perceived value and expectations of success.

Figaredo (2009) argues that workshop learning can begin with lived experience that creates a personal need to learn, and he critiques music education that privileges the final product over the processes that generate it. This helps explain why the strongest engagement in my study appeared in the electronics phase. Students were not only following instructions but were acting on a need to troubleshoot, make the artefact work, and help others reach the same outcome.

However, there are limits. The evidence is qualitative and comes from one school with resource constraints and a recent history of little collaborative practice. Even so, the pattern was stable across classes and sessions. The science teacher's account and the circulation of the artefact outside school both align with a coherent picture of improved engagement linked to the theremin and to the structure of the workshops.

In theoretical terms, the data align with the SEVT perspective. The activities increased intrinsic value through curiosity and the pleasure of making. They improved attainment or identity value as students gained recognition among peers and family. They also broadened utility through links to science and to social uses of the artefact. At the same time, they lowered perceived cost through a low musical entry point and through peer help. The result was sustained participation, persistence, and initiative, with visible effects inside and outside the classroom.

Catalano et al. (2001) organise evidence on adolescent problem behaviours through risk and protective factors. They identify academic failure and low commitment to school as school-based risk factors that are closely tied to disaffection. They also describe protective factors, such as opportunities and support for prosocial involvement and recognition for prosocial behaviour, which can strengthen bonding. Read against my findings, the workshop created repeated opportunities for prosocial contribution (helping a peer, sharing tools, teaching a step) and made that contribution visible, which supported persistence during troubleshooting.

Figaredo's (2009) account anticipates these value shifts. He links workshop participation to recognition within the peer group and, at times, within the family, which can reinforce motivation and commitment. In my study, that recognition was attached to a functioning

artefact that could be shown, explained, and used beyond the classroom, which made value more visible and socially shared across settings.

7.3 Research Question 2: In What Ways can the Theremin be Used to Improve Interdisciplinarity Across Science and Music in Brazilian Schools?

My data shows that interdisciplinarity grows when tasks make students translate ideas in both directions (music → science / science → music). This transdisciplinary perspective is reinforced by de la Garza and Travis (2019), who argue that science and the arts can mutually enrich one another. They suggest that scientific knowledge can gain depth through aesthetics and ethics, and that the arts can be informed by processes of discovery and experimentation. In practice, students move between sound and gesture on one hand, and light and circuit behaviour on the other. The same artefact (the theremin) carries the link. The same vocabulary also travels across music and science lessons. The students named parts, tested ideas, and explained how the device works, both scientifically (polarity, resistor, connector) and artistically (glissando, tremolo, pitch). In engagement terms, this translation work supported cognitive engagement through explanation and application, and agentic engagement through student-initiated testing, revision, and decision-making (Fredricks et al., 2004; Reeve & Tseng, 2011).

This two-way movement between disciplines aligns with Tobias's (2017) argument that interdisciplinary music–technology work can operate at the level of distinction, where making and performing reorganise what is learned and whose knowledge counts. It can also be read alongside Uptis's (2001) description of overlapping spheres of influence between music, technology, education, and wider cultural life. In my study, the artefact travelling home created one practical overlap between these spheres as students used the instrument to explain, demonstrate, and negotiate meaning with family and peers beyond school. This again echoes Peters' (2017) point that the issue is how and why technology is used because the interdisciplinarity here depended on designed translation tasks rather than on the presence of electronics alone. Medvinsky (2017b) similarly argues that technology integration matters when it invites exploration of nontraditional ways of being a musician rather than reproducing existing classroom routines. This kind of student-led continuation beyond school is consistent with evidence that student-initiated technology use outside class can be more strongly associated with achievement than teacher-assigned use (Zhai et al., 2018).

Two pathways produced these links. Some links were mediated. I named how electronics, energy, and sound connected to both science and arts. However, other links were

spontaneous. Students led the bridge themselves, and they brought the science textbook, matched circuit symbols to the board, and checked wire polarity on Google. The mix of pathways differed by class. Mediated links were more frequent in Year 8A, but spontaneous links were stronger in Year 8D.

Classroom examples were given by the science teacher, who reported that students showed her the printed board during a circuit lesson. She asked about parts, and a girl took the board from her bag and pointed out the components by name. In Year 8D, students opened the science book in the focus group, found a resistor drawing, and discussed current direction and polarity. This was the students' initiative. It was not a prompt from me or another teacher.

The theremin makes this easier because it offers a simple chain that students can see and hear. Gesture changes light on the sensor → Light changes the signal → Signal changes pitch. When students named LDRs and battery plugs and then adjusted sound in performance, they were already translating across domains: science concepts helped with musical control; music made the circuit more meaningful.

The accessibility of the theremin also helped. The arts teacher noted that students could begin playing and testing the theremin by feel. There were no complex fingerings at the start. This initially freed students from abstract sound parameters. This led the students to: i) Experience the instrument and explore gesture, sound, and control; ii) Representation: drawing, label parts in plain language, and describe "how it works"; and iii) Application: perform, explain to someone else, and take the artefact home. This ERA cycle kept both subjects – music and science – in view (Lowrie et al., 2018).

Planned interdependence also mattered. I split the procedures for construction so that no single student knew the whole method. One group printed the board, another etched, and another soldered. Later, each student received a kit and had to rely on peers to complete the device. This design created and facilitated dialogues and interactions that crossed both science and music tasks.

Not every student saw the interdisciplinary link at first. In Year 8B, some said the workshops had no connection to regular lessons. In Year 8D, initial answers were also negative. The link appeared when students opened their textbook and discussed polarity and current direction. This is a useful constraint as interdisciplinarity is not automatic and must be built into tasks and into the talk. Teacher reports support this picture. The science teacher could see differences between students who joined the workshops and those who did not. The ones who participated in the workshops connected theory to the artefact they had built; they returned to

show the board and to name components in later lessons. That is a strong sign that ideas travelled across classes.

These notes point to a template that future STEAM projects can adopt:

- set a shared bridge: one artefact, one basic vocabulary, and two subject lenses;
- work the ERA cycle with clear prompts for each stage;
- keep roles flexible so students can rotate between musical choices (or other artistic choices) and circuit (or another scientific platform) reasoning; and
- ask the students to explain the device to a nonspecialist at home or in the community and to bring that story back to class.

The last item will help ensure the interdisciplinary bridge does not end at the classroom door.

7.4 Research Question 3: In What Ways can a Theremin-Based Teaching and Learning Project Enhance Peer Interaction in Science and Music?

Peer interaction changed in form and quality. Classes moved from “each in a corner” and fixed pairs to flexible groups that shared roles and support. Teacher intervention dropped as students organised who to ask and when to move across tables. The room behaved less like separate islands and more like an organic community of practice.

Green’s (2008) study helps interpret why these peer shifts were not superficial. Her account shows that when classroom music-making becomes more peer directed, students who were previously disaffected can still take meaningful roles, and group cohesion can develop in an organic way because contribution is visible and negotiated within the group. My case extends that insight into a STEAM build context. Planned interdependence, tool scarcity, and a shared artefact created repeated reasons to ask for help, offer help, and move between roles, which made inclusion observable in day-to-day problem-solving rather than dependent on teacher-managed grouping. This movement from disaffection towards engaged participation is consistent with motivational models that treat engagement and disaffection as related but distinct states that are visible in behavioural and emotional participation (Skinner et al., 2008, 2009).

Howell (2017) similarly foregrounds context and informality when interpreting technology in music education, and this matters here because the main driver of peer interaction was the shared artefact and the task structure, not a screen-based tool. Medvinsky (2017a) argues that technology-rich music learning should support student voice and choice, which helps interpret why role rotation, peer teaching, and student-led decision-making became more

common across the workshops. Vanderlinde's (2017) Universal Design for Learning framing further supports the claim that multiple entry points and flexible modes of participation are central to inclusive peer interaction. This aligns with Kirschner and Tomasello's (2010) claim that music evolved to become a "tool that fosters social bonding and group cohesion, ultimately increasing prosocial ingroup behaviour and cooperation" (p. 354). My study provides empirical evidence of how the theremin afforded this because the project required repeated coordination around a shared artefact and common outcomes. Students had to share tools and components, test boards, and solve faults in pairs or small clusters. These conditions made prosocial acts visible in everyday classroom work.

What students did is concrete. No one quit in the electronics phase, even when first attempts failed. Students who finished early helped classmates building their boards, traced faults, and resoldered joints side by side. Roles emerged (builder, tester, helper) while remaining fluid. Students circulated between clusters as needs arose. A pair with a motor challenge split the drilling task with precision: one stabilised the board, and the other operated the drill. These episodes show mutual dependence and visible inclusion in action.

These patterns link directly to social and agentic engagement. Socially, students were no longer working for the teacher alone but for one another as well because their progress depended on peers finishing tasks and sharing tools. Agentially, they were not simply following instructions. They chose who to assist, which role to take, and when to move from their own board to someone else's. Teaching a peer how to position the iron, how long to heat a joint, or how to check polarity are agentic moves because the student shapes the learning conditions of others, not only their own. This can also be read as agentic engagement, where students contribute constructively to the flow of activity by making suggestions, seeking clarification, and shaping how the group proceeds (Reeve & Tseng, 2011), alongside social and behavioural forms of engagement that are organised through peer relationships and participation opportunities (Reschly & Christenson, 2012, 2022).

Three design choices explain these shifts. The first was planned interdependence that made help necessary because everyone needed peers to complete a working device. Scarcity by design (limited tools and theremins) – the second design choice – encouraged collaboration rather than passivity. The third choice was that the circuit provided objective evidence: the theremin either worked or it did not, which reduced personal friction and turned frustration into joint troubleshooting. Students compared traces and shared quick fixes. The interaction was purposeful, not merely social.

From the SEVT perspective, these peer patterns changed both value and cost. Social value increased as students gained recognition for being helpful, careful, or precise. A student who could “fix” a silent board in a few minutes became important to the group. At the same time, the perceived cost of asking for help dropped. The norm became to walk over, compare boards, and ask “What did you do here?” rather than to hide errors. This helped sustain persistence and reduced the risk that early failure would lead to withdrawal.

The ERA sequence also helps to read these interactions. In the Experience phase, students often began by watching someone else (myself or a peer) solder or drill before trying themselves. In the Representation phase, they explained procedures to one another in plain language or pointed to the PCB. In the Application phase, they shared sound with the finished theremin and demonstrated to family or to the science teacher. Peer interaction was present at each point: observing, explaining, and performing.

7.5 Summary

This Chapter 7 answers my three research questions using engagement theory, an SEVT lens, and the ERA sequence. Across four Year 8 classes in one Brazilian public school, theremin-based workshops: increased behavioural, cognitive, emotional/affective, and agentic engagement; made interdisciplinarity more regular through two-way translation between music (sound/gesture) and science (light/circuit); and shifted peer interaction from fixed pairs to flexible, purposeful collaboration. In this case, these changes were tied to both the theremin’s affordances and the workshop design: visible musical intention shown by hand movements, alternative notation as an inclusive way to represent sound, low-barrier musical dialogue, achievable construction that invites peer teaching, and portability that carries learning beyond the class.

Three design choices consistently supported these shifts – immediate feedback, planned interdependence, and a tangible artefact that travels home – raising perceived value and keeping work visible beyond the classroom. Interdisciplinary links were achieved via both teacher–researcher mediation and independent student-led moves. Evidence is qualitative, single site, and gathered by me as the teacher–researcher in this project, with validation through triangulation and systematic coding.

CHAPTER 8 – CONCLUSION

My study examined how theremin-based, practical workshops raised student engagement, strengthened interdisciplinarity between science and music, and promoted peer interaction in a Brazilian public school. Although the workshops took place soon after COVID-19 restrictions eased, the value of this work does not depend on the pandemic context; it lies in what became possible when students engaged in structured making and creative exploration around a shared artefact. The study was conducted in 2022. Across four Year 8 classes, the pattern was consistent: students stayed on task, took initiative, helped one another, connected ideas across subjects, and took the artefact home, which triggered discussion among family members. The effect was sustained across sessions, classes, and spaces.

Tasks were hands on and offered immediate feedback. Planned interdependence meant that no single student controlled the whole building process in the electronics workshops, and no one could carry out all the artistic theremin activities alone (such as theremin conversations or group compositions). In both the music and electronics workshops, students needed one another to complete the sequential tasks. This led to real exchanges of help and explanation in their problem-solving and learning. Flexible roles let them rotate between building, testing, and performing. The ERA (Experience → Represent → Apply) arc linked action to explanation and then to use. A tangible artefact travelled between school and home, and students used it to show what they had learned and to talk about science and music with family and friends.

In this Chapter 8, I summarise these findings, answer the three research questions, outline the original contribution of the study, discuss implications for practice, and indicate limitations and directions for future research.

8.1 Summary of Findings

My main findings show that introducing an interdisciplinary, hands-on project led to observable improvements in several dimensions of student engagement. The workshops facilitated a gradual shift from isolated, pair-based work to more organic and autonomous group collaboration. This shift mattered because, before the workshops, students and teachers described collaboration as rare and largely restricted to fixed pairs within friendship circles, with frequent reports of uneven contribution and parallel work rather than joint problem-solving. The workshops also reinforced the importance of agency and belonging. Hands-on activities were effective in generating intrinsic motivation, empowering disaffected students to discover

new skills, participate in class, and take pride in their creations. My project also enabled the extension of learning beyond the school environment, with students sharing the theremin and related knowledge with peers and family members. This process supported sustained engagement and the development of new learning identities. This summary uses engagement as a multidimensional construct and focuses on observable change in behavioural, emotional, and cognitive participation (Fredricks et al., 2004; Skinner et al., 2008, 2009) while also accounting for agentic engagement as students' proactive contribution into the flow of learning activities (Reeve & Tseng, 2011). This extension beyond school reflects what Calabrese Barton and Tan (2018) call practices sustained across spaces, and it can be understood as a shift in identities in practice as students carry competence, recognition, and explanation work across settings (Tan et al., 2013). This also aligns with O'Neill's (2015) account of transformative music engagement where young people braid learning spaces and take more ownership over their participation.

Social and emotional bonds with peers and support staff emerged as primary motivators for school attendance, supporting the view that engagement is shaped by students' environments as much as by individual interest. These relationships formed a support structure that kept students involved, even when they were not particularly interested in the academic content. Moreover, students used what they had learned in science and music at home, with peers, and in their communities. This showed that engagement can extend beyond the classroom when activities have clear, concrete value. This was evident as students showed greater persistence, autonomy, and a willingness to invest in learning when they saw practical and social relevance in their work. In place-based terms, the theremin acted as a bridge between classroom activity and local life, making learning discussable with real audiences at home and in the community (Sobel, 2004).

The music education literature suggests that active engagement with music can be associated with more positive attitudes towards school and, in some programmes, better attendance. However, Hallam (2015) notes that evidence linking music participation to improved school attendance is not always conclusive, and that the wider literature does not always establish a clear causal relationship between music participation and attendance. This supports interpreting the social and behavioural shifts in my workshops as plausible pathways towards reengagement, even when broader attitudes towards school remained mixed. Before the theremin workshops, students often expressed negative attitudes towards school, sometimes with irony or cynicism. Yet my observations and participation in the workshops revealed that these negative attitudes often coexisted with ambivalence towards school rather

than complete detachment. The change suggests that disengagement is rarely absolute and that meaningful interventions can help reactivate latent connections to the school environment.

As a qualitative inquiry, the evidence is visible as change in participation and interaction across the intervention period. In this setting, small shifts, such as restoring group work and increased willingness to take part in creative tasks, represented meaningful progress in a challenging environment. Many students initially found it hard to relate abstract ideas in science and art to their own experience. Over time, activities that joined both subjects gave them new ways to understand what they were learning in these subjects, to talk about their learning, and to see it as valuable.

Even under conditions of instability, expulsion, or risk, some students showed resilience and continued to participate and support their peers. These moments point to engagement as being complex, situated, and dynamic. Engagement emerges from a blend of emotions, relationships, beliefs about self, and broader life circumstances.

Catalano et al. (2001) frame school-engagement-related outcomes through a similar risk and protective factor lens. In their review, academic failure and low commitment to school are school-based risks linked to adolescent problem behaviours, whereas opportunities and support for prosocial involvement and recognition for prosocial behaviour function as protective factors. In my study, the theremin project created structured moments for prosocial involvement and recognition of competence, including for students who were often positioned as “disruptive” in regular lessons.

Learners who resisted abstract, theory-heavy work often became participative when tasks were hands on, social, and scaffolded, showing that context and design matter. The most effective elements in the workshops could combine (i) concrete-to-abstract scaffolds (as in the drops activity translating pitch/dynamics into a visual-kinetic script); (ii) clear, visible steps with roles that reduced group rigidity (as in the step-by-step theremin assembly that improved following instructions and made contribution easier for previously disruptive students); (iii) opportunities for ownership of a self-built artefact (as in the motivation that rose as students saw they could construct an instrument to take home); and (iv) interdisciplinary contexts that supported explanation and application (as in the electronics component that made “written science” concrete). These points show that when classroom design supports scaffolding, clear roles, ownership, and interdisciplinary application, students can move from marginal or resistant positions to active participation, changing the classroom dynamic itself

8.2 Answers to the Research Questions

8.2.1 Research Question 1 – In what ways does using the Theremin improve student engagement in science and music?

Engagement rose across behavioural, cognitive, emotional, social, and agentic dimensions. Students persisted through failure, searched for information, expressed pride when circuits worked, and supported peers. Pekrun and Linnenbrink-Garcia (2022) treat emotions as antecedents of engagement, with engagement mediating the effects of emotions on achievement. In this thesis, the make-test structure made these links visible because students moved quickly between failure, repair, and success. Tamura et al. (2022) describe motivational engagement as dynamic and responsive to affective experiences, expectancy beliefs, and values, and this lens helps explain why emotions, such as frustration, relief, and pride, were tied to persistence and to students' willingness to retry, seek help, and stay on task.

In practical terms, engagement increased because effort had clear, local consequences. Students could hear and see whether an action improved the circuit or the performance. This reduced the delay between effort and outcome, which made persistence more likely, and it also made contribution visible to peers and the teacher.

These changes were not limited to staying busy. Students used strategies that indicate cognitive engagement, such as comparing symbols with the textbook, checking connections, and revising a plan after a failed test. Agentic engagement was visible when students initiated tests, chose roles, and sought help from a peer before approaching the teacher.

A boundary condition is that increased participation did not automatically produce uniform conceptual understanding. Some students still needed explicit prompts to connect practical actions to formal explanations in science and music.

8.2.2 Research Question 2: In what ways can the Theremin be used to improve interdisciplinarity across science and music in Brazilian schools?

Links between subjects went both ways. Interdisciplinarity became more than a general theme when it was carried by an artefact that required students to move between two representational systems. Students translated between gesture/sound and light/circuit behaviour. Naming electronic components and musical terms, drawing both the circuit and music, and performing with the theremin meant science and music were addressed in the same task. Interdisciplinarity improved when the same action could be discussed in both disciplinary

languages. A single change in hand position could be treated as a musical decision and as a scientific event, which helped students see that both subjects were relevant to the same task.

This two-way translation also became visible when the device behaved unexpectedly, and students had to interpret circuit components and signal flow; translate those ideas into gesture, sound, and musical choice; and then translate back again during troubleshooting. The link was reinforced when I explicitly named connections (for example, sensor input and pitch change) and when students produced spontaneous bridges (for example, using the science textbook to interpret symbols). Gil Curiel and de la Garza (2019) suggest that interdisciplinary work often becomes issue centred and postdisciplinary with the shared problem taking precedence over disciplinary labels. This was supported by simple representations that travelled across activities: drawings of the circuit, visual scores, and the physical board itself. These representations allowed students to explain, label, and revisit connections without needing advanced terminology at the start. A practical criterion for STEAM design in similar settings is that interdisciplinarity becomes more robust when students are prompted to represent the link in more than one mode (talk, gesture, drawing, component naming, and testing), not only to perform it.

A boundary condition is that the link was weaker on abstract activities or when students could not see how the workshop task related to their regular lessons. The bridge became clearer when teachers named the link and when students used the artefact during science lessons or at home. Where students initially reported “no connection”, the link tended to appear after repeated make-test cycles and after opportunities to explain the device to others, suggesting that transfer required time and structured prompts rather than being automatic.

8.2.3 Research Question 3: In what ways can a theremin-based teaching and learning project enhance peer interaction in science and music?

Classes shifted from fixed pairs to flexible, purposeful collaboration with peers – or, as I called them, organic. Students taught one another specific procedures and relied less on the teacher for small decisions. This shift was supported by planned interdependence and scarcity by design. Build procedures were distributed and tools were limited, so progress depended on peers completing steps, sharing equipment, and circulating practical knowledge. As a result, help-seeking and peer teaching were part of the work rather than optional add-ons, and collaboration became a visible route to completing a functioning device.

Peer interaction increased because troubleshooting created immediate reasons to talk. Students asked for confirmation, compared procedures, and corrected small errors

together, which produced short episodes of peer teaching and help-seeking. The make-test structure also reduced the social cost of participation because faults were material and audible. A silent circuit or unstable pitch made the problem public, and a repair produced an immediate outcome. This supported joint attention and quick turn-taking around troubleshooting, and it helps explain why peer interaction increased even in a cohort described as reluctant to do group work in regular lessons.

Interaction also changed in structure. Roles rotated between building, testing, and explaining. Students who finished early often became assistants for peers who were still assembling or repairing a circuit, and quiet students could contribute as testers or explainers. In these terms, the workshops align with Green's (2008) account of peer-directed learning, while extending it to a low-cost STEAM build where cooperation was organised around a shared artefact, immediate feedback, and shared tools.

A boundary condition is that these interaction gains depended on task design. When roles were not visible or when resources were not shared, peer work was more likely to collapse back into fixed pairs or parallel work. At the same time, the peer gains were bounded by the task. Where classroom routines returned to individual or worksheet-based work, the same interaction patterns were not guaranteed, which reinforces the need to treat peer engagement as a product of task design and classroom norms rather than as a stable trait.

8.3 Original Contribution

My research makes an original contribution to research on student engagement and STEAM at the lower secondary level by specifying how a single, low-cost musical artefact can organise participation, interdisciplinarity, and peer interaction through identifiable design features and instrument affordances in a Brazilian public school. It contributes a case-based explanation of conditions and mechanisms, supporting analytic generalisation rather than claims of universal impact.

More specifically, this study broadens the repertoire of STEAM practice by showing how a low-cost optical theremin can bring hands-on electronics, musical performance, troubleshooting, and peer teaching together within a resource-constrained lower-secondary classroom. In doing so, it extends the educational and social use of the theremin beyond music-making alone, using the artefact as a bridge for interdisciplinary learning and the reengagement of students at risk of disaffection.

This contribution builds on Tobias's (2017) critique of technological determinism by specifying how and why a particular musical technology was situated in practice (Peters, 2017). It also aligns with technogenesis accounts that treat learning with technology as a codevelopment of people, tools, and ways of thinking over time (Hayles, 2012).

My study reports how theremin-based workshops can raise behavioural, cognitive, emotional/affective, social, and agentic engagement in the aforementioned setting. This study found that the gains come from task design (hands on, immediate feedback, planned interdependence) and the uniqueness of the theremin (uncommon playability, direct gesture-to-sound connection, visible electronics). This refines technology-in-music claims by showing concrete mechanisms rather than tool effects. It adds a case-based account that links specific design decisions to observable shifts in engagement, which strengthens the explanatory detail often missing from claims about technology improving motivation or participation. This multidimensional framing aligns with core engagement models (Fredricks et al., 2004; Reschly & Christenson, 2012, 2022) and with definitions of agentic engagement as students shaping their learning conditions through constructive contribution (Reeve & Tseng, 2011).

In this study, "mechanisms" refer to specific, observable pathways through which the workshop design shaped engagement. Hands-on tasks with immediate feedback reduced the delay between action and outcome, making effort more likely to continue. Planned interdependence embedded collaboration into the work, so participation was not optional but necessary to complete the circuit and troubleshoot faults. The theremin's gesture-to-sound mapping and visible electronics made abstract ideas more tangible, which supported students' strategy use, persistence, and willingness to experiment.

The analytical process also showed why the original three-dimensional engagement framework (Fredricks et al., 2004) was not sufficient on its own for this case. Behavioural, cognitive, and emotional/affective engagement helped organise much of the data, but they did not adequately describe students' initiative or the quality of peer interaction. Returning to the literature on social engagement (Fredricks et al., 2016; Gladstone et al., 2022) and agentic engagement (Reeve & Tseng, 2011) made these patterns more legible. In this sense, the constructivist grounded theory process did not reject the earlier framework but showed why these later extensions were necessary to interpret this case.

In other words, the study does not argue that technology raised engagement by itself. It shows how particular design features and affordances organised attention, interaction, and meaning-making in ways that produced gains across engagement dimensions. This position

aligns with Tobias's (2017) warning against technological determinism and his use of technogenesis to frame change as coevolution between people and technologies rather than technology as a direct cause. In Tobias's terms, the project is closer to distinction than assimilation. The theremin was not used to digitise routine classroom tasks. Instead, its gestural interface, immediate feedback, and visible circuitry supported forms of musical engagement that are atypical in school programmes and required corresponding shifts in pedagogy and interaction. This also aligns with Peters' (2017) argument that the issue is not whether to integrate Information and Communication Technology (ICT) devices, but how and why they are used in context, and with Vanderlinde's (2017) Universal Design for Learning perspective that participation depends on offering multiple pathways for engagement, expression, and peer interaction. In Medvinsky's (2017a) terms, the aim was for technology to operate as a scaffold that becomes transparent to musical experience while increasing students' voice and choice. Finally, the findings remain consistent with evidence that outcomes depend on conditions of implementation, including time, support, and clear pedagogical aims (Merrick & Joseph, 2023; Rexhepi et al., 2024).

An accessible instrument and a tangible build that students could physically assemble, test, and troubleshoot enacted two-way interdisciplinarity: from sound/gesture to light/circuit and back. Rather than treating STEAM as art-enhanced science (as proposed by Chu et al., 2019), observations of students in the workshops found a dialogue of equality, not a hierarchy, with ideas moving back and forth between both areas. This extends STEAM accounts that describe integration as a one-directional add-on by showing reciprocal movement between disciplinary ideas and practices during making and performance.

Another point is that a tangible instrument build could help motivate group work at lower secondary level. This aligns with Green's (2008) evidence that learner-directed, peer-group work can strengthen cooperation and draw previously disaffected students into participation, while my case suggests that similar dynamics can be organised around building and performing a self-built artefact, not only around repertoire-based group performance. The gains arose from design (planned interdependence, scarcity) rather than from the tool alone. In this respect, the contribution is not only that the theremin can support interdisciplinarity but that it can be used as a shared object around which roles, responsibilities, and problem-solving become visible, which helps explain why peer interaction increased even in a setting where group work was usually rare.

This research also extends existing research on collaborative, artefact-based learning. Calabrese Barton and Tan's (2018) work on STEM-rich making and practices sustained across spaces is carried here into a music-based STEAM context through a self-built artefact that moved between school and everyday settings. Jakobsen et al.'s (2016) build-test-perform model is further extended through the central role of troubleshooting, repair, and peer teaching during instrument construction.

8.4 Implications for Practice

My research provides an evidence-based exemplar of how an accessible musical instrument, the theremin, can be used to integrate science and music learning. STEAM interventions that prioritise practical, creative, and collaborative work can shift engagement from passive participation to agency, curiosity, and a sense of ownership. With support to explore, build, and perform in an autonomous way, students developed resilience and learned to value effort and persistence. This research shows that the theremin can act as both a scientific artefact and a platform for artistic expression to integrate disciplines (music and science).

Hallam and Himonides (2022) argue that making music with others requires teamwork underpinned by trust and respect, and this joint action supports shared performance goals. In practical terms, this supports treating peer interaction as a design outcome: teachers can plan moments of shared goals, not only individual exploration, so that coordination and mutual support are necessary for success. This aligns with my finding that troubleshooting and brief public explanations helped make contribution visible and made collaboration functional.

From an academic emotional perspective, task design can support emotion regulation by shaping appraisals, competence-related beliefs, and the learning environment (Pekrun & Linnenbrink-Garcia, 2012). Pekrun and Linnenbrink-Garcia describe intervention types that target emotion-oriented regulation, appraisal-oriented regulation, competence-oriented strategies, and instructional design. In practical terms, this suggests planning small steps with immediate checks, treating errors as part of making, and structuring peer help so frustration remains workable and students can achieve relief and pride through repair.

For practice, this implies that "technology integration" should be treated as a design and inclusion problem, not as an add-on. Following Peters (2017), the decision is guided by how and why the tool is used and what forms of participation it enables. Following Vanderlinde (2017), planning should provide multiple pathways for students to engage, communicate ideas, and participate in peer interaction. Following Medvinsky (2017a), technology should support core

musical processes and become transparent to musical experience rather than drawing attention away from it. In addition, teachers need time and support to implement these approaches under real-world constraints (Merrick & Joseph, 2023). Evidence from quasi-experimental work suggests that carefully designed digital environments can improve learning outcomes and participation when implementation is supported and pedagogically coherent (Rexhepi et al., 2024).

For teachers and school leaders, building engagement requires more than developing different formats of delivering content or managing behaviour. Effective approaches attend to behavioural, cognitive, emotional/affective, social, and agentic dimensions, and create opportunities to link classroom learning to everyday life. When students perceive value in a project, participation increases. This research provides evidence that the theremin can be used as both an accessible entry point and a teaching tool to make learning relevant in Brazilian public schools where limited resources and disrupted learning histories can constrain opportunities for practical, collaborative work. Outside Brazil, the same principles remain applicable, but they should be adapted to local constraints and routines, including available lesson time, access to materials, and norms around group work and assessment.

Merrick and Joseph (2023) show that technology integration is shaped by teacher self-efficacy and confidence, while Rexhepi et al. (2024) note that inequality in access and infrastructure, alongside the need for teacher training, can constrain implementation. Taken together, this suggests the principles in this thesis need to be adapted to local resourcing and teacher capacity rather than being treated as a one-size solution.

This thesis offers a transferable set of design principles for STEAM teaching and learning in resource-constrained settings: a shared artefact; ERA-shaped tasks; planned interdependence; flexible roles; and public (even if brief) explanations in class and at home. These principles can be combined with local curriculum goals, assessment routines, and available materials.

Situated Expectancy-Value Theory (SEVT) research offers a parallel design lens. In SEVT, participation and persistence are expected when students believe they can succeed and when the task is worth doing relative to its perceived cost (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000). In practice, this implies that STEAM workshop design should plan for competence, building in feedback and visible progress

8.5 Limitations

This is a qualitative, single-site study in which I, as the researcher, also taught. Attendance varied with weather, resources were limited, and students were coming back to school after COVID-19 lockdowns. To ensure my findings are credible, I triangulated student focus groups, teacher interviews, and my reflective journal, and I used systematic NVivo coding and category sorting to make analytic decisions transparent and traceable. I minimised bias by explicitly coding criteria and cross-checking critical episodes with teacher testimony. Other limitations I recognise from my study, such as political issues, lack of resources, and the predominance of teacher-centred classrooms, remain beyond the scope of any single intervention.

Because I taught while researching, my presence and relationships with students may have shaped participation and focus group talk. Focus groups can amplify peer norms and social desirability, so I treated them as accounts of shared meaning and experience, not as individual reports. The study therefore supports explanation of mechanisms and conditions, but it does not estimate effect sizes or prevalence. Although the study does not estimate prevalence, it offers transferable design principles for resource-constrained settings, such as a shared artefact, ERA-shaped tasks, planned interdependence, flexible roles, and brief public explanations in class and at home. These principles specify conditions under which the mechanisms described in this thesis became possible, but they require adaptation to local constraints and routines, including lesson time, access to materials, and norms around group work and assessment.

Recurring political changes at the administrative level were shown to undermine continuity and sustainability of educational projects, while the lack of access to basic items (such as prescription glasses or suitable clothing) directly impacts attendance and learning. The high dropout rate and absenteeism required frequent adaptation during the workshops, and these broader systemic challenges cannot be addressed by classroom innovation alone. Implementation is also shaped by teacher confidence and self-efficacy as well as constraints, such as time, support, and access to infrastructure and training. For these reasons, applying the design principles described here depends on local resourcing and teacher capacity, not only on the classroom task itself.

It is also necessary to recognise that not all students automatically translated increased engagement into deeper understanding of scientific or artistic concepts. Some needed explicit, ongoing support to make the link between school knowledge and practical application, highlighting the importance of teacher mediation in the learning process. In this study, design

choices, such as visual scoring and short feedback loops, alongside structured peer roles, helped make participation and troubleshooting feasible, even when conceptual understanding developed unevenly. However, even when conceptual understanding remained uneven, students' increased willingness to participate, persist, and collaborate created better conditions for learning to develop over time, and it provided teachers with clearer opportunities to intervene and consolidate key ideas.

8.6 Directions for Future Research

My study suggests that specific design choices, such as immediate feedback (both in electronics and musically with gestures on the theremin), meaningful roles in the build, accessible musical entry points, and an artefact that students could take home, increased student participation at school. Girls led circuit layout and soldering and became reference points for peers during troubleshooting and assembly, which suggests that structured making tasks can redistribute expertise in ways that are not always visible in teacher-centred classrooms; pairs with motor challenges split tasks and achieved precision; and quiet students became reliable testers and explainers. Further research is needed across more than one school to examine whether these patterns hold under different routines, staffing, resourcing levels, and cohort characteristics.

Given postpandemic reports of increased technology use alongside uneven teacher confidence and preparation (Merrick & Joseph, 2023), future research could also examine what professional learning and support nonspecialist teachers need to implement similar, low-cost, artefact-based STEAM sequences in their own settings. At least three testable propositions emerge from my findings, and the study can be treated as a pilot that motivates larger scale research designed to examine them more systematically:

1. When make-test feedback is immediate, perceived cost drops and persistence rises in lower-secondary STEAM.
2. Planned interdependence holds measurable gains in peer-teaching episodes when compared with fully resourced, individual builds.
3. Allowing the artefact to travel beyond school increases the frequency of cross-subject talk (science ↔ arts) in subsequent lessons.

To examine these propositions further, future studies could:

- (a) follow student cohorts over time to see whether gains in engagement and interdisciplinarity persist after the workshops and for how long;

- (b) test variations of the sequence (other sensors, digital builds, or other accessible instruments) to isolate what is theremin specific from what is design specific;
- (c) compare classes with a control group;
- (d) map peer networks over time to see whether “go-to” student helpers remain the same or if the role gets passed around to other students; and
- (e) combine qualitative classroom data with quantitative engagement/achievement measures.

A further area of research to study is long-term retention. Do students still recognise and use pitch/height/rhythm learned through visual-gestural theremin activities months later? Do they still remember resistor/capacitor/polarity distinctions learned in the build, even if they do not follow STEM tracks? The arts and science teachers in this study both reported the need for frequent revisiting of fundamentals; a longitudinal design could show whether artefact-based learning slows that forgetting curve.

Finally, this project would benefit from other educators and researchers inventing new musical, dramatic, or visual prompts – especially people who are not thereminists. Fresh eyes might find affordances I did not use (or was not able to see), and that, in turn, could push student engagement, peer interaction, and art-science integration further.

8.7 Final Thoughts

My research provides evidence that hands-on, interdisciplinary activities can improve student engagement in public school settings facing complex challenges. The findings show that projects like the theremin workshops can promote collaboration, motivation, and practical learning, even among students who have previously struggled to participate. While such interventions are not a solution to all structural issues, they offer a practical approach that can be adapted by educators seeking to address disengagement and support student development. This work contributes to current discussions about the value and limits of STEAM initiatives in education and highlights the need for flexible strategies to address disengagement in schools.

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APPENDICES

Appendix A – Ethics committee application approval

Te Wānanga Toi Tangata
Division of Education
The University of Waikato
Private Bag 3105
Hamilton,
New Zealand, 3240

Division of Education Research
Ethics Committee (DEREC)
fedu.ethics@waikato.ac.nz
www.waikato.ac.nz



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

22/3/2022

Dear Christian de Sá Quimelli

**Division of Education Research Ethics Committee Application Approved
FEDU013/22**

I am pleased to advise you that your ethics application for the project entitled “Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art” was approved by Te Wānanga Toi Tangata Division of Education Research Ethics Committee on March 22nd, 2022.

Please be aware that the Te Wānanga Toi Tangata Division of Education Research Ethics Committee must be advised (by memo) of any changes to the details recorded in your ethics application. Please send any such advice to fedu.ethics@waikato.ac.nz. You will receive a memo of approval once the change(s) has been considered.

Kind regards

Co-chairs

Te Wānanga Toi Tangata Division of Education Research Ethics Committee (DEREC)

Appendix B – Participation Information Sheet – Teachers

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Participant Information Sheet – (Teachers)

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to participate in this investigation.

Purpose of this research

I am undertaking some research to develop new ways to improve interdisciplinarity, promote inclusion of disaffected students and enhance peer interaction in schools using science and art. As part of this research, I have received permission from [principal] to run a music and physics project for students in your school. I would like to work with the fundamental 8 class of your school. I would like to interview you to find out more about the students who will participate in the study. This interview's objective is to gather data from a wider perspective, so I can understand the students in a deeper way. I wish to know about student engagement in school and peer interaction in class. Your point of view and impressions will be part of my data triangulation along with the focus group interview I will make with the students and my own reflective journal.

Your role

If you decide to participate in this study, you will be asked to take part in two interviews with the researcher. Each interview will be at a time that is convenient for you inside the school surroundings. Each interview will take **20-30 minutes** and will be **audio recorded**. There are no 'right' or 'wrong' answers to the interview questions. The aim is to identify your experiences. You will be given the opportunity to review a transcript of the interviews to ensure it accurately reflects your views. This will be emailed to you and should take no more than **15-20 minutes** to review. Each interview and transcript review process can take up to 1 hour.

Consent to participate

Your involvement in this research is entirely voluntary. You have the right to choose not to participate or to withdraw without consequences of any kind up until the time you approve the transcription of your interview. If you do consent to participate, you will be asked to sign a consent form before the interview. [Note: the science or the music teacher will have to agree to this. Only one of them is needed.] You will be asked to give up your class time for the workshops/creative component for a total of 10 classes. [Note: it is preferable that music classes be chosen for this case because of the researcher background (music teacher).¹] The music and science content covered in this research is the same to what is provided in the curriculum for this year. In this way, any replacement of music or science classes with the workshops will generate no loss of content or gaps in teaching. The content will be discussed with you in detail, so you understand which parts of the curriculum will be covered before the project begins.

Confidentiality and anonymity

Every effort will be made to protect your identity and the identity of the school you work at. However, please be aware that this cannot be completely guaranteed. In the research outputs, you and the school will be referred to by a pseudonym. Data collected during the interview will be treated as confidential.

What I will do with the data

Data in this study is being collected for research purposes. Your personal details will be kept confidential. The recording and transcription of the interview may be shared with my supervisors. The results of the study will be published and may be presented at academic conferences. Nothing that might allow you to be identified will be included in any materials that are published or presented. You will be sent a short summary of the

¹ There is no problem whatsoever if the science teacher agrees to it..

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



findings of the research. Publications arising from this study will be made available to you as a participant and to any other interested parties who may request them. In accordance with University policy, all hard copy and electronic materials from the study will be stored securely for a minimum of five years following the conclusion of the study.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XL. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix C – Participation Consent Form – Teachers

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com Phone: +55 42 99111-5624

PARTICIPANT CONSENT FORM – (Teachers)

By signing this consent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to take part in this study as outlined to me.

I understand that:

- My participation is voluntary and I can withdraw at any time without consequence, until I have approved the transcription of my interview;
- My participation involves two interviews of approx. 20-30 minutes each and review of the transcription of these interviews – up to 1 hour each including time to review the transcripts; The interviews will be audio-recorded;
- All information about me will be treated as confidential;
- There are no 'right' or 'wrong' answers to the interview questions;
- [Note: the science or the music teacher will have to agree to this. Only one of them is needed.]: I will give up my class time for the workshops/creative component for a total of 10 classes.
- I will receive a summary of the research findings;
- I will receive no payment for participating in this research; and
- The researcher will make every effort to protect my identity, but that cannot be completely guaranteed.

Name:	
Signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLI. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix D – Participation Information Sheet – Students’ Parents or Caregivers (of those not participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Participant Information Sheet – (Students’ parents or caregivers)

Obs: for those whose children will NOT participate in the focus group interviews

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to let your child participate in this investigation.

Purpose of this research

I would like to develop new ways to improve interdisciplinarity, promote inclusion of disaffected students and enhance peer interaction in schools using science and art. For this purpose, I am inviting your child to participate in a study in her/his school involving music and electronics.

Your role

If you decide to let your child participate in this study, she/he will engage in the following activities at school:

- 1) Music workshop with the Theremin instrument;
 - 2) Electronic workshop where she/he will learn how to build an electronic instrument;
 - 3) Creative workshop where the child will compose and play with the previously build instrument; and
- These activities will consist of weekly meetings of 50min over a school term – a 10-week period.

Workshops will take place during Music classes. The students that don't wish to participate in the activities will have regular curricular Music classes with the classroom teacher.

Consent to participate

The involvement of your child in this research is entirely voluntary. You have the right to choose to not let her/him participate or to withdraw without consequences of any kind. If you do consent to let your child participate, you will be asked to sign a consent form before the intervention.

Confidentiality and anonymity

Every effort will be made to protect your child's identity. However, please be aware that this cannot be completely guaranteed. In the research outputs, your child will be referred to by a pseudonym. Data collected during the intervention will be treated as confidential. Some activities will be photographed and/or filmed and will be used for research purpose only. Identities will be preserved through face blur.

Health and safety

All relevant health and safety policies and procedures will be followed during the electronics workshop, and I will be liaising with the principal in this area. These safety policies and procedures can be found in the Caderno de orientações para utilização do laboratório escolar de ciências da natureza da rede estadual de ensino do Paraná, available in the link:
http://www.biologia.seed.pr.gov.br/arquivos/File/PDF/cadern_lab_2013.pdf.

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



What I will do with the data

Data in this study is being collected for research purposes. Your child's personal details will be kept confidential. The information gathered in the activities may be shared with the research supervisors. The results of the study will be published and may be presented at academic conferences. Nothing that might allow your child to be identified will be included in any materials that are published or presented. In accordance with University policy, all hard copy and electronic materials from the study will be stored securely for a minimum of five years following the conclusion of the study.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix E – Participation Information Sheet – Students’ Parents or Caregivers (of those participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
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Private Bag 3105
Hamilton, New Zealand, 3240



Participant Information Sheet – (Students’ parents or caregivers)

Obs: for those whose children will participate in the focus group interviews

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to let your child participate in this investigation.

Purpose of this research

I would like to develop new ways to improve interdisciplinarity, promote inclusion of disaffected students and enhance peer interaction in schools using science and art. For this purpose, I am inviting your child to participate in a study in her/his school involving music and electronics.

Your role

If you decide to let your child participate in this study, she/he will engage in the following activities at school:

- 1) Music workshop with the Theremin instrument;
- 2) Electronic workshop where she/he will learn how to build an electronic instrument;
- 3) Creative workshop where the child will compose and play with the previously build instrument; and
- 4) Focus group interview.

These activities will consist of weekly meetings of 50min over a school term – a 10-week period.

Workshops will take place during Music classes. The students that don't wish to participate in the activities will have regular curricular Music classes with the classroom teacher.

Note regarding item number 4 – focus group interview: the focus group is a group interview where I will discuss with the students about their relationship with schools subjects, their engagement in school and their peer relationships. There won't be any right or wrong answers and there won't be any kind of relation between this interview and their school records or grades.

Consent to participate

The involvement of your child in this research is entirely voluntary. You have the right to choose to not let her/him participate or to withdraw without consequences of any kind. If you do consent to let your child participate, you will be asked to sign a consent form before the intervention.

Confidentiality and anonymity

Every effort will be made to protect your child's identity. However, please be aware that this cannot be completely guaranteed. In the research outputs, your child will be referred to by a pseudonym. Data collected during the intervention will be treated as confidential. Some activities will be photographed and/or filmed and will be used for research purpose only. Identities will be preserved through face blur.

Health and safety

All relevant health and safety policies and procedures will be followed during the electronics workshop, and I will be liaising with the principal in this area. These safety policies and procedures can be found in the Caderno de orientações para utilização do laboratório escolar de ciências da natureza da rede estadual de ensino do Paraná, available in the link:

http://www.biologia.seed.pr.gov.br/arquivos/File/PDF/cadern_lab_2013.pdf.

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



What I will do with the data

Data in this study is being collected for research purposes. Your child's personal details will be kept confidential. The information gathered in the activities may be shared with the research supervisors. The results of the study will be published and may be presented at academic conferences. Nothing that might allow your child to be identified will be included in any materials that are published or presented. In accordance with University policy, all hard copy and electronic materials from the study will be stored securely for a minimum of five years following the conclusion of the study.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLIII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix F – Participation Consent Form – Students’ Parents or Caregivers (of those not participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
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Hamilton, New Zealand, 3240



Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com Phone: +55 42 99111-5624

PARTICIPANT CONSENT FORM – (Students’ parents or caregivers)

Obs: for those whose children will NOT participate in the focus group interviews

By signing this consent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to let my child take part in this study as outlined to me.

I understand that:

- My child’s participation is voluntary and she/he can withdraw at any time without consequence;
- My child’s participation involves music, electronic and composition workshops;
- All relevant health and safety policies and procedures will be followed during the electronics workshop;
- All information about my child will be treated as confidential;
- Some activities will be photographed and/or filmed;
- There are no costs for me or my child for participating in these activities;
- Neither I nor my child will receive payment for participating in this research; and
- The researcher will make every effort to protect my child’s identity, but that cannot be completely guaranteed.

Name of the parent/caregiver:	
Name of the children:	
Parent/caregiver signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLIV. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix G – Participation Consent Form – Students’ Parents or Caregivers (of those participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
 The University of Waikato
 Private Bag 3105
 Hamilton, New Zealand, 3240



PARTICIPANT CONSENT FORM – (Students’ parents or caregivers)

Obs: for those whose children will participate in the focus group interviews

By signing this consent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to let my child take part in this study as outlined to me.

I understand that:

- My child’s participation is voluntary and she/he can withdraw at any time without consequence;
- My child’s participation involves music, electronic, composition workshops and focus group interviews;
- All relevant health and safety policies and procedures will be followed during the electronics workshop;
- All information about my child will be treated as confidential;
- Some activities will be photographed and/or filmed;
- There are no costs for me or my child for participating in these activities;
- Neither I nor my child will receive payment for participating in this research; and
- The researcher will make every effort to protect my child’s identity, but that cannot be completely guaranteed.

Name of the parent/caregiver:	
Name of the children:	
Parent/caregiver signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLV. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix H – Participation Information Sheet – Students (not participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Participant Information Sheet – (Students)

Obs: for those children who will not participate in the focus group interviews

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to participate in this investigation.

Purpose of this research

I would like to develop new ways of working with science and art in schools. For this purpose, I am inviting you to participate in a study involving music and electronics.

Your role

If you decide to participate in this study, you will engage in the following activities at school:

- 1) Music workshop with the Theremin instrument x 3 (50-60 min each) – up to 3 hours total;
- 2) Electronic workshop where you will learn how to build an electronic instrument x 4 (50-60 min each) – up to 4 hours total; and
- 3) Creative workshop where you will compose and play with the previously build instrument x 3 (50-60 min each) – up to 3 hours total.

These activities will consist of weekly meetings of 50 min over a school term – a 10-week period.

Workshops will take place during Music classes. The students that don't wish to participate in the activities will have regular curricular Music classes with the classroom teacher.

Assent to participate

Your involvement in this research is entirely voluntary. You have the right to choose to not participate or to withdraw without consequences of any kind. If you do assent to participate, you will be asked to sign an assent form before the intervention.

Confidentiality and anonymity

Every effort will be made to protect your identity. However, please be aware that this cannot be completely guaranteed. In the research outputs, you will be referred to by a pseudonym. Data collected during the intervention will be treated as confidential. Some activities will be photographed and/or filmed and will be used for research purpose only. Identities will be preserved through face blur.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLVI. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix I – Participation Information Sheet – Students (participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
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Hamilton, New Zealand, 3240



Participant Information Sheet – (Students)

Obs: for those children who will participate in the focus group interviews

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to participate in this investigation.

Purpose of this research

I would like to develop new ways of working with science and art in schools. For this purpose, I am inviting you to participate in a study involving music and electronics.

Your role

If you decide to participate in this study, you will engage in the following activities at school:

- 1) Music workshop with the Theremin instrument x 3 (50-60 min each) – up to 3 hours total;
- 2) Electronic workshop where you will learn how to build an electronic instrument x 4 (50-60 min each) – up to 4 hours total;
- 3) Creative workshop where you will compose and play with the previously build instrument x 3 (50-60 min each) – up to 3 hours total; and
- 4) Focus group interview x 2 (40 min) - Up to 80 min.

These activities will consist of weekly meetings of 50 min over a school term – a 10-week period.

Workshops will take place during Music classes. The students that don't wish to participate in the activities will have regular curricular Music classes with the classroom teacher.

Note regarding item number 4 – focus group interview: the focus group is a group interview where we will discuss about school related things. There won't be any right or wrong answers and there won't be any kind of relation between this interview and your school records or grades.

Assent to participate

Your involvement in this research is entirely voluntary. You have the right to choose to not participate or to withdraw without consequences of any kind. If you do assent to participate, you will be asked to sign an assent form before the intervention.

Confidentiality and anonymity

Every effort will be made to protect your identity. However, please be aware that this cannot be completely guaranteed. In the research outputs, you will be referred to by a pseudonym. Data collected during the intervention will be treated as confidential. Some activities will be photographed and/or filmed and will be used for research purpose only. Identities will be preserved through face blur.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLVII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix J – Participation Assent Form – Students (not participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
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Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com Phone: +55 42 99111-5624

PARTICIPANT ASSENT FORM – (Students)

Obs: for those children who will NOT participate in the focus group interviews

By signing this assent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to take part in this study as outlined to me.

I understand that:

- My participation is voluntary and I can withdraw at any time without consequence;
- My participation involves music, electronic and composition workshops;
- Some activities will be photographed and/or filmed;
- There are no costs for me for participating in these activities;

Name:	
Signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLVIII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix K – Participation Assent Form – Students (participating in the Focus Groups)

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
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Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com Phone: +55 42 99111-5624

PARTICIPANT ASSENT FORM – (Students)

Obs: for those children who will participate in the focus group interviews

By signing this assent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to take part in this study as outlined to me.

I understand that:

- My participation is voluntary and I can withdraw at any time without consequence;
- My participation involves music, electronic, composition workshops and focus group interviews;
- Some activities will be photographed and/or filmed;
- There are no costs for me for participating in these activities;

Name:	
Signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on XLIX. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix L – Participation Information Sheet – Principal

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Participant Information Sheet – (Principal)

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Thank you for your interest in this research. This information sheet provides important information about the study. Please read it carefully and ask any questions you have before consenting to participate in this investigation.

Purpose of this research

I am undertaking research to develop new ways to improve interdisciplinarity, promote inclusion of disaffected students and enhance peer interaction in schools using science and art. For this to happen, I need your permission to run a music and physics project for students in your school. I would like to work with the *fundamental 8* class of your school.

If you decide to let the students of your institution participate in this study, they will engage in the following activities at school:

- 1) Music workshop with the Theremin instrument;
- 2) Electronic workshop where they will learn how to build an electronic instrument;
- 3) Creative workshop where they will compose and play with the previously build instrument; and
- 4) Focus group interview.

These activities will consist of weekly meetings of 50 min over a school term – a 10-week period.

Workshops will take place during Music classes. The students that don't wish to participate in the activities will have regular curricular Music classes with the classroom teacher.

Data collection will be through semi-structured interviews with the teachers, focus groups with the students, and my own reflective journal.

Consent to participate

Your school involvement in this research is entirely voluntary.

Teachers and students have the right to choose not to participate or to withdraw without consequences of any kind.

The consent of teachers, students and their parents/care-givers will be obtained through individual consent forms.

If you do consent to let your school participate, you will be asked to sign a consent form before the study.

Confidentiality and anonymity

Every effort will be made to protect your identity, the identity of teachers, students, and the institution. However, please be aware that this cannot be completely guaranteed. In the research outputs, all the participants and the school will be referred to by a pseudonym. Data collected during the study will be treated as confidential. Some activities will be photographed and/or filmed and will be used for research purpose only. Identities will be preserved through face blur.

Health and safety

Every effort will be made to ensure the safety of the young people participating in this research. The students will need to work in groups and potential harm could arise as a result of group dynamics. I will do everything within my power to mitigate this, carefully observing group dynamics and stepping in where necessary. Another potential harm comes from the electronic workshop. The children will use soldering irons with a burning hazard. These irons present first-degree burns in worst-case scenarios but are still a possibility. All instructions and safety protocols will be presented and discussed with the students and/or classroom teachers and followed during this activity.

These safety policies and procedures can be found in the Caderno de orientações para utilização do laboratório escolar de ciências da natureza da rede estadual de ensino do Paraná, available in the link: http://www.biologia.seed.pr.gov.br/arquivos/File/PDF/cadern_lab_2013.pdf.

If you do consent to let your school participate, you will be asked to discuss this matter further with the researcher.

What I will do with the data

Data in this study is being collected for research purposes. Your personal details will be kept confidential. The recording and transcription of the interview may be shared with my supervisors. The results of the study will be published and may be presented at academic conferences. Nothing that might allow you to be identified will be included in any materials that are published or presented. You will be sent a short summary of the findings of the research. Publications arising from this study will be made available to you as a participant and to any other interested parties who may request them. In accordance with University policy, all hard copy and electronic materials from the study will be stored securely for a minimum of five years following the conclusion of the study.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on L. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix M – Participation Consent Form – Principal

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com Phone: +55 42 99111-5624

PARTICIPANT CONSENT FORM – (Principal)

By signing this consent form, I agree that:

- I have been informed about and understand the purpose of the study;
- I have been given the opportunity to ask questions; and
- I agree to let the institution I am responsible for as the role of principal to take part in this study as outlined to me.

I understand that:

- The participation of the institution I am responsible for, the teachers and students is voluntary and can be withdraw at any time without consequence;
- All information about the ones involved in this study will be treated as confidential;
- Some activities will be photographed and/or filmed;
- I will receive a summary of the research findings;
- I will receive no payment for letting my school participate in this research;
- There are no costs for my institution for participating in these activities;
- The researcher will make every effort to protect the identity of the ones involved, but that cannot be completely guaranteed.

Name:	
Signature:	
Date:	

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on 11. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix N – Letter to the Principal

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Letter to the Principal

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Dear principal,

My name is Christian de Sá Quimelli. I am a PhD student at the University of Waikato (New Zealand), and I am undertaking research to develop new ways to improve interdisciplinarity, promote inclusion of disaffected students and enhance peer interaction in schools using science and art.

For this to happen, I need to run a music and physics project for your *fundamental 8*.

I kindly request a meeting to discuss the possibility of carrying out these activities in your school. You will also have the opportunity to ask any questions you may have regarding this research.

The activities will have no costs for your institution, and all data gathered will be treated confidentially.

If you agree to meet with me to discuss the matter, you can contact me by phone or email, both of which are provided at the beginning of this letter.

Thank you very much for your attention and I wish you and your institution all the best.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on LII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix O – Interview Guide – Teachers

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Private Bag 3105
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Interview Guide – (Teachers)

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Semi-structured interview

Guiding questions:

Note to the interviewed teacher: Please remember that there are no right or wrong answers to this interview. You will only state your perception on the matter.

Section 1) [warming up questions]

- 1) Has being a teacher in your workplace changed over the past few years?
- 2) How have your ideas of teaching changed over this time?

Section 2)

- 3) I would like you to tell me about student engagement in your subject. Please note that this is not a question about your ability as a professional or how much you can captivate your students, but your perception of students towards the subject you teach.
 - a. Do they engage well?
 - b. Do they bring real life examples to the class?
- 4) What is your perception of student engagement in school in general?
 - a. And about student satisfaction in school?

Section 3)

- 5) How do you perceive the students' understanding of the aspects of music/science? [the last word changes depending on the teacher being interviewed]
 - a. How much effect does this have on your classes?
- 6) Can you tell me about peer interaction among the students?
 - a. Do the students get along in group activities?
- 7) Do you identify any disaffected students in class? [note: no names are needed, just the information if there are disaffected students or not, and if there are few or many of them in the fundamental 8]
 - a. What do you think is the greater motive behind student disaffection in these cases?
 - i. How do you usually respond to these cases?

Section 4) [closure question]

- 8) Is there anything else that you feel that we should have talked about but didn't?

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on LIII. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix P – Interview Guide – Students

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Focus Group Guide – (Students)

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

Focus Group Interview

Guiding questions:

Note to the interviewed students: Please remember that there are no right or wrong answers to this conversation. You will only state your perception on the matter. There is no evaluation to them, and they will not affect by any means your grade or your school records.

Section 1) [warming up question]

- 1) How is daily life in your school?

Section 2)

- 2) If you could speak about satisfaction at school, how would you express yourself about it?
 - a. How do you feel about school?
 - i. Do you look forward to coming to school?
- 3) How do you feel about science? Please, note that I am not talking about the science teacher, but the science subject.
 - a. Do you like/enjoy it?
 - i. Does it make sense to you?
- 4) In the same way, how do you feel about music?

Section 3) [This section is for the pre-workshop focus group]

- 5) Try to recall in your head the last time you worked with group projects at school.
 - a. How do your groups usually work?
 - b. How do you deal with this kind of peer-related work?
 - i. Are they difficult to handle?
 1. How do you normally overcome these challenges?

Section 4 [This section is for the post-workshop focus group]

- 6) Regarding the electronic workshop, what was it like to teach/learn from a colleague?
 - a. Was it difficult?
 - b. What challenges did you perceive at it?
 - i. How did you overcome those challenges?
 - c. Were you able to understand the connection between the workshops and the school subjects?
- 7) Did the workshops change your perception of science and/or music in any way?
 - a. And in school in general?

Section 5) [closure question]

- 8) Is there anything else that anyone feels that we should have talked about but didn't?

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on LIV. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix Q – Evidence of Class Curriculum Alignment for Music and Science with the Research Project

Faculty of Education
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Evidence of class curriculum alignment for music and science with the research project

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

This appendix serves as evidence of how my proposed intervention aligns with the class curriculum for music and science. This is to verify that students will not be missing out on the intended curriculum learning through participation in my project.

Curriculum

The Brazilian curriculum is administrated and regimented by the *Lei de Diretrizes e Bases da Educação Nacional (LDB)* - Legal guidelines and bases of national education from the *Ministério da Educação (MEC)* - Ministry of Education². The current LDB is the nº 9.394/1996³. Each one of the 27 Brazilian federative units⁴ can build its own curriculum on top of this document. Although they might contain variations and regional differences due to the continental size of the country, the core of these documents remains the same.

The state where this intervention is taking place – *Paraná* – has its documentation on the following website: <http://www.referencialcurricularparana.pr.gov.br/>. This website has curriculum information separated by year and subject.

The fundamental 8 year – the class chosen for this research – has their specific curriculum on this link: <http://www.referencialcurricularparana.pr.gov.br/modules/conteudo/conteudo.php?conteudo=84>.

The Science curriculum for this year can be found here: <http://www.referencialcurricularparana.pr.gov.br/modules/conteudo/conteudo.php?conteudo=47>, and the Music curriculum for this year here: <http://www.referencialcurricularparana.pr.gov.br/modules/conteudo/conteudo.php?conteudo=37>.

Brazilian nomenclature of specific areas within school subjects

In the curriculum of the state of *Paraná* the subjects are named *Unidade Temática* – Thematic Unit, the broad areas within the subjects are named *Objetos de Conhecimento* – Knowledge Objects, and the specific topics are named *Objetivos de Aprendizagem* – Learning Objectives. For instance, if I want to discuss the topic of initiatives that contribute to restoring environmental balance in the science curriculum for this specific year I'll need to address it this way:

Unidade Temática – Thematic Unit:
Terra e Universo – Earth and Universe.

Objetos de Conhecimento – Knowledge Objects:
Sistema Sol, Terra e Lua / Água / Dinâmicas climáticas – Solar system, Earth and Moon / Water / Climate dynamics.

Objetivos de Aprendizagem – Learning Objectives:
(EF08CI16) *Discutir iniciativas que contribuam para restabelecer o equilíbrio ambiental a partir da identificação de alterações climáticas regionais e globais provocadas pela intervenção humana.* – Discuss initiatives that contribute to restoring environmental balance from the identification of regional and global climate changes caused by human intervention.

The code EF08CI16 is for the specific topic for the climate discussion matter. Every specific topic has its own code to be addressed.

² In this document I'll address the original subject name in Portuguese followed by the English translation.

³ <http://basenacionalcomum.mec.gov.br/>

⁴ 26 states and 1 federal district

Areas involved in this research

Considering the nomenclatures stated in the previous item, the subjects from the fundamental 8 class that are addressed in this intervention are:

1) *Unidade Temática* – Thematic Unit: *Música* – Music

- a. *Objetos de Conhecimento* – Knowledge Objects: *Contextos e práticas* – Contexts and practices
 - i. *Objetivos de Aprendizagem* – Learning Objectives:
 - 1. (EF69AR19) *Identificar e analisar diferentes estilos musicais, contextualizando-os no tempo e no espaço, de modo a aprimorar a capacidade de apreciação da estética musical.* – Identify and analyze different musical styles, contextualizing them in time and space, in order to improve the ability to appreciate musical aesthetics.
 - a. *Subtópico: Pesquisar e identificar (ludicamente) músicas que utilizam recursos tecnológicos.* – Subtopic: Search and identify (ludically) songs that use technological resources.
 - b. *Subtópico: Identificar a música produzida no Século XX, a minimalista e a eletrônica, hip hop, reggae entre outros.* – Subtopic: Identify music produced in the 20th century, minimalist and electronic, hip hop, reggae, among others.
- b. *Objetos de Conhecimento* – Knowledge Objects: *Elementos da linguagem* - Language elements
 - i. *Objetivos de Aprendizagem* – Learning Objectives:
 - 1. (EF69AR20) *Explorar e analisar elementos constitutivos da música (altura, intensidade, timbre, melodia, ritmo etc.), por meio de recursos tecnológicos (games e plataformas digitais), jogos, canções e práticas diversas de composição/criação, execução e apreciação musicais.* – Explore and analyze constitutive elements of music (pitch, intensity, timbre, melody, rhythm, etc.), through technological resources (games and digital platforms), games, songs and various practices of composition/creation, performance and appreciation of music.
 - a. *Subtópico: Produzir diferentes composições, por meio de recursos digitais, e alternativos dentro da indústria cultural.* – Subtopic: Produce different compositions, through digital and alternative resources within the cultural industry.
- c. *Objetos de Conhecimento* – Knowledge Objects: *Notação e registro musical* – Musical notation and recording
 - i. *Objetivos de Aprendizagem* – Learning Objectives:
 - 1. (EF69AR22) *Explorar e identificar diferentes formas de registro musical (notação musical tradicional, partituras criativas e procedimentos da música contemporânea), bem como procedimentos e técnicas de registro em áudio e audiovisual.* – Explore and identify different forms of musical recording (traditional musical notation, creative scores and contemporary music procedures), as well as audio and audiovisual recording procedures and techniques.
 - a. *Subtópico: Apreciar e compor registros de partituras convencionais e não convencionais.* – Subtopic: Appreciate and compose conventional and unconventional scores.

2) *Unidade Temática* – Thematic Unit: *Matéria e energia* – Matter and energy

- a. *Objetos de Conhecimento* – Knowledge Objects: *Fontes e tipos de energia, Transformação de energia, Circuitos elétricos* - Energy sources and types, Energy transformation, Electrical circuits
- i. *Objetivos de Aprendizagem* – Learning Objectives:
1. (EF08CI02) *Construir circuitos elétricos com pilha/bateria, fios e lâmpadas ou outros dispositivos e compará-los a circuitos elétricos residenciais.* – Build electrical circuits with batteries, wires and light bulbs or other devices and compare them to residential electrical circuits.
 2. (EF08CI03) *Classificar equipamentos elétricos residenciais (chuveiro, ferro, lâmpadas, TV, rádio, geladeira etc.) de acordo com o tipo de transformação de energia (da energia elétrica para a térmica, luminosa, sonora e mecânica, por exemplo).* – Classify residential electrical equipment (shower, iron, lamps, TV, radio, refrigerator, etc.) according to the type of energy transformation (from electrical energy to thermal, light, sound and mechanical energy, for example).

These areas are addressed in the intervention in a way that students will not be missing out on the national curriculum.

Research and curriculum alignment

For a matter of comparison, the subject codes align with the research as stated below:

(EF69AR19) – Music elements such as pitch, volume and melody are explored using the Theremin instrument. Music appreciation will be attained by listening to prepared pieces for the instrument played by the researcher. Searching and identifying music that uses technological resources playfully is accomplished by the gestural movements that are needed to play the instrument. Identifying 20th century electronic music is obtained by the nature of the instrument – the first electronic instrument invented in 1919.

(EF69AR20) – Exploring and analysing music elements is addressed in the previous topic. Composing using alternative methods is performed in both the music workshop and in the creative component element of the intervention.

(EF69AR22) – Exploring and identifying creative and alternative music notation is achieved in the music workshop in the intervention. Composing using this kind of notation is performed in both the music workshop and in the creative component.

(EF08CI02) – Building electric circuits with batteries is accomplished in the electronic workshop.

(EF08CI03) – Classification of electric equipment in accordance with its type of energy transformation is achieved in the electronic workshop.

Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on LV. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix R – Backup Workshop in Case of Denial of Participation of Any Key Figure

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240



Backup workshop in case of denial of participation of any key figure

Project title: Theremin: interdisciplinarity, equality and inclusion in schools through Science and Art
Researcher: Christian de Sá Quimelli
Email: christianquimelli@gmail.com
Phone: +55 42 99111-5624

This appendix suits to answer the question “what will be done if someone denies participation after setting up almost everything?”

Minimum staff needed

For the full intervention to work I need approval from the principal and the participation of both the science and music teachers - who will be interviewed two times, one at the beginning and the other one at the ending. One of them (most probably the music teacher given my background) will have to give up her/his classroom time to allow the intervention to happen. So, in case any of these three figures declines in participating the intervention cannot happen fully.

Most probable case scenario

The first case that comes to mind is me getting approval from the principal to make the intervention, one of the teachers accepting to take part in it with interviews and supporting it by giving their classroom time, and the other teacher not willing to take part in it at all. In this case, a power imbalance is created, and the teacher not willing to participate can be put in a disadvantage situation with the principal and the other teacher. She/he might be considered the “guilty” element of not allowing the research to take place in their school.

Substitution workshop

In this case, I’ll offer to make a stepped-down version of this workshop that does not require any kind of data gathering. I’ve made many of these workshops in different schools in my region, where I show the instrument, make the students play it and give them a brief explanation of the science behind it. These workshops take usually 1,5 hours – 2 hours (around two school classes) to happen. This way the students get in touch with the instrument and receive a short science and art workshop, the school staff won’t have power imbalance issues and I won’t be overloaded with a long intervention where I won’t be able to gather data.

Other schools

As I stated before in the ethics application, if I’m not able to perform the intervention fully on this school I’ll contact the *Secretaria da Educação e do Esporte - SEED* (Brazil) that “is the institution that manages all the schools in the state where I live” to indicate me another school for me to make this intervention.

Other scenarios

Different scenarios than the one described might take place. They will all be addressed with the same ethics concept presented above.

Evidence

There is evidence below that this shorter workshop has been managed by me in a school context and excellent results were achieved:





Research approval and contact information

This research has been approved by the University of Waikato Division of Education Ethics Committee on LVI. Approval number: XXXX. For further information, please contact:

Researcher – Christian de Sá Quimelli	christianquimelli@gmail.com
Dr Bronya Dean – Co-supervisor	bdean@waikato.ac.nz

Appendix S – Categories generated by primary coding:

DISAFFECTION

POSITIVITY

DISAPPOINTMENT

MIXED FEELINGS

SOCIOECONOMIC HARDSHIPS – RELATING TO STUDENTS' LIVES

SOCIOECONOMIC HARDSHIPS – RELATING TO SCHOOL RESOURCES

INEQUALITY

PERSONAL DEVELOPMENT

GROUP WORK – POSITIVE EXPERIENCE

GROUP WORK – NOT ENGAGING OR NOT HAVING THEM

POLITICAL ISSUES DISRUPTING SCHOOL

TEACHER'S AGGRESSIVE/SARCASTIC BEHAVIOUR

GAP IN SCHOOL-RELATED KNOWLEDGE

SCHOOL ABSENCE – Student Related

SCHOOL ABSENCE – Teacher Related

STUDENT INATTENTION AND DISTRACTIBILITY

SCHOOL SUBJECT

UNABLE TO PERFORM SCHOOL ACTIVITY

COVID

POST COVID

ENGAGEMENT

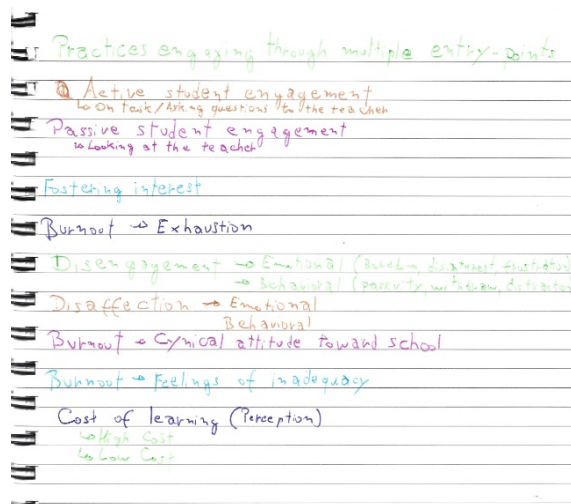
NOT ENGAGING

Appendix T - Handwritten codes on a notebook

Engagement	↳ In the school ↳ In science ↳ In Arts	→ Engagement → Disengagement → Disaffection
What drives them?	↳ Active, energetic approach oriented involvement with academic tasks	
How do they engage?		
Why do they engage in this or that particular way?		
What leads them to a low- or non-existent engagement?		
Empowerment		
Dis		
Motivator factor to school continuity		
Group cooperation/cohesion/prosocial ingroup behavior		
Inclusion		
Disaffection		
Informal learning		
Group learning		
Peer-to-peer learning		
Improvising		
Composing		
Accessibility		
Group cohesion		
Empowerment of non-profit musically trained student		
Musical expression		
Group musical instrument-making		
Group musical composing		
Group music performance		
Voluntary helping/spontaneous cooperative problem solving		
Collective action		
Positive attitudes towards school		
Attendance		
Re-engagement		
supporting positive development of young people from areas of high deprivation		
Not fully engaged with education		
Peer behavior		
Involvement in the criminal justice system		
Absence of enthusiasm		
Students disinterest		
Students alienation		
Problematic conduct (that might result in expulsion)		
monotonous experience (boring)		
Exerting minimal effort		
Gamification Effort		
Sustained engagement with formal learning (short, medium and long-term)		
Democratic music learning		
Creative projects		
Motivated		
well-behaved student		
High participation level		
Focused student		
Enhanced musical skills		
More confident		
Independent-learning skill		
Leadership skills		
Sense of accomplishment		
Collaboration		
Positive school climate		
Academic achievement		
Decreased disaffection		
Change of negative attitude/perception towards education		
Improving social conduct through engaging with music		
Diminishing aggressive behaviors		
Improvement of self-esteem		
Less violation of the rules		
Social Justice/equality		
Technology powered classroom		
Opportunity to engage in music		
School subject isolation		
Transformation		
Technology induced transformation of human material		
Technology as an external		
Structural change is the practice		
Technological assimilation		
Student-centered education		
Situating technology		
Addressing cultural and social problems		
Art enhancing science teaching/learning		
Integration of Arts into Science Curriculum		
Integrative approach		

Science concepts acquired in a more creative and engaging way.	Raised motivation and interest in Science
Hands-on activity	Authentic experience in the learning process
Group discussion	Integrating Arts into Science
Incorporation of interdisciplinary content from the arts	Interdisciplinary Collaboration between Science and Art
Attracting students' interest	Application of scientific concepts through artistic expression
Teaching STEM in creative and engaged ways	Vicious cycle of Power within the educational system
Enriching students' learning experiences	Subordination within the educational system
Improving affective aspects of learning	Oppression within the educational system
Opportunities to work collaboratively with peers	Oppression discussions
Development of concepts	Oppression inflection/elaboration
Art catalysing science	Oppressive practices
Science catalysing Art	Disconnection/Lack of engagement
Improving the teaching/learning of science	Self perception
Improving the teaching/learning of Art	Dialectical inquiry
Engaging students in STEM	Reflective process
Inquiry-based teaching	Gaining new insights
Relation with previously established knowledge	Overcoming challenges/constraints
Experiencing scientific concepts in a practical way	Personal transformation
Wider community connection	Responsive learning
	Unstereotyped potential

Positive change through collaborative, active and transformative forms of music engagement	Realized accomplishment potential
Transformative music engagement/transformative vision to be Encouraging practices/empowering practices	Social justice
Expansive learning opportunities	Optimized youth voices
Developing self knowledge	Wellbeing
Developing learning relationships	Musical flourishing
Developing sense of empowerment	Experimental process
Deep/meaningful experience	Student-centered process
Youth empowerment	Active practice/engaged in active practice
Positive change	Reimagined musicianship
Creation of new possibilities	Opportunities to explore non-traditional ways of doing music
Power imbalance disengaging students from the educational process	Engaging with technological devices to innovation
Construction of knowledge through open-proposal	Unusual ways of producing music
Experimental and participatory approach	Unusual ways of composing
Participatory approach	Unusual relationship with music/art
Free of judgement	Transdisciplinary Approach
Supportive environment	Insights
Self-expression	Engagement generated by interdisciplinarity
Self-direction	Practices sustained across time
Long-lasting engagement	Practices consistent across time
	Practices sustained across spaces



(Photographs taken by author – 2024)

Note. These photographs document the handwritten stage of the analytical process and are included to show how codes, memos, and developing categories were worked through manually. They are not intended to provide the primary readable record of the code labels. The categories generated during the earlier coding stage are listed in Appendix S, while the final coding structure is provided in textual form in Appendix W.

(Photographs taken by author – 2024)

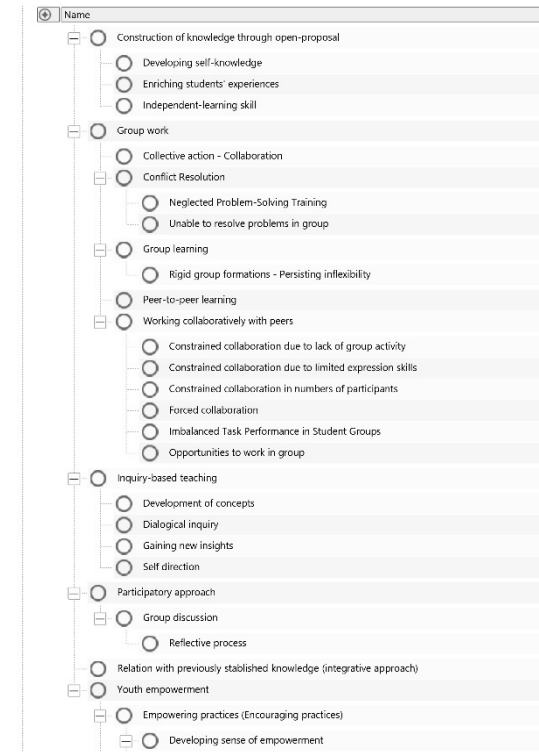
Note. This figure documents the initial handwritten organisation of the developing code tree. Because some labels are not legible at thesis-page scale and the structure continued to change after this stage, the final coding structure should be read in conjunction with Appendices V and W, particularly the textual codebook in Appendix W.

Appendix V – Code tree imported from NVivo using the printing tool

Codes



Codes



Codes



Codes



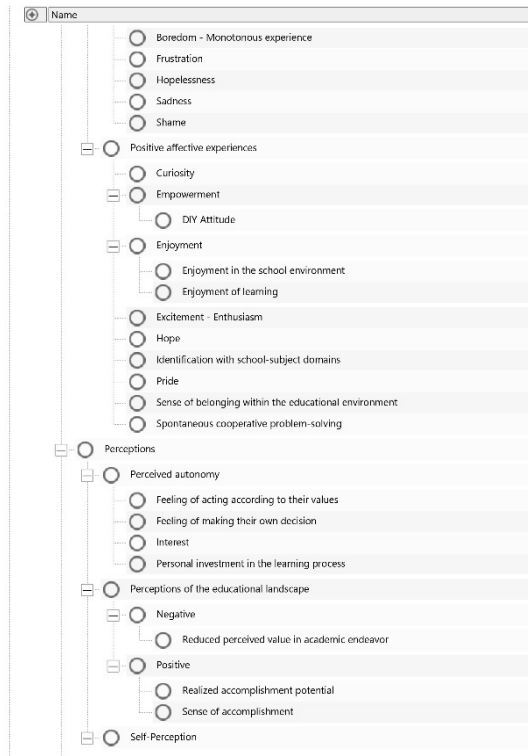
Codes

Name
Self-regulating practices
Autoregulation
Checking over homework assignments
Problem-solving
Dynamics
Adaptive dynamics
Embrace of mastery-goal orientation
High self-efficacy fostered towards school
Overcoming challenges
Valuing of academic tasks
Voluntary helping
Maladaptive dynamics
Disparate engagement dynamics
Last-minute studying
Not being able to abstract concepts
Not being able to retain knowledge
Self-handicapping
Motivational Beliefs
Reasons and values
Amotivation-Disaffection
Extrinsic motivation-identification (tangible rewards or fear of social punishment)
Intrinsic motivation Introjection (pleasant experiences coming from the engagement)
Self-efficacy and goals
Goal orientation
Mastery
Mastery-approach goals (achieving task mastery)
Mastery-avoidance (to avoid failing to master a specific job)
Performance
Performance-approach (to surpass others in ability)
Performance-avoidance (to avoid being surpassed by others)
Perception of being competent in an activity - feeling of competence

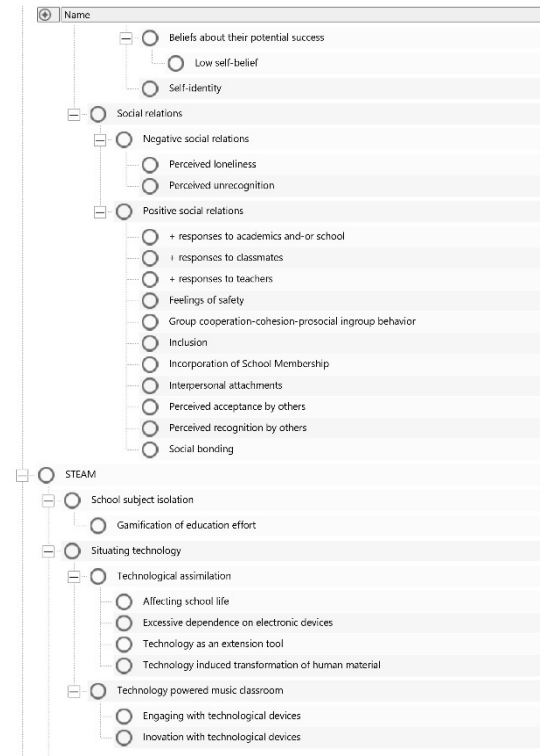
Codes

Name
Sense of personal commitment
Valuing of activities
Value of learning
Beliefs concerning significance of school
Perceived cost of learning
High cost
Low cost
Perception of relevance of acquired knowledge to future goals-endeavors
Values ascribed to academic pursuits influencing students' choices
Valuing of learning
Emotional - Affective Engagement
Emotional Activation
Negative High Activation (Tense-Angry)
Negative Low Activation (Feeling tired-exhausted-burnout)
Positive High Activation (Excited Elated)
Positive Low Activation (Passive attention-relaxed-calm) i.e. looking at the teacher
Emotional-Affective experiences
Disengagement - Disaffection
Anger
Disinterest in the academic setting
Disrespectful behavior
Feeling of being rejected by the school context
Feelings of inadequacy - incompetence
Negative responses - Cynical attitude
To academics
To classmates
To school
To teachers
Poor behavior
Negative affective experiences
Anxiety

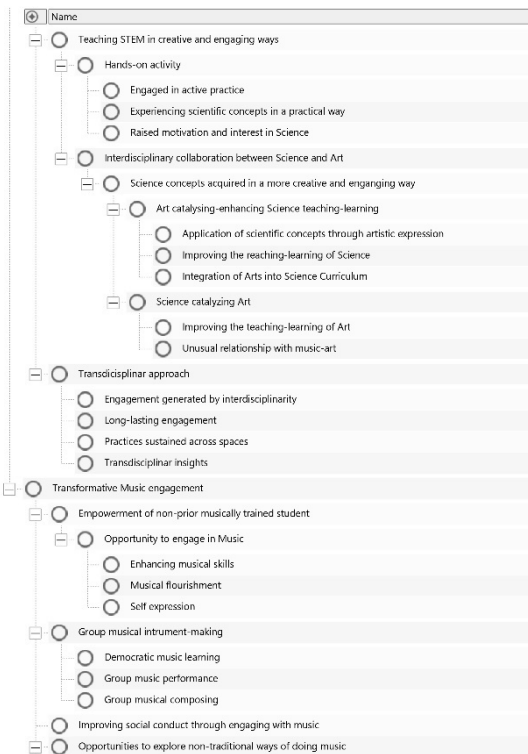
Codes



Codes



Codes



Codes



(Images produced by author – 2024)

Note. This appendix provides a visual representation of the final code tree exported from NVivo. A readable textual version of the coding structure, including the individual code labels, is provided in Appendix W.

Appendix W – Codes

This is the code tree as exported from the NVivo software using the Export Codebook tool.

Name
Contexts of Learning
High-Risk Behavior and Adverse Experiences
Marginalization
Drug trafficking
Public Property Damage - Vandalism
Racism
Sexual Risk Behaviors
Substance use
Violent behavior
Politics affecting school negatively
Poverty
Insufficient physical activity
Public Funding
Disparities in public funding distribution
Public Funding Shortages - Insufficient School Resources
Public programs keeping kids at school
Unhealthy dietary habits
Unmet basic needs
Unstable housing
Oppression
Oppression discussions
Oppression inflection-elaboration
Oppressive practices within the educational system
Cycle of oppression and reaction
Humiliation Dynamics
Perfectionism
Power imbalance disengaging students
Subordination within the educational system
Vicious cycle of power within the educational system
Unjust practices
Student-centered education
Construction of knowledge through open-proposal

Developing self-knowledge
Enriching students' experiences
Independent-learning skill
Group work
Collective action - Collaboration
Conflict Resolution
Neglected Problem-Solving Training
Unable to resolve problems in group
Group learning
Rigid group formations - Persisting inflexibility
Peer-to-peer learning
Working collaboratively with peers
Constrained collaboration due to lack of group activity
Constrained collaboration due to limited expression skills
Constrained collaboration in numbers of participants
Forced collaboration
Imbalanced Task Performance in Student Groups
Opportunities to work in group
Inquiry-based teaching
Development of concepts
Dialogical inquiry
Gaining new insights
Self direction
Participatory approach
Group discussion
Reflective process
Relation with previously established knowledge (integrative approach)
Youth empowerment
Empowering practices (Encouraging practices)
Developing sense of empowerment
Transformative vision - Personal transformation
Optimized youth voices
Supportive environment
Accessibility
Deep-meaningfull experience
Wider community connection

Developing confidence
Expansive learning opportunities
Social justice
Supporting positive development of young people from areas of high deprivation
Addressing cultural and social problems
Engagement
Behavioral Engagement
Active engagement
Participating in class-related activities
Attendance
Involvement in school
On-task behaviors
Time on task
Re-engagement
Change of negative attitude-perception towards school
Decreased disaffection
Diminished aggressive behaviors
Self-esteem improvement
Responding to school requirements
Adherence to school rules - Less violation of the rules
Attendance
Taking initiative in class-related activities
Active participation within the school setting
Asking questions to the teacher
Positive endeavors
Behavioral disaffection
Learned helplessness
Apathy
Atmosphere of negation
Disconnection
Giving up
Low attendance
Low retention
Purposefully withholding effort
Exerting minimal effort
Making no effort at all - Passivity

Unprepared for class
Withdrawing behaviorally
Maladaptive behavioral engagement
Actively resisting teachers directives
Behavioral disruptions
Being distracted
Engagement Disparities - Overall Adherence Challenges
Involvement in the criminal justice system
Problematic conduct (might lead to expulsion)
Goal-oriented engagement
Avoidance of disruptive behaviors
Focused attention
Goal-setting
Positive effort-conduct
Cognitive Engagement
Cognitive strategies
Actively seeking additional information
Learning and self-experience
Linking learning to personal experience
Not being able to link learning and self-experience
Self-regulating practices
Autoregulation
Checking over homework assignments
Problem-solving
Dynamics
Adaptive dynamics
Embracement of mastery-goal orientation
High self-efficacy fostered towards school
Overcoming challenges
Valuing of academic tasks
Voluntary helping
Maladaptive dynamics
Disparate engagement dynamics
Last-minute studying
Not being able to abstract concepts
Not being able to retain knowledge

Self-handicapping
Motivational Beliefs
Reasons and values
Amotivation-Disaffection
Extrinsic motivation-Identification (tangible rewards or fear of social punishment)
Intrinsic motivation-Introjection (pleasant experiences coming from the engagement)
Self-efficacy and goals
Goal orientation
Mastery
Mastery-approach goals (achieving task mastery)
Mastery-avoidance (to avoid failing to master a specific job)
Performance
Performance-approach (to surpass others in ability)
Performance-avoidance (to avoid being surpassed by others)
Perception of being competent in an activity - feeling of competence
Sense of personal commitment
Valuing of activities
Value of learning
Beliefs concerning significance of school
Perceived cost of learning
High cost
Low cost
Perception of relevance of acquired knowledge to future goals-endeavors
Values ascribed to academic pursuits influencing students' choices
Valuing of learning
Emotional - Affective Engagement
Emotional Activation
Negative High Activation (Tense-Angry)
Negative Low Activation (Feeling tired-exhausted-burnout)
Positive High Activation (Excited-Elated)
Positive Low Activation (Passive attention-relaxed-calm) i.e. looking at the teacher
Emotional-Affective experiences
Disengagement - Disaffection
Anger
Disinterest in the academic setting

Disrespectful behavior
Feeling of being rejected by the school context
Feelings of inadequacy - incompetence
Negative responses - Cynical attitude
To academics
To classmates
To school
To teachers
Poor behavior
Negative affective experiences
Anxiety
Boredom - Monotonous experience
Frustration
Hopelessness
Sadness
Shame
Positive affective experiences
Curiosity
Empowerment
DIY Attitude
Enjoyment
Enjoyment in the school environment
Enjoyment of learning
Excitement - Enthusiasm
Hope
Identification with school-subject domains
Pride
Sense of belonging within the educational environment
Spontaneous cooperative problem-solving
Perceptions
Perceived autonomy
Feeling of acting according to their values
Feeling of making their own decision
Interest
Personal investment in the learning process
Perceptions of the educational landscape

Negative
Reduced perceived value in academic endeavor
Positive
Realized accomplishment potential
Sense of accomplishment
Self-Perception
Beliefs about their potential success
Low self-belief
Self-identity
Social relations
Negative social relations
Perceived loneliness
Perceived unrecognition
Positive social relations
+ responses to academics and-or school
+ responses to classmates
+ responses to teachers
Feelings of safety
Group cooperation-cohesion-prosocial ingroup behavior
Inclusion
Incorporation of School Membership
Interpersonal attachments
Perceived acceptance by others
Perceived recognition by others
Social bonding
STEAM
School subject isolation
Gamification of education effort
Situating technology
Technological assimilation
Affecting school life
Excessive dependence on electronic devices
Technology as an extension tool
Technology induced transformation of human material
Technology powered music classroom
Engaging with technological devices

Innovation with technological devices
Teaching STEM in creative and engaging ways
Hands-on activity
Engaged in active practice
Experiencing scientific concepts in a practical way
Raised motivation and interest in Science
Interdisciplinary collaboration between Science and Art
Science concepts acquired in a more creative and engaging way
Art catalysing-enhancing Science teaching-learning
Application of scientific concepts through artistic expression
Improving the reaching-learning of Science
Integration of Arts into Science Curriculum
Science catalyzing Art
Improving the teaching-learning of Art
Unusual relationship with music-art
Transdisciplinary approach
Engagement generated by interdisciplinarity
Long-lasting engagement
Practices sustained across spaces
Transdisciplinary insights
Transformative Music engagement
Empowerment of non-prior musically trained student
Opportunity to engage in Music
Enhancing musical skills
Musical flourishing
Self expression
Group musical instrument-making
Democratic music learning
Group music performance
Group musical composing
Improving social conduct through engaging with music
Opportunities to explore non-traditional ways of doing music
Musical expression
Composing (musically)
Reimagined musicianship
Unusual ways of composing music

Improvising (Musically)
Unusual ways of producing music
Positive change through collaborative, active, and transformative forms of music engagement

Appendix X - Hidden/implied subject in the modern Japanese language

This appendix reflects on my personal journey throughout the PhD process, highlighting how learning another language – specifically Japanese – became both a hobby and a valuable tool for maintaining motivation. The Japanese linguistic concept of the hidden or implied subject influenced my approach to simplifying and naming most of my codes during data analysis. This small appendix aims to help the reader understand how this idea shaped my thinking and coding process.

An example of the hidden subject would be two friends conversing, where A offers a brownie to B. If we were to construct the sentence from scratch and grammatically perfect, it would be something like A looking at B and asking, “Do you want to eat this brownie?” (このブラウニーを食べたいですか?). While B looks at A and responds, “Yes, I want to eat this brownie.” (はい、このブラウニーが食べたいです。). Even if we were to simplify the correct grammatical language to spoken English (street/casual English), there is a limit to how much we can summarize and reduce the word count without losing meaning. One of the most common reductions in this case would be A asking B, “You wanna eat this?” (これを食べたいですか?) while B responds to A with a short affirmative phrase like “Yes” (はい) or “Sure” (もちろん).

This reduction would already be valid for grammatical economy, as we removed the subject from B’s response after being asked by A. Due to the nature of A’s question, where the offer contains the subject “you,” a quick response from B shows that there is no change of subject within the dialogue, thus a simple affirmative demonstrates B’s acceptance of A’s offer to eat the brownie.

However, modern spoken Japanese allows for an additional reduction in A’s offer. If A is holding a plate of brownies, looking at B, and slightly raising the plate while speaking, we end up with obvious elements in the interaction. A is looking at B, so it becomes clear to B that A is speaking to him. There is nothing else in A’s hands besides the plate of brownies, and this plate is raised in B’s direction. Therefore, there is no room for the conversation to be about any other object besides the brownies. So A asks, “Hey, eat?” (ね、食べる?), while B responds, “Oh, eat!” (おっ、食べる!).

This is a linguistic usage that, from the perspective of an English speaker, might be considered archaic – if not even primitive – but because there are no other possible interpretations, it has been embraced by Japanese speakers, thus creating a more practical and quicker informal speech between acquaintances. There is no mention or possibility of inserting any other person or subject into the sentence or context, making it clear that A understands that B will not misinterpret his offer (all examples taken from ToKini Andy, 2022).

By adopting this principle of simplicity and clarity in language, I was able to streamline my coding process and make the resulting categories more accessible and intuitive. This small but meaningful shift not only reflected my personal growth during the PhD journey but also contributed to a more transparent and efficient approach to data analysis in my research.