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Teaching Sustainability in Design: Assessing the Usability of the Design for Amelioration Tool

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	Comment	Response
	Reviewer 1	
1	The literature has been written well, and both theoretical and practical aspects of the DfA and design for sustainability have been discussed thoroughly. Some examples of the tools in the context of design education specifically can enhance the literature part.	Few examples of use of sustainability tools in the context of design education have been added.
	Reviewer 2	
1	The paper introduces a pedagogical tool aimed at embedding sustainability into the design process through a structured, qualitative framework. While the tool appears useful in the classroom setting, its originality could be more clearly articulated. The authors are encouraged to clarify how the DfA tool meaningfully differs from existing frameworks by offering a more direct comparison with tools such as LCA, the Okala Wheel, or the Sustainability Compass. A comparative table might be helpful here. Additionally, the paper would benefit from a more explicit statement about the conceptual or pedagogical gap it addresses and what new knowledge it contributes to the field.	A table comparing LCA, Okala, Sustainability Compass, and DfA has been added and the gap that the DfA tool addresses emphasised.
2	The literature review covers foundational texts across sustainability, pedagogy, and design methods, but tends to rely heavily on older or broadly established sources. There is limited engagement with more recent or critical research specific to sustainability tools in design education. The review would be strengthened by incorporating newer work, as well as by synthesizing rather than listing sources, to more effectively position the DfA tool within current discourse and competing pedagogical approaches.	Recent references – Ahmad et al (2018) and Lubis et al. (2022) have been added and paragraph amended to further clarify the positioning of the DfA tool.
3	The methodology is appropriate for the study's educational context. However, the analysis lacks sufficient detail and transparency. The description of the "qualitative synthesis" approach does not include information on how themes were derived or coded, and there is no discussion of researcher bias, particularly important given the dual role of the first author as both instructor and researcher. Clarifying the analytic process and	This has been addressed. A paragraph discussing researcher bias was added. It is soon explained in the following part that there was no thematic analysis with coding and formal theme categorisation conducted but rather through summarising key findings assessing integration of the DfA tool into the design process, challenges and limitations of the DfA tool, student perception of the tool in

	reflecting on positionality would help strengthen the credibility of this section	guiding sustainability, and suggestions for the tool.
4	The results are well-organized and supported by student examples and quotations that help illustrate the use of the tool across project stages. That said, the analysis is largely descriptive and would benefit from more critical interpretation. There is little discussion of divergent experiences, challenges in use, or examples where the tool may have fallen short. The conclusions are consistent with the findings but could be deepened by critically examining the level of student engagement with sustainability thinking.	This has been expanded.
5	The implications for design education are clearly stated, especially in relation to early-stage integration of sustainability and structured critical thinking. However, the broader claims around industry use and societal impact are somewhat speculative and not supported by evidence in the study. Narrowing the focus to implications for curriculum development and student learning would be more appropriate and aligned with the study's findings.	The focus has been narrowed to the scope of design education alone.
6	The manuscript is clearly written and accessible, with a logical structure and effective use of visuals to support the argument. The tone is generally appropriate, though in some places the language becomes repetitive or overly enthusiastic. The authors may want to review for redundancy and ensure that all claims are grounded in evidence rather than perceived success.	Some redundant and/or overtly enthusiastic sentences all throughout the manuscript had been amended.
Editors		
1	Strengthening the arguments regarding the paper's originality and deepening the qualitative analysis.	This has been added to the conclusion section.
2	The conclusion section should not be presented in bullet points	This has been amended.

Teaching Sustainability in Design: Assessing the Usability of the Design for Amelioration Tool

Abstract
Sustainable design education plays a critical role in equipping future designers with the knowledge and tools necessary to address environmental, social, and economic challenges. The Design for Amelioration (DfA) tool is a qualitative sustainability-oriented design tool developed to integrate people, planet, and profit – the three pillars of sustainability – into the design process. This study evaluates the usability and effectiveness of the DfA tool in an educational setting, examining its reception among industrial design students, its impact on the design process, and areas for potential improvement. A cohort of second- and third-year industrial design students applied the DfA tool in their studio projects over a 12-week period, using its structured framework to guide their decision-making. By incorporating people, planet, and profit, the tool encouraged students to balance social responsibility, environmental impact, and economic viability in their designs. After project completion, focus group discussions (FGDs) were conducted to gather insights into students' experiences. The findings indicate that the DfA tool was well-received, with students finding it accessible and beneficial in structuring their design process around sustainability. They appreciated its ability to promote holistic thinking across the three sustainability pillars, though they suggested refinements such as greater flexibility between stages and optional weightings for each pillar. This study underscores the importance of structured sustainability tools in design education and provides insights into how tools like the DfA can be refined to enhance pedagogical impact. The findings contribute to sustainable design education discourse and highlight the role of usability-focused tools in shaping future design practices.

Keywords: Design for Amelioration, sustainable design education, design for sustainability, industrial design pedagogy, sustainability assessment tools

Introduction

Sustainability has become a central focus in industrial design, with designers increasingly expected to develop solutions that balance social, environmental, and economic considerations. As global challenges such as climate change, resource depletion, and social inequalities intensify, design education must prepare students to integrate sustainability into their decision-making processes. UNESCO (2020) underscores the role of Education for Sustainable Development (ESD) in fostering values such as sufficiency, fairness, and solidarity, ensuring that sustainability principles are embedded in future practices.

Despite the recognised benefits of ESD – including enhanced problem-solving, critical thinking, design, planning, and collaboration skills – its integration into industrial design curricula remains inconsistent (Park et al., 2022; Venegas-Mejía et al., 2025). This aligns with a cross-institutional synthesis of current practice in sustainable product design education, which reports persistent implementation challenges in higher education (Watkins et al., 2021). One of the primary challenges is the lack of structured tools that guide students in applying sustainability principles in practical design contexts (Ahmad et al., 2018; Vicente & Camocho, 2024). Many educators also lack sufficient training and experience in teaching sustainability, further hindering its adoption (Eames et al., 2010; Fekih Zguir et al., 2021).

Industrial design students often find sustainability difficult to translate into tangible design outcomes. Many existing tools are either highly technical – such as Life Cycle Assessment (LCA), which requires detailed environmental data – or overly conceptual, failing to provide structured guidance for integrating sustainability throughout the design process (Ahmad et al., 2018; Vicente & Camocho, 2023). As a result, sustainability considerations are frequently introduced too late in the design process, limiting their impact on early-stage decision-making.

To bridge this gap, the Design for Amelioration (DfA) tool was developed by the primary author of this study as a structured, qualitative decision-making framework that enables designers to systematically evaluate their work based on sustainability principles. The tool is grounded in the triple bottom line (TBL) framework, which balances people (social equity), planet (environmental responsibility), and profit (economic viability) in design decision-making (Elkington, 1998). Unlike retrospective assessment tools that evaluate sustainability after a product has been designed, the DfA tool integrates sustainability considerations from the ideation stage onward.

It provides a structured, step-by-step framework that prompts students to assess existing solutions, weigh trade-offs, and refine their designs based on sustainability impacts.

This study evaluates the usability and effectiveness of the DfA tool within an industrial design education setting. A case study was conducted within an industrial design studio course at a university in New Zealand, where students were introduced to the DfA tool and encouraged to apply it in project-based learning activities. Through focus group discussions (FGD), students' experiences were analysed to assess the usability of the tool, its role in sustainability-driven decision-making, and potential areas for refinement.

The findings of this study contribute to the ongoing discourse on sustainability education in design, offering practical insights into the effectiveness of structured sustainability tools (Faludi et al., 2023). By examining student engagement with the DfA tool and identifying areas for improvement, this research provides recommendations for enhancing sustainability-focused design education and ensuring that future designers are equipped with practical frameworks for integrating sustainability into the design process.

Theoretical Framework

Triple bottom line (TBL) and sustainability in design education

The DfA tool is underpinned by the triple bottom line (TBL) framework (Elkington, 1998), emphasising the need to balance people, planet, and profit in design decision-making. The TBL approach has been widely adopted in business and policy sectors to evaluate the long-term viability of solutions, ensuring that sustainability is not solely defined by environmental performance but also by social and economic considerations (Slaper & Hall, 2011).

Despite its widespread recognition, applying TBL in design education presents challenges. Many sustainability tools focus primarily on environmental impacts (planet) while providing limited guidance on social (people) and economic (profit) factors, leading to an imbalance in sustainability trade-offs (Ahmad et al., 2018; Vicente & Camocho, 2023). Additionally, the fragmentation of sustainability tools often results in students using disconnected methods, rather than a holistic framework that considers sustainability at every stage of the design process (Xu et al., 2025).

Structured design frameworks and sustainability integration

The DfA tool aligns with existing structured design methodologies, ensuring that sustainability is integrated into every phase of the design process.

- **Double diamond process** (Design Council, 2007). A divergent-convergent thinking framework that moves through problem exploration, definition, development, and solution refinement. The DfA tool aligns with this approach by structuring sustainability considerations into each phase, ensuring that trade-offs between people, planet, and profit are continuously evaluated.
- **Design thinking** (Brown, 2009; Cross, 2011) A human-centred approach that emphasises empathy, ideation, prototyping, and iteration. The DfA tool integrates this mindset by encouraging designers to consider real-world impacts and refine solutions based on sustainability-driven insights.
- **Okala eco-design strategy wheel** (Belletire et al., 2012) A visual tool that provides designers with a suite of environmentally friendly design strategies. However, unlike the DfA tool, it does not offer a clear methodology for balancing trade-offs across environmental, social, and economic dimensions.

Unlike data-intensive quantitative assessment tools such as LCA, which primarily evaluate environmental impacts retrospectively, the DfA tool provides a proactive and qualitative framework for assessing sustainability across all three pillars throughout the design process. By guiding designers through structured decision-making at every stage, DfA ensures ~~continuous~~ improvement without requiring extensive technical expertise, making it well-suited for integrating sustainability considerations into creative and iterative design workflows (Lubis et al., 2022).

Cognitive and behavioural approaches in design education

Effective design education involves guiding students through structured, iterative processes that enhance their decision-making skills and problem-solving abilities, a core principle of design thinking (Cross, 2011). The DfA tool is designed to break down sustainability into manageable steps, with clear, stage-based prompts that ensure that students engage with each pillar of sustainability systematically rather than making intuitive, unstructured choices.

Furthermore, behavioural design principles suggest that structured decision-making frameworks can significantly influence sustainability priorities in design projects (Thaler & Sunstein, 2008). By embedding explicit prompts for sustainability evaluation, the DfA tool acts as a "nudge", encouraging students to internalise and justify their sustainability choices rather than bypassing them due to time constraints or lack of familiarity with sustainability assessment methods.

Literature Review

The integration of sustainability principles into industrial design has been a growing area of academic and professional focus. Sustainability is now recognised as a fundamental consideration in product and service development, but the challenge remains in effectively embedding sustainability thinking into design education (Kuzmina & Lofthouse, 2023). This literature review examines existing research on design for sustainability (DfS) tools, the triple bottom line (TBL) approach, sustainability education methodologies, and the barriers to effective sustainability integration in industrial design curricula. It also highlights the gap in structured tools that holistically incorporate people, planet, and profit into the design process and positions the Design for Amelioration (DfA) tool as a response to these challenges.

Design for Sustainability (DfS) Tools

A range of DfS tools exist to help designers consider environmental, social, and economic factors in their work. These tools generally fall into two broad categories:

- **Quantitative assessment tools**, such as Life Cycle Assessment (LCA), focus on measuring environmental impact through metrics like carbon footprint, material toxicity, and energy consumption (Ahmad et al., 2018) While LCA is widely used in industry as well as in design education (Leonardi et al., 2022; Suppipat et al., 2023), its complexity and data-intensive nature make it less practical for early-stage design education, where students may lack access to detailed product data (Lubis et al., 2022).
- **Qualitative and heuristic tools,** which are designed to guide decision-making without requiring detailed technical knowledge, often relying on visual aids and structured frameworks (Vicente & Camocho, 2023) These tools include the Okala Eco-Design Strategy Wheel (Belletire et al., 2012) and sustainable design cards for prompting sustainability considerations in brainstorming sessions. While useful for stimulating ideas, these qualitative and heuristic tools do not provide a structured methodology for evaluating and refining sustainability strategies.

As most DfS tools were found to be inadequate in structure and underperforming in different sustainability factors (Ahmad et al., 2018) as well as incompatible at all stages of the design process (Lubis et al., 2022) F, the DfA tool builds on these approaches by providing structured, iterative decision-making prompts that align with the three pillars of sustainability. Unlike LCA, ~~it~~ DfA does not require quantitative data but instead helps students assess sustainability considerations in a systematic, qualitative manner. Unlike Okala Eco-Design Strategy Wheel, it can be used at any stage of the design process (**Table 1**).

Table 1. Comparing the DfA tool with other sustainability tools

Tool	Method	Primary Focus	Stage of Application	Typical Entry Point	Notes
Life Cycle Assessment (LCA)	Quantitative	Planet	Late (primarily)	Post-specification verification;	Requires detailed data; best for

Commented [A1]: [Reviewer 1] The literature has been written well, and both theoretical and practical aspects of the DfA and design for sustainability have been discussed thoroughly. Some examples of the tools in the context of design education specifically can enhance the literature part.

Commented [A2R1]: Two recent examples of use of sustainability tool in the context of design education (Leonardi et al., Suppipat et al.) have been added.

Commented [A3]: [Reviewer 2]
The literature review covers foundational texts across sustainability, pedagogy, and design methods, but tends to rely heavily on older or broadly established sources. There is limited engagement with more recent or critical research specific to sustainability tools in design education. The review would be strengthened by incorporating newer work, as well as by synthesizing rather than listing sources, to more effectively position the DfA tool within current discourse and competing pedagogical approaches.

Commented [A4R3]: Recent studies by Ahmad et al. (2018) and Lubis et al. (2022) had been added and paragraph amended to further clarify the positioning of the DfA tool.

Commented [A5]: [Reviewer 2] The paper introduces a pedagogical tool aimed at embedding sustainability into the design process through a structured, qualitative framework. While the tool appears useful in the classroom setting, its originality could be more clearly articulated. The authors are encouraged to clarify how the DfA tool meaningfully differs from existing frameworks by offering a more direct comparison with tools such as LCA, the Okala Wheel, or the Sustainability Compass. A comparative table might be helpful here. Additionally, the paper would benefit from a more explicit statement about the conceptual or pedagogical gap it addresses and what new knowledge it contributes to the field.

Commented [A6R5]: A table comparing LCA, Okala, Sustainability Compass, and DfA has been added and the gap that DfA addresses emphasised.

				screening LCA possible earlier	environmental impact validation.
Okala Eco-Design Strategy Wheel	Qualitative	Planet	Early to mid (primarily)	Concept ideation to detailing	Strategy-oriented; can be revisited iteratively but lacks social/economic coverage.
Design for Amelioration (DfA)	Qualitative	People, Planet, Profit	All stages	Introduced with the brief; revisited at each gate	Structured prompts for iterative use; integrates TBL throughout design.
Sustainability Compass	Qualitative / semi-quantitative	People, Planet, Profit*	All stages (strategic emphasis)	Project framing; reused at reviews or decision gates	Uses NESW framework: Nature (Planet), Economy (Profit), Society & Wellbeing (People).

Triple bottom line (TBL) and sustainability in industrial design

The Triple Bottom Line (TBL) framework, introduced by Elkington (1998), redefined business success by expanding its focus beyond financial profit to include social and environmental impact. While widely adopted in business sustainability, integrating this three-pillared approach into design disciplines remains a challenge. This integration requires deeper systemic changes (McBride, 2011).

In design, sustainability principles – encompassing social, environmental, and economic considerations – are essential for evaluating the long-term viability of solutions (Waage, 2007). Research indicates that embedding these principles into product development fosters both innovation and sustainability by promoting a holistic approach to design decisions (McAloone & Bey, 2009).

However, applying the TBL framework in early-stage design remains difficult. Many sustainability tools prioritise environmental impact, offering limited guidance on social sustainability (Xu et al., 2025). Similarly, economic sustainability is often overlooked, leading to financially unfeasible design solutions (Vicente & Camocho, 2023). Even when environmental sustainability is emphasised, designers frequently struggle to balance sustainability with functionality (Lubis et al., 2022).

The DfA tool directly addresses these challenges by structuring the design process around TBL principles. Unlike conventional tools, DfA ensures that all three dimensions – people, planet, and profit – are continuously assessed and balanced throughout the project lifecycle, leading to more viable and impactful design solutions.

Sustainability education and design pedagogy

Education for sustainable development (ESD) has evolved over the past two decades, equipping students with theoretical knowledge, critical thinking skills, and hands-on experience in sustainability (Blewitt, 2008; Buckler & Creech, 2014; Kishita et al., 2018; Tilbury & Wortman, 2004). Sustainability education has been increasingly recognised as essential in preparing students to tackle climate change, resource depletion, and social inequalities by integrating sustainable thinking into their professional practice (UNESCO, 2020).

Within design education, three key pedagogical approaches have proven effective in embedding sustainability principles:

- **Project-based learning (PBL),** which engages students in real-world design challenges where sustainability is contextualised within design processes (Park et al., 2022).
- **Systems thinking,** which helps students recognise interconnected relationships between materials, manufacturing, social equity, and product use, fostering a holistic approach to sustainability education (Sherman & Burns, 2015).

- **Human-centered design (HCD),** which ensures that solutions are desirable, feasible, and viable by deeply understanding users' needs and aspirations, emphasising empathy, iteration, and collaboration to create impactful outcomes that are rooted in real human experiences (IDEO, 2015).

While these approaches have improved student engagement with sustainability, studies indicate that students need structured tools that provide clear guidance on how to embed sustainability into design (Faludi et al., 2023). The DfA tool aligns with project-based learning by allowing students to apply sustainability principles within real-world design projects, ensuring a balance between theory and practice.

Barriers to effective sustainability integration in industrial design curricula

Despite growing awareness and advancements in sustainability education, several barriers continue to hinder the full integration of sustainability principles into design curricula.

- **Complexity of sustainability concepts.** Many students find sustainability overwhelming due to the broad scope of its principles and the conflicting trade-offs involved in decision-making (Ahmad et al., 2018). Without structured guidance, sustainability considerations can become abstract and difficult to apply in real-world design contexts. The DfA tool addresses this issue by breaking sustainability down into manageable decision-making steps, ensuring that students progressively integrate sustainability assessments rather than being burdened with all considerations at once.

- **Lack of structured tools for early-stage design.** Most existing sustainability tools, such as Life Cycle Assessment (LCA) and other quantitative assessment methods, are designed for later-stage evaluations when product specifications are already defined (Pigosso et al., 2014). This means sustainability considerations are often introduced too late in the design process, limiting students' ability to explore sustainable alternatives from the outset. The DfA tool fills this gap by embedding sustainability thinking from the conceptual phase onward, helping students frame sustainability considerations early and iteratively.

- **Difficulty in balancing the three pillars of sustainability.** Existing sustainability tools tend to prioritise environmental considerations (planet) while neglecting social (people) and economic (profit) factors (Xu et al., 2025). This imbalance can lead to conceptually strong designs that fail to be financially viable or socially equitable. The DfA tool explicitly requires students to assess all three pillars at every stage of the design process, ensuring a holistic sustainability approach rather than an environmentally dominant one.

- **Addressing these barriers through structured design tools.** To overcome these challenges, structured, student-friendly tools are needed to provide clear sustainability prompts while still allowing for flexibility and creativity in design. The DfA tool was developed with these needs in mind, offering an accessible, step-by-step framework that ensures sustainability is consistently integrated into decision-making without restricting design freedom. By guiding students through structured comparisons, trade-off analyses, and final sustainability evaluations, the tool serves as a practical bridge between sustainability theory and applied design practice.

Research Design

This study adopts a qualitative case study approach to evaluate the usability and effectiveness of the Design for Amelioration (DfA) tool in an industrial design education context. A case study methodology was selected as it enables an in-depth exploration of how students engage with the DfA tool, its influence on their sustainability decision-making process, and the challenges they encounter (Yin, 2018).

The research is framed within a constructivist paradigm, recognising that students' understanding of sustainability is shaped by their prior knowledge, experiences, and interactions with structured design tools (Creswell & Poth, 2018). By analysing students' real-world engagement with the tool, this study provides practical insights into the role of structured sustainability frameworks in design education.

The study is designed around three core research questions:

- How do industrial design students perceive and engage with the DfA tool?
- How does the tool influence sustainability considerations in their design process?
- What refinements can enhance the practical usability of the tool for future applications?

To explore these questions, the study was conducted over one semester of 12 weeks within ~~an~~ two industrial design studio course~~s~~ at a New Zealand university. The research design incorporates multiple qualitative methods:

- Student design projects, where participants applied the DfA tool to guide sustainability decisions in their work.
- Focus group discussions (FGDs) following project completion to capture students' reflections on the tool's effectiveness.
- Thematic analysis to extract key themes related to usability, impact on sustainability decision-making, and areas for refinement.

By adopting this multi-method qualitative approach, the study provides rich, contextualised data on how students engage with structured sustainability frameworks within the constraints of real-world design projects.

To mitigate potential researcher bias, the first author, who served as both the researcher and the convenor-lecturer for the two courses, ensured that the DfA tool was not a required part of the curriculum. Students were not evaluated on their use or understanding of the tool. They did not receive extra credit for using it, nor were they penalised for choosing not to. This approach helped ensure that participation remained voluntary and free from undue influence.

Commented [A8R7]: This has been addressed. A paragraph discussing researcher bias was added.

Commented [A7]: [Reviewer 2] There is no discussion of researcher bias, particularly important given the dual role of the first author as both instructor and researcher. Clarifying the analytic process and reflecting on positionality would help strengthen the credibility of this section.

Methods

Participants

~~The study involved second- and third-year industrial design students at a New Zealand university, enrolled in two separate studio courses running for 12 weeks. The first author of this study was the convenor and lecturer for both courses. Students were informed about the study at the beginning of the course and invited to participate. They were also informed that Pparticipation was voluntary and did would not affect the final grades of the students. Students who chose to participate were required to utilise the DfA tool to guide their design projects toward sustainability throughout the course. Students who opted out were not required to use the tool and were not expected to incorporate sustainability considerations into their projects.~~

The study involved second- and third-year industrial design students enrolled in two separate 12-week studio courses at a New Zealand university. The first author served as the convenor and lecturer for both courses. At the start of the semester, students were informed about the study and invited to participate voluntarily, with assurances that participation would not affect their final grades.

Students who chose to participate were asked to use the DfA tool to guide sustainability decisions in their design projects. Those who opted out were not required to use the tool and were not expected to incorporate sustainability considerations into their work.

A total of twelve students were enrolled across the two courses, with six students in each. Of these, ten chose to participate in the study. The group included four second-year students and six third-year students. Table 1 presents an overview of the participating students, including their year level and the topics of their individual studio projects.

Table 2. Participating students and their studio project topics

Student	Year	Studio project
A	2	Measuring cup
B	2	Ergonomic nail polishing station

C	2	Handcrafted solid wood guitar case
D	2	Automotive air purifier
E	3	Multifunctional stool for university dorms
F	3	Coffee grounds spinning necklace pendant
G	3	Sustainable cork bag
H	3	Nature glow lamp
I	3	Innovative modular storage system for boats
J	3	Detachable magnetic headlamp

Since the DfA tool was designed to accompany designers throughout their design process, students applied the tool from the early conceptualisation phase to the final project presentation.

Procedure

At the start of the course, students attended an in-person presentation and tutorial introducing the Design for Amelioration (DfA) tool. This session covered the tool's development and provided step-by-step instructions on how to integrate it into their design process. The tool was structured into three stages:

- Stages 1 and 2 were prescriptive, offering structured guidelines to assess sustainability.
- Stage 3 was descriptive, serving as an evaluative tool for reviewing the sustainability outcomes of their designs.

To support their use of the tool, students received the following resources:

- Printed handouts of the DfA tool, including an Introduction page (Fig. 1) explaining its purpose and how to apply it throughout the design process. The inner pages (Fig. 3, Fig. 4, Fig. 5) contained the actual DfA templates, which students used to document and assess sustainability considerations at each stage of their projects.
- A digital, editable PDF version of the tool, allowing students to complete and modify their sustainability assessments electronically.
- Opportunities for consultation, enabling students to seek guidance from the lecturer at any point during the course regarding the tool's application.

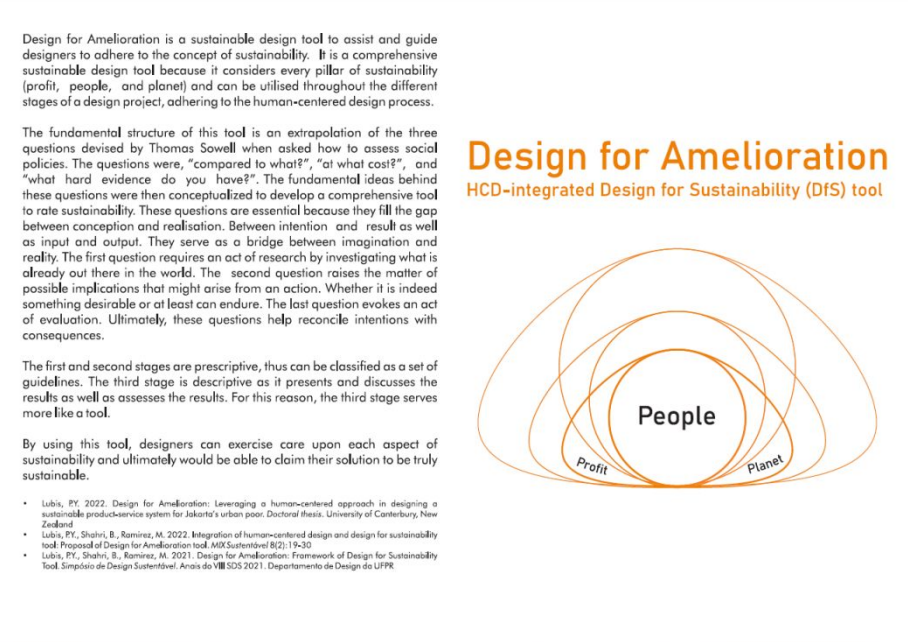


Fig. 1 The introduction page of the DfA tool explaining its development and how to use it alongside the design process presented to students

Data Collection

The collection of data was structured into two parts to examine how students engaged with the DfA tool and assess its usability in guiding sustainability-driven design decision-making.

Part A: Structured use of the DfA tool in design projects.

Students were required to systematically apply the DfA tool at three structured stages of their design process (Fig. 2), aligning with the Inspiration, Ideation, and Implementation phases of the Human Centred Design methodology (IDEO, 2015). This ensured that sustainability was embedded throughout their project development rather than considered retrospectively. Each stage of the tool facilitated a distinct activity:

- **Stage 1: Inspiration – Comparative sustainability mapping.** Students analysed existing design solutions and assessed sustainability trade-offs using the People, Planet, and Profit framework (Fig. 3). The aim was to establish a baseline understanding of sustainability in their project domain. A comparative mapping exercise helped students visually assess where their proposed solution improved upon or differed from existing designs.

- **Stage 2: Ideation – Cost-benefit sustainability trade-offs**. In this stage, students used the tool to structure concept development, comparing and justifying design options based on sustainability considerations. They weighed the benefits and limitations of different approaches, ensuring sustainability was a guiding principle in decision-making (Fig. 4).

- **Stage 3: Implementation – Assessing final design outcomes**. The final stage of the DfA tool focused on evaluating the sustainability performance of the completed design. Students reflected on how effectively their solutions addressed sustainability goals, documented key improvements, and identified any remaining challenges (Fig. 5).

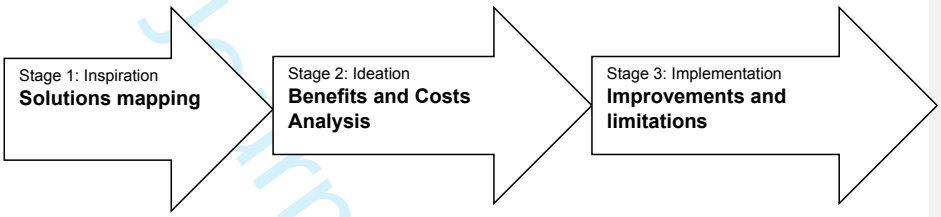


Fig. 2 Stages of the Design for Amelioration tool and activities associated with each stage.

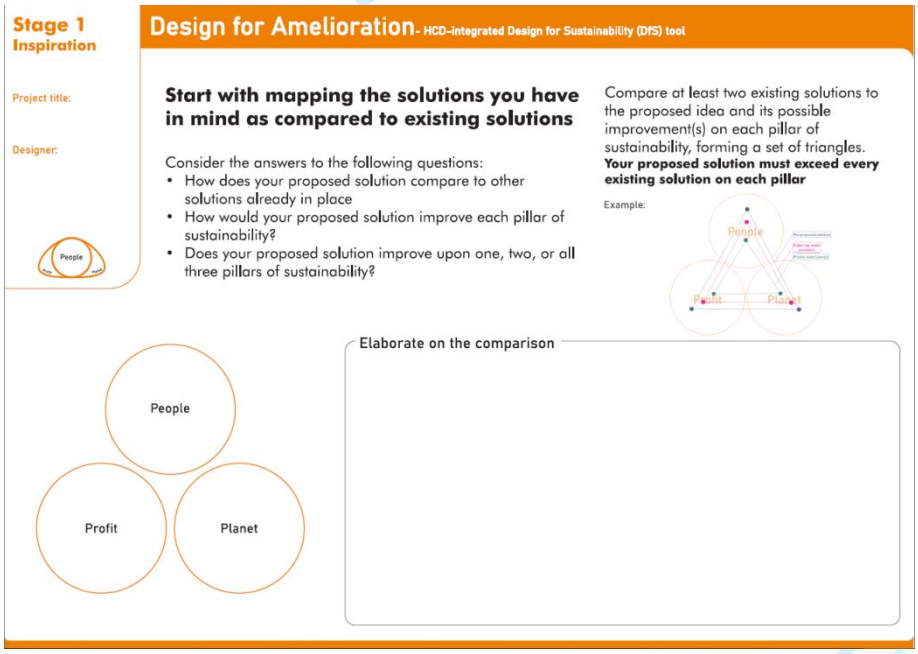


Fig. 3 Stage 1: Inspiration of the Design for Amelioration tool

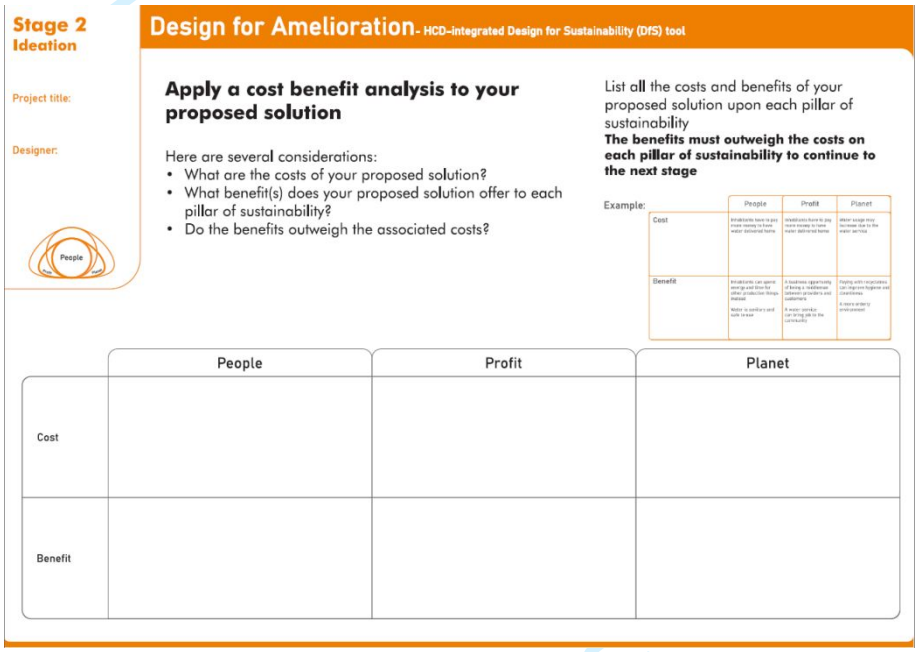


Fig. 4 Stage 2: Ideation of the Design for Amelioration tool

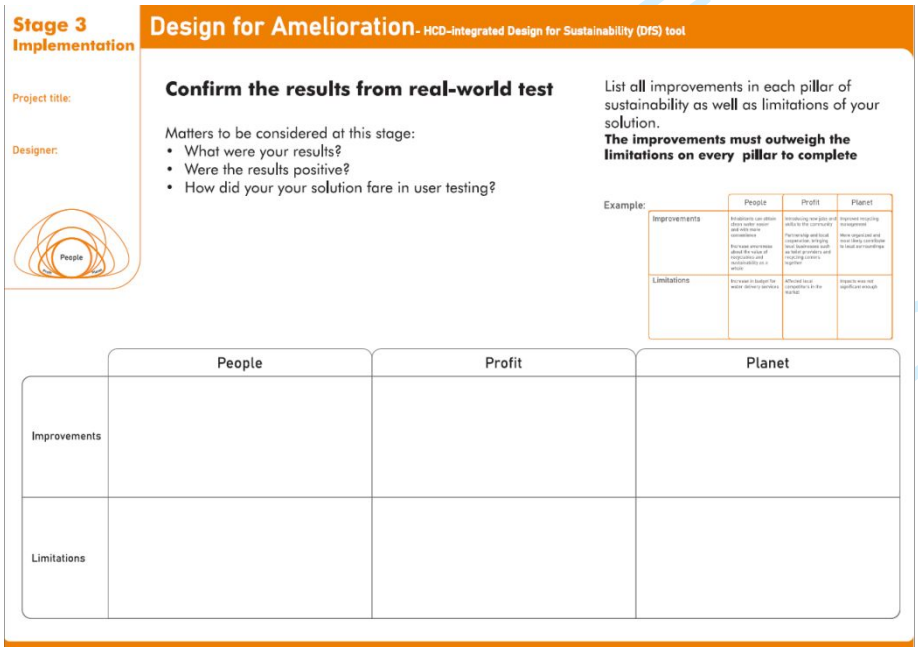


Fig. 5 Stage 3: Implementation of the Design for Amelioration tool

Throughout the project, students documented their engagement with the tool via folio submissions, poster presentations, and verbal reflections during final presentations. Some students adapted the DfA tool's format to align with their project themes, indicating a high degree of comprehension and flexibility in applying the framework.

Part B: Focus group discussions (FGD).

At the conclusion of the 12-week studio courses, following their final project presentations, students participated in two focus group discussions (FGDs) – one for second-year students and another for third-year students.

The FGDs were semi-structured, combining guided questioning with open-ended reflection, allowing students to articulate their experiences while also engaging in peer-influenced discussions (Muratovski, 2021). The sessions provided in-depth insights into how students perceived the Design for Amelioration (DfA) tool and how it shaped their design process. The discussions were guided by the following prompts:

- What do you think about the Design for Amelioration (DfA) tool?
- How easy was it to use the DfA tool?
- How did the tool help guide your design process toward sustainability?
- How can the tool be improved?
- What is the likelihood of you using the DfA tool again in the future?

Each FGD lasted approximately 15 minutes and was audio-recorded and transcribed to ensure a comprehensive dataset for analysis. While the above questions structured the discussions, students were encouraged to share additional reflections beyond these prompts. The recordings were later analysed to identify key themes related to the usability and impact of the DfA tool.

Data Analysis

A qualitative synthesis approach was used to analyse the collected data, focusing on summarising key insights from student project documentation and focus group discussions (FGDs). The analysis process included:

- **Familiarisation with data.** Audio recordings of the FGDs were transcribed, and student project documentation was reviewed to gain an overview of how students interacted with the DfA tool throughout their design process.
- **Identifying key patterns.** Recurring observations related to usability, engagement, and sustainability integration were noted across the transcripts and project reports.
- **Synthesising findings.** The key insights from student reflections were grouped under broad themes, such as structured sustainability thinking, challenges in tool application, and overall user experience.

Rather than conducting a detailed thematic analysis with coded data and formal theme categorisation, the study focused on extracting and summarising key findings to assess:

- How effectively students integrated the DfA tool into their design process.
- Challenges or limitations students encountered when using the tool.
- Student perceptions on the usefulness of the tool for guiding sustainability decision-making.
- Suggestions for improving the tool's usability and relevance in design education.

No software was used in the analysis; all findings were synthesised manually through iterative review and discussion of the collected data. The synthesised findings provide a practical understanding of the DfA tool's impact on design education, informing recommendations for its future development and application.

Results and Findings

The findings provide insights into how students applied the DfA tool in their industrial design studio projects and assess its usability and effectiveness in guiding sustainability-focused decision-making.

Commented [A9]: [Reviewer 2] However, the analysis lacks sufficient detail and transparency. The description of the "qualitative synthesis" approach does not include information on how themes were derived or coded.

Commented [A10R9]: It is soon explained in the following part that there was no thematic analysis with coding and formal theme categorisation conducted but rather through summarising key findings assessing integration of the DfA tool into the design process, challenges and limitations of the DfA tool, student perception of the tool in guiding sustainability, and suggestions for the tool.

Integrating the DfA tool in industrial design studio projects

At the end of the course, all students presented their final design projects to the class. They displayed models and prototypes and used PowerPoint slides to explain their design process and key decisions. Students who participated in this study provided detailed explanations of how they used the DfA tool and incorporated it into their design workflows. This was further reflected in their design project documentation, including folios and promotional posters.

Approximately half of the students redesigned the format and illustrations of the DfA tool to align with their project themes, while others used the printed handouts distributed at the beginning of the course. This suggests a high level of comprehension and engagement, as some students felt confident enough to adapt and visually integrate the tool into their project documentation.

Stage 1: Inspiration – Comparative sustainability mapping.

In this stage, students compared at least two existing design solutions with their proposed solution to assess sustainability trade-offs. One example comes from Student F, a third-year student working on coffee ground jewellery and fidget-spinning necklaces. Using the DfA tool's triangular mapping system, Student F compared the proposed solution against two existing jewellery products (Fig. 6). The visualisation suggested that the proposed design could potentially outperform existing solutions across all three sustainability pillars. However, it is important to acknowledge that this mapping is inherently subjective, as students have the flexibility to assign values that may favor their own designs over existing alternatives.

In terms of the People pillar, Student F's jewellery was intended to provide therapeutic benefits, promoting mindfulness and stress relief through its fidget-spinning function. For the Planet pillar, the use of biodegradable coffee grounds aimed to reduce waste and environmental impact, offering a potentially more sustainable alternative to conventional materials. Under the Profit pillar, the design was considered to have strong marketability, with its unique aesthetic and functionality increasing its potential demand. By mapping the sustainability impact of different solutions, Student F demonstrated an early-stage reflection on how design choices influence multiple dimensions of sustainability, highlighting the role of structured sustainability assessments in encouraging critical consideration of trade-offs in design decision-making.

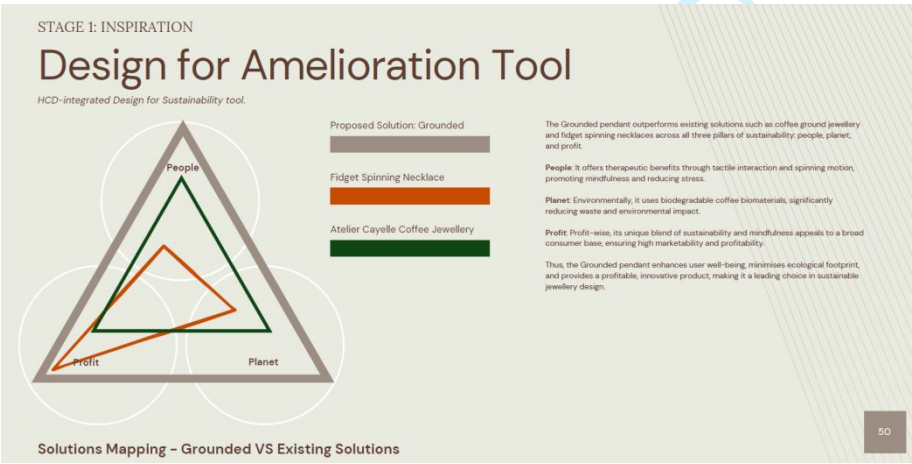


Fig. 6 Use of DfA tool by Student F to map solutions during Stage 1: Inspiration

Stage 2: Ideation – Weighing sustainability trade-offs.

At this stage, students evaluated the benefits and costs associated with their proposed design across the three sustainability pillars. Student A, a second-year student designing measurement cups, used the DfA tool to assess how their proposed solution balanced usability and sustainability trade-offs. As shown in Fig. 7, the student identified several perceived advantages and limitations of the design. In terms of the People pillar, the design was intended to improve ergonomics, ease of cleaning, and overall comfort, although it also introduced a steeper learning curve for first-time users. Under the Planet pillar, the selected material supported durability and recyclability, yet aspects of the production process still had an environmental footprint. From the Profit perspective, the design was positioned as cost-efficient for mass production, though the initial manufacturing costs were recognised as a potential financial barrier.

This structured evaluation encouraged students to think critically about trade-offs, ensuring that sustainability was considered not just in idealised terms but in practical applications. However, it is important to acknowledge that these assessments are inherently subjective, and students — aware that their work would be evaluated — may have been inclined to emphasise the benefits of their designs more prominently than the shortcomings. Like many designers, they may have focused on highlighting strengths while minimising the practical challenges. Nevertheless, the structured format of the DfA tool played a valuable role in prompting students to explicitly consider both benefits and costs. While they may have naturally placed more weight on positive aspects, the tool ensured that they could not entirely overlook the trade-offs involved in their design decisions. This exercise reinforced a habit of structured critical thinking, which is crucial in sustainability-driven design, where acknowledging and mitigating limitations is just as important as recognising benefits.

Amelioration

Cost benefit analysis to proposed solution
What are the cost of the proped solution?
What benefit(s) does the proposed solution offer to each piller of sustainability?
Do the benefits outweigh the associated costs?

	People	Profit	Planet
Cost	They have to constantly take off the grip and put into another measuring cup/spoon to change. More time and a greater learning curve to use.	People will buy less measuring cups/spoons as they won't lose them. More expensive materials used.	May include some components that are harder to recycle.
Benefit	Less likely to lose them, so less money spent and less time lost trying to find them. Easier to clean. More visually appealing. Intuative expeirence. More comfortable to hold. Due to a more human centred design.	Possibly more customers buying them, as people may reccommend them.	Less consumption, buting lost or missing measuring cups/spoons. Sustainable materials used, be repurpased easily.

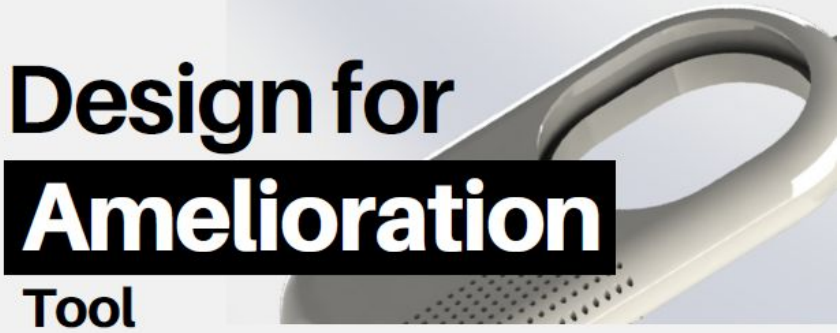
Fig. 7 Use of DfA tool by Student A to weigh benefits and costs during Stage 2: Ideation

Stage 3: Implementation – Assessing limitations and improvements.

The final stage required students to reflect on their completed design, identifying both limitations and areas for improvement. Student D, a second-year student designing an air purifier, used the DfA tool to document both the positive outcomes and the remaining challenges (Fig. 8). In terms of the People pillar, the purifier aimed to improve accessibility to clean air, which could contribute to better community health and well-being. However, the initial costs for users to adopt and adapt to the new solution were identified as a significant concern, along with the possibility of slow uptake due to user resistance. For the Planet pillar, the product had the potential to positively impact air quality, promoting better management of resources and waste, yet its production process

required resource consumption, which introduced some environmental trade-offs. Under the Profit pillar, the design was expected to contribute to economic growth through new business models, increasing awareness and adoption of sustainable practices. However, the high upfront investment posed financial risks, and there was a possibility of adverse effects on existing businesses and competitors.

This structured reflection process reinforced real-world design constraints, prompting students to critically evaluate their solutions beyond theoretical sustainability goals. While the tool facilitated a comprehensive assessment of sustainability impacts, it also highlighted the inherent trade-offs that come with innovation, demonstrating the importance of balancing economic viability, social impact, and environmental responsibility in design decision-making.



Real-World Testing Results Table

	People	Profit	Planet
Improvements	Easier access to essential services and products. Improved community health and well-being.	Growth in local economies through new business models. Increased awareness and adoption of sustainable practices.	Better management of resources and waste. Positive impacts on local ecosystems and biodiversity.
Limitations	Increased costs for users to adopt and adapt to the new solution. Potential resistance or slow uptake from the community.	Initial financial investment may be high and risky. Potential adverse effects on existing businesses and competitors.	Initial resource consumption and environmental impact during the setup phase. Potential for unforeseen environmental side effects.

Fig. 8 Use of DfA tool by Student D to list improvements and limitations of their design outcomes during Stage 3: Implementation

Insights into the usability of the Design for Amelioration tool

Following the final presentations, participating students engaged in a focus group discussion (FGD) to reflect on the usability and impact of the DfA tool. Their responses were categorised into five themes, each aligning with the discussion questions posed by the researchers (Fig. 9).

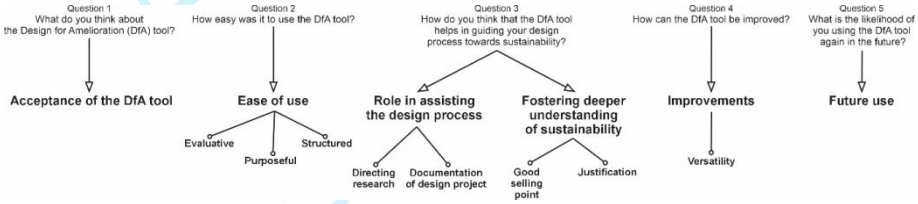


Fig. 9 Five themes identified from the data collected

Theme A: Acceptance of the Design for Amelioration tool.

Students generally found the DfA tool useful and easy to understand, particularly in guiding sustainability considerations without being overly complex. Student B commented, *"I think it was very helpful, especially at this stage… for the scope of our project. It was… it was not something that was incomprehensible. Often these kinds of tools are very literature-based and very hard to interpret, but this was very easy to use and understand."* This accessibility made it more approachable compared to traditional sustainability frameworks.

Several students demonstrated their engagement with the tool by visually customising it within their design folios and project posters, indicating a strong degree of comprehension and adaptability in applying it to their projects. While some students may have done this to match the aesthetic of their project documentation, it also suggests that they had internalised the tool's structure and concepts to the extent that they felt comfortable modifying its presentation.

Theme B: Ease of use and structured thinking.

Students ~~appreciated~~ recognised that the DfA tool helped them structure their research and design decisions, making sustainability considerations more systematic and explicit. However, some students found the linear structure of the tool restrictive, as their design processes were often iterative rather than sequential.

Student I reflected on this challenge, explaining, *"I felt like I deviated sometimes in the short proposal… the steps I wanted to take didn't always align with the tool's structure. I would hit a roadblock, skip a step, and then have to go back. Moving through the tool in a linear way didn't always fit with my design strategy. But I think, just to get started, it was ~~beneficial.~~ beneficial... ~~especially~~ in comparing my ideas to what's already on the market."*
Despite these concerns, students valued the tool's clarity and step-by-step approach, particularly in its ability to help compare existing solutions and justify design decisions. Student J emphasised this, explaining, *"When I research, I like to put everything on paper and gather as much information as possible. The structure of the tool was really helpful in organising my findings, and having the examples made it much easier to understand."*
The visual elements of the tool, especially in Stage 1: Inspiration, were seen as particularly effective in prompting sustainability reflections. Most students appreciated that the tool did not require long written responses but instead encouraged concise, bullet-point documentation, making it more practical to integrate into their workflow.

A common sentiment among students was that the DfA tool should remain in its current structured format rather than be converted into an app. Student J expressed this preference, explaining, *"I kept thinking about whether it could be an app, but personally, I don't think I'd prefer that. Downloading an entire application just for one tool doesn't seem practical. I think an editable PDF would work better… it's simpler, but you could still integrate additional features if needed."*

Theme C: Role in assisting the design process and understanding sustainability.

Students acknowledged that the DfA tool played a valuable role in structuring their sustainability assessments, helping them reflect on both the positive and negative impacts of their design decisions. Student J noted, *"It gives you good guidelines on where you should be focusing."* The requirement to explicitly list benefits and

Commented [A11]: [Reviewer 2] The manuscript is clearly written and accessible, with a logical structure and effective use of visuals to support the argument. The tone is generally appropriate, though in some places the language becomes repetitive or overly enthusiastic. The authors may want to review for redundancy and ensure that all claims are grounded in evidence rather than perceived success.

Commented [A12R11]: Several words throughout were change to minimise redundancy and overt enthusiasm.

limitations was particularly impactful, as students were challenged to think beyond their initial assumptions. Student G appreciated this aspect, explaining, *"I like how it includes both—not just the benefits, but also the limitations of the design you're thinking of."*

The tool also deepened students' understanding of sustainability, particularly in recognising the interconnections between People, Planet, and Profit. Student B reflected on this, stating, *"I think it serves a really good purpose because it makes you start thinking about sustainability and how the three pillars are connected."* Several students indicated that using the DfA tool had sparked a broader interest in sustainability, with some expressing curiosity about other sustainability assessment tools that incorporate more detailed and quantitative analyses.

Theme D: Areas for Improvement

Students suggested several refinements to enhance the DfA tool's usability and adaptability. One key recommendation was to allow for adjustable weightings between the three sustainability pillars, enabling greater flexibility based on the specific priorities of a project. Student I proposed this idea, explaining, *"Even if we keep the three pillars, it would be useful to adjust their weighting because different projects prioritise different aspects. For example, in a disability-focused project, the People pillar might be more important than the Planet."*

Another commonly mentioned improvement was greater flexibility in navigating between stages, as students often found themselves needing to move back and forth between different stages rather than following a strict sequence. Given the non-linear nature of design, many felt that the tool could be restructured to better accommodate iterative workflows.

Students also discussed the potential benefits of integrating lifecycle analysis, suggesting that it could encourage deeper sustainability assessments beyond the initial design phase. Student F elaborated on this idea, explaining, *"Another feature that could be useful is having a visual representation specifically for lifecycle analysis, similar to the existing one. If we were to break down each stage of our product's life, we might gain different insights—like how it will be disassembled and how each piece will be disposed of after use. A post-use visual could be really helpful."*

Theme E: Likelihood of future use.

All students expressed a strong likelihood of using the DfA tool in future projects, particularly when sustainability was a key consideration. Student I affirmed this sentiment, stating, *"If the focus is on sustainability… definitely. It will be helpful."* Many students also recognised the tool's potential for industry applications, particularly in providing a structured method for justifying sustainability claims in professional practice. Student B noted, *"We will definitely use it again. I think it's good to consider all three aspects."*

Overall, students successfully integrated the tool into their design workflow, using it to:

- Identify sustainability gaps in existing products, helping to define areas for improvement.
- Compare and justify materials and design choices based on the three sustainability pillars.
- Reflect on final design outcomes and propose refinements to enhance sustainability performance.

While students acknowledged some limitations in the tool's structure, they found it to be a ~~valuable~~ useful framework for organising sustainability assessments, promoting critical thinking, and facilitating clear documentation of design decisions. These insights inform potential refinements to the DfA tool, ensuring that it remains an effective resource for both design education and professional practice.

Discussion

This study examined how industrial design students applied the DfA tool in their studio projects and evaluated its usability and effectiveness in guiding sustainability decision-making. The findings provide insights into the benefits, challenges, and potential refinements of the tool, contributing to broader discussions on integrating structured sustainability frameworks into design education.

Supporting structured sustainability thinking in design education

The findings demonstrate that the DfA tool effectively structured students' sustainability considerations, ensuring that people, planet, and profit were assessed systematically throughout the design process. This structured approach contrasts with more conventional open-ended sustainability discussions, which students often find difficult to apply in practical design work (Lubis et al., 2022).

Students particularly valued the DfA tool's guidance in identifying sustainability gaps in existing products, structuring material and design trade-offs, and critically reflecting on the final impact of their design choices. This aligns with research highlighting the importance of decision-support tools in helping novice designers navigate sustainability complexities (Pigosso et al., 2014).

Moreover, the tool facilitated holistic design thinking, ensuring that sustainability was not treated as an afterthought but integrated throughout the project's development. This finding supports previous studies suggesting that structured tools help students balance trade-offs and refine their reasoning in sustainability-oriented design (Vicente & Camocho, 2023).

Strengths of the DfA tool in student engagement and decision-making

One of the most significant benefits of the DfA tool was its accessibility and ease of use, with students appreciating its clear structure and visual components. Unlike quantitative sustainability assessment tools, which often require technical expertise and extensive data, the DfA tool provided a qualitative framework that was adaptable to early-stage design processes.

Students also emphasised that the tool improved their ability to justify sustainability decisions, reinforcing the importance of structured reasoning in design education. The requirement to document both sustainability benefits and trade-offs encouraged a critical evaluation of design decisions, rather than a superficial application of sustainability principles.

These findings align with prior research indicating that qualitative design tools are particularly effective in educational contexts, as they allow for flexibility, creativity, and structured decision-making without the need for specialised sustainability expertise (Cross, 2011).

Challenges and areas for improvement

While students found the tool beneficial, they also identified areas where its structure could be refined to better align with their design workflows.

- **Non-linear design processes.** Some students found the stage-based approach restrictive, as their design processes did not always follow a sequential order. This reflects existing critiques of structured tools in design education, which often struggle to accommodate the iterative and non-linear nature of real-world design work (McAloone & Bey, 2009). A potential refinement would be allowing students to move between different stages more fluidly, rather than adhering to a strict step-by-step structure.

- **Weighting of sustainability pillars.** Several students suggested that the relative emphasis on people, planet, and profit should be adjustable, depending on project needs. This aligns with broader discussions in sustainability education, where different projects may require different sustainability priorities (Xu et al., 2025). For example, a project focused on inclusive design might prioritise social sustainability, while a project exploring alternative materials might focus more on environmental impact. Allowing students to modify the weighting of each pillar could enhance the tool's adaptability across diverse project types.

- **Lifecycle considerations.** While the DfA tool encouraged sustainability reflection, some students suggested integrating lifecycle assessment principles to extend sustainability thinking beyond the initial design phase. This reflects growing trends in circular economy approaches, which emphasise designing for long-term impact, material recovery, and product longevity (Ahmad et al., 2018). A potential refinement could involve expanding the tool to include lifecycle mapping exercises, prompting students to consider end-of-life strategies alongside product development.

Implications for design education

The findings reinforce the value of structured tools in sustainability education, particularly in supporting:

- **Early-stage sustainability integration.** Encouraging students to embed sustainability principles from the outset, rather than applying them retrospectively.
- **Critical reflection on trade-offs.** Helping students recognise that sustainability decisions involve balancing multiple competing factors.
- **Accessible, qualitative decision-making.** Providing a framework that guides sustainability assessments without requiring technical expertise.

By addressing student-identified challenges, future iterations of the DfA tool could further enhance its usability and relevance in design education especially in curriculum development and student learning. ~~and professional practice.~~

Conclusion

This study assessed the usability and effectiveness of the Design for Amelioration (DfA) tool in an industrial design education context, analysing its role in supporting sustainability decision-making in student design projects.

The findings indicate that the DfA tool successfully~~:~~
~~P~~provided structured guidance for sustainability assessments, helping students move beyond theoretical discussions toward practical sustainability integration. It also
~~E~~encouraged critical thinking and trade-off analysis, ensuring that sustainability was evaluated holistically rather than in isolation. Moreover, the DfA tool also succeeded in
~~H~~helpe~~d~~ing students articulate and justify their sustainability choices, strengthening their ability to communicate their design rationale effectively.

At the same time, there had been a range of students' experiences, from finding the tool too restrictive to their design processes to benefitting from systematic structure that the tool offered. All of the challenges in use and other areas where the tool had fallen short helped identify the ~~the study identified~~ key areas where the tool could be improved~~:~~, such as offering
~~G~~a greater flexibility across design stages: allowing non-linear navigation to better align with iterative design workflows. Another area includes
~~A~~allowing adjustable weighting for sustainability pillars: enabling context-specific prioritisation of people, planet, and profit. Lastly, the tool can be improved through incorporating
~~Incorporation of~~ lifecycle considerations: extending sustainability assessments to account for long-term impacts beyond the design phase.

The study reinforces the need for structured sustainability tools in design education, demonstrating that decision-support frameworks can help students develop more responsible and well-informed design solutions. Beyond academia, the DfA tool ~~could also~~has the possibility to be adapted for industry applications, particularly for designers seeking an intuitive method for integrating sustainability considerations into their work.

While this study provides important insights, further research could explore~~:~~
~~L~~longitudinal studies assessing how students apply sustainability principles after exposure to the DfA tool~~.~~,
~~C~~comparative analyses with other sustainability tools to determine the most effective approaches for different design contexts~~.~~, and
~~P~~potential industry adoption of the DfA tool, particularly in small and medium-sized enterprises (SMEs) and freelance design practices.

As sustainability continues to be a central challenge in design, tools like the DfA tool have the potential to bridge the gap between sustainability education and practical application. By refining and expanding such frameworks, design education can better equip students with the skills and methodologies necessary to create solutions that are environmentally, socially, and economically responsible.

Through ongoing refinement, structured tools like the DfA tool can play a transformative role in shaping how future designers approach sustainability, fostering a generation of professionals who are not only aware of sustainability challenges but also equipped with the means to address them effectively.

Commented [A13]: [Reviewer 2] The implications for design education are clearly stated, especially in relation to early-stage integration of sustainability and structured critical thinking. However, the broader claims around industry use and societal impact are somewhat speculative and not supported by evidence in the study. Narrowing the focus to implications for curriculum development and student learning would be more appropriate and aligned with the study's findings.

Commented [A14R13]: The focus has been narrowed to the scope of design education alone.

Commented [A15]: [Editor] The conclusion section should not be presented in bullet points.

Commented [A16R15]: This had been amended.

Commented [A17]: [Reviewer 2] There is little discussion of divergent experiences, challenges in use, or examples where the tool may have fallen short. The conclusions are consistent with the findings but could be deepened by critically examining the level of student engagement with sustainability thinking.

Commented [A18R17]: This has been expanded.

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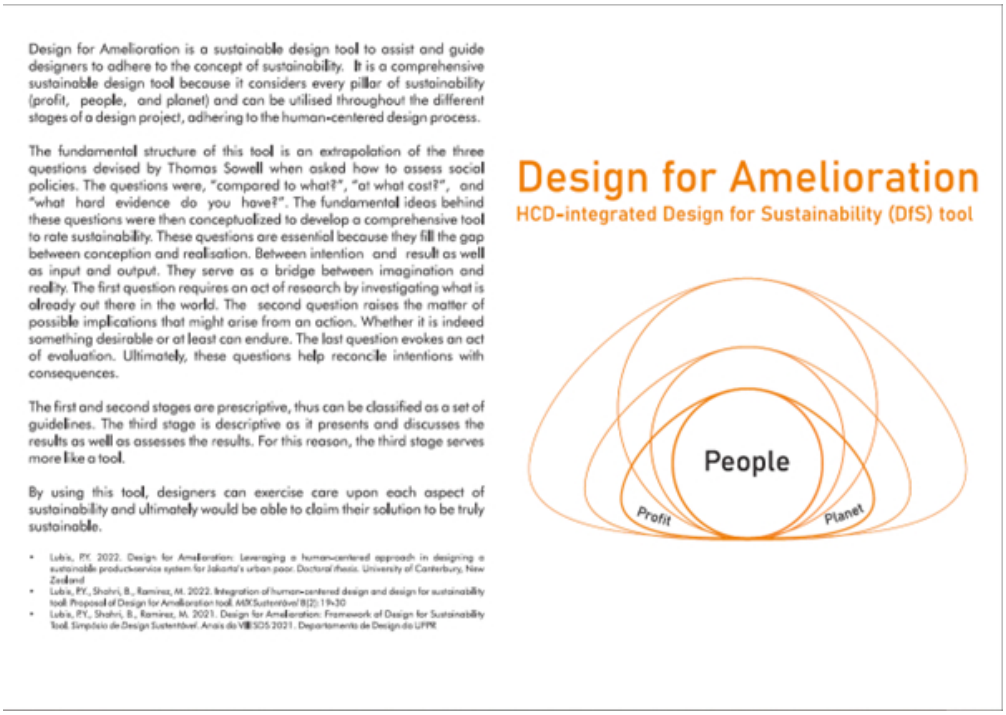
Table 1. Comparing the DfA tool with other sustainability tools

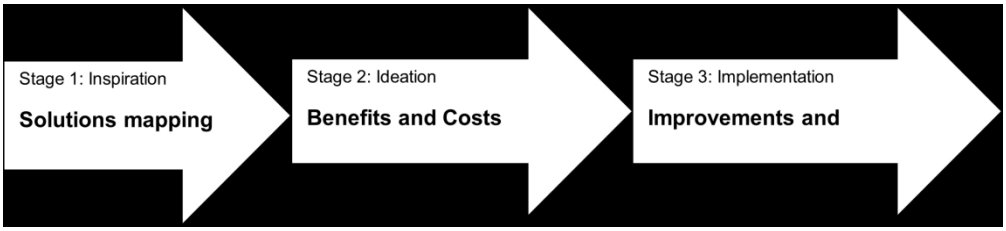
Tool	Method	Primary Focus	Stage of Application	Typical Entry Point	Notes
Life Cycle Assessment (LCA)	Quantitative	Planet	Late (primarily)	Post-specification verification; screening LCA possible earlier	Requires detailed data; best for environmental impact validation.
Okala Eco-Design Strategy Wheel	Qualitative	Planet	Early to mid (primarily)	Concept ideation to detailing	Strategy-oriented; can be revisited iteratively but lacks social/economic coverage.
Design for Amelioration (DfA)	Qualitative	People, Planet, Profit	All stages	Introduced with the brief; revisited at each gate	Structured prompts for iterative use; integrates TBL throughout design.
Sustainability Compass	Qualitative / semi-quantitative	People, Planet, Profit*	All stages (strategic emphasis)	Project framing; reused at reviews or decision gates	Uses NESW framework: Nature (Planet), Economy (Profit), Society & Wellbeing (People).

Table 1. Participating students and their studio project topics

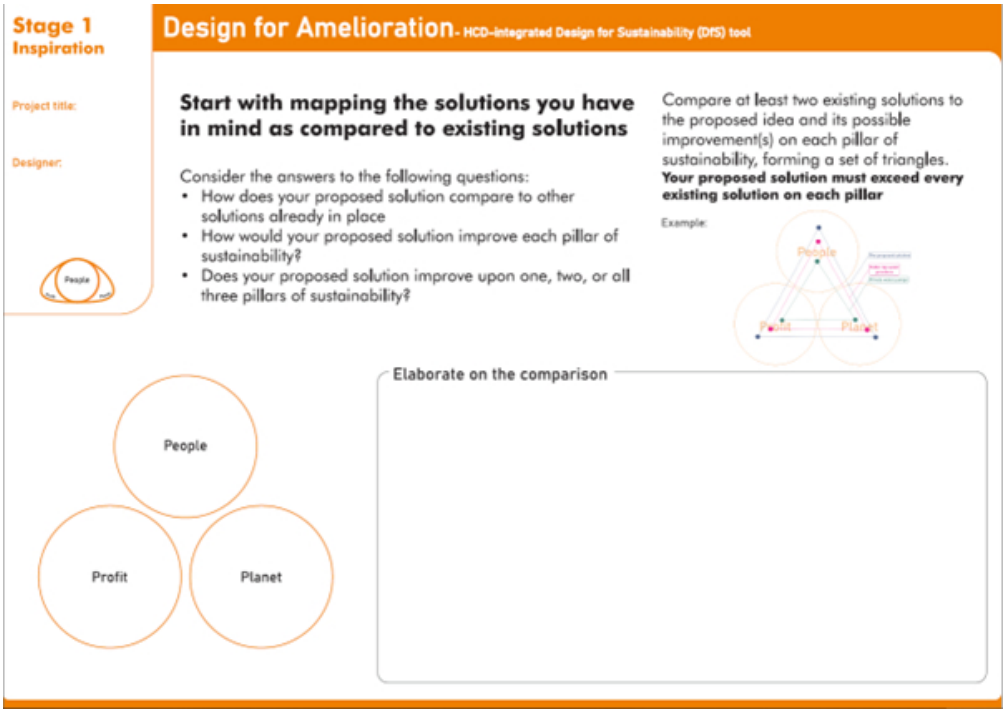
Student	Year	Studio project
A	2	Measuring cup
B	2	Ergonomic nail polishing station
C	2	Handcrafted solid wood guitar case
D	2	Automotive air purifier
E	3	Multifunctional stool for university dorms
F	3	Coffee grounds spinning necklace pendant
G	3	Sustainable cork bag
H	3	Nature glow lamp
I	3	Innovative modular storage system for boats
J	3	Detachable magnetic headlamp



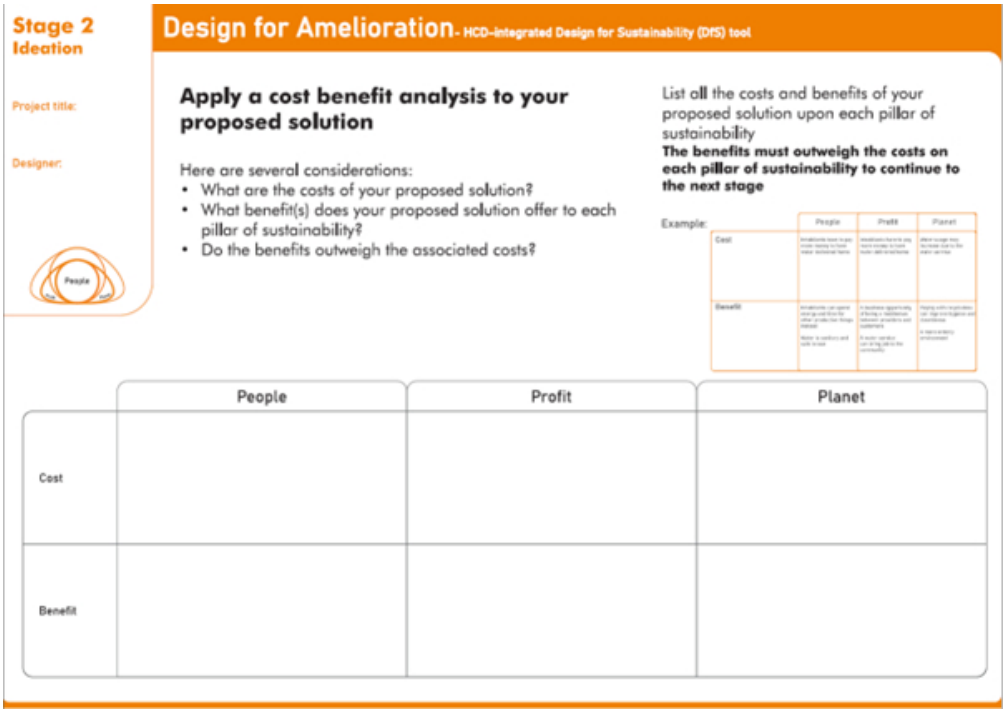
402x284mm (38 x 38 DPI)



414x92mm (130 x 130 DPI)



402x284mm (38 x 38 DPI)



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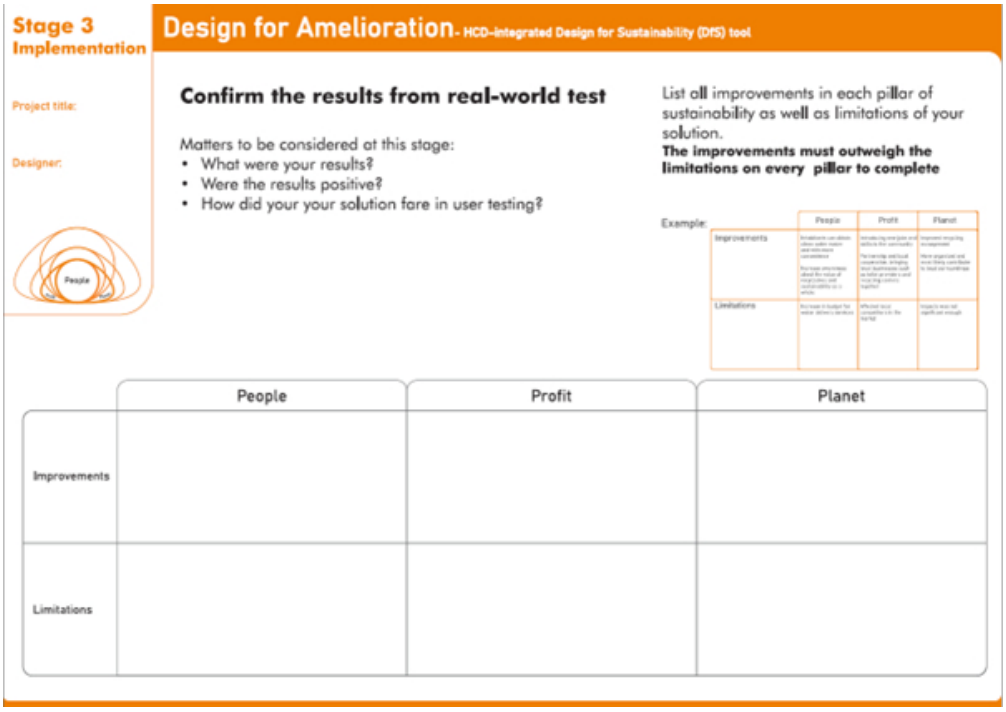
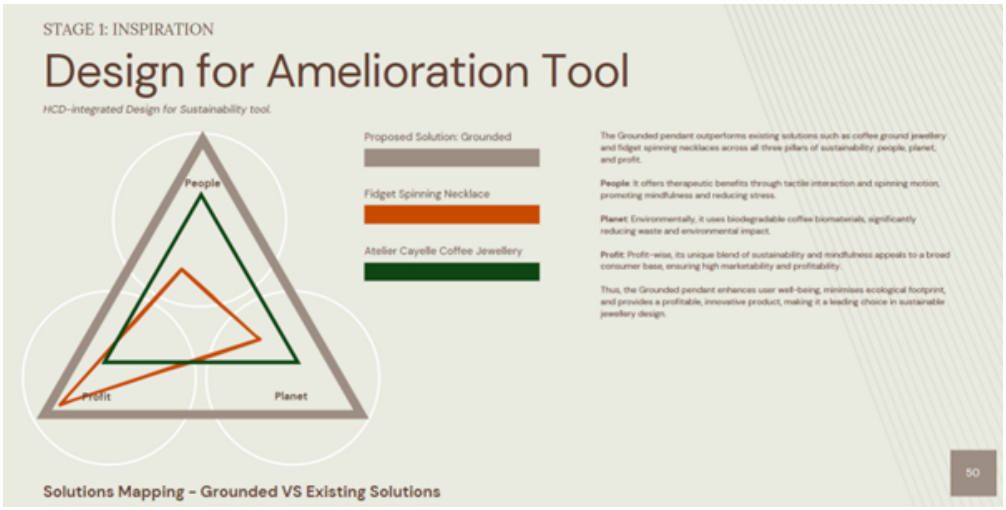


402x282mm (38 x 38 DPI)



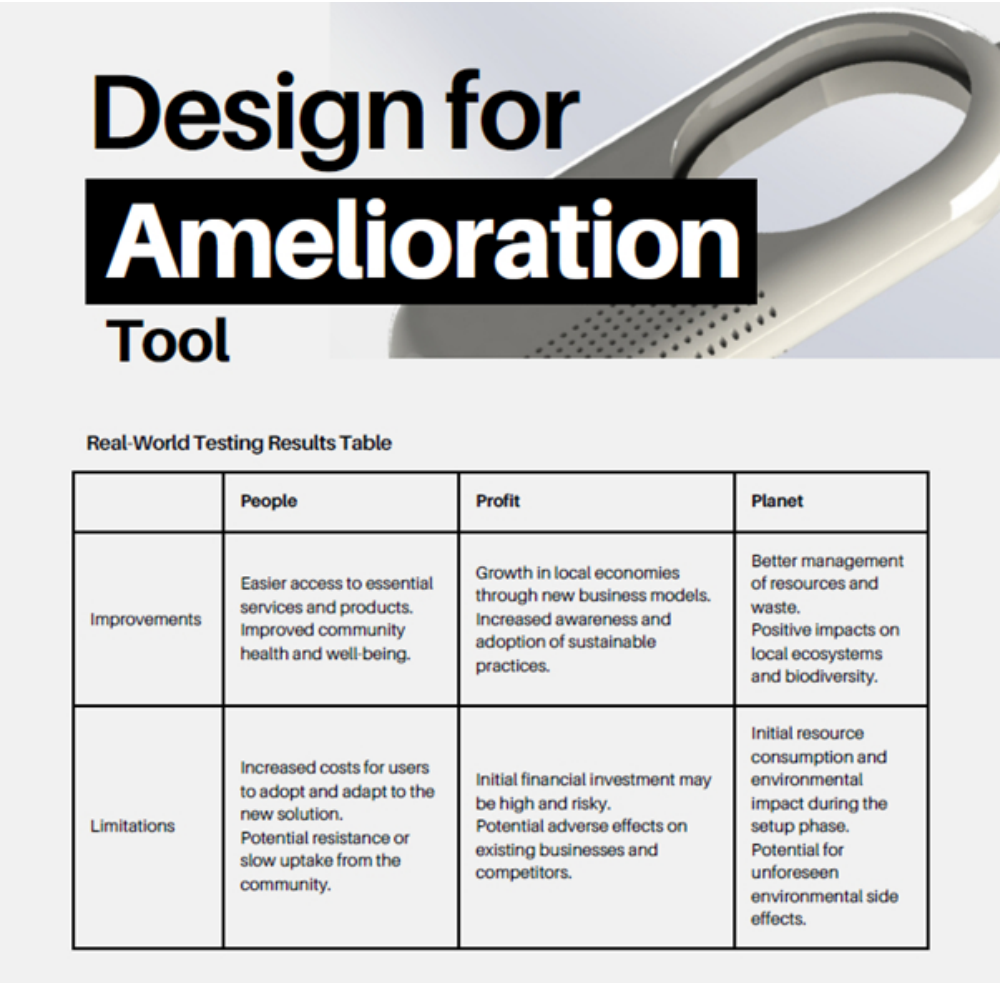
402x202mm (38 x 38 DPI)

Amelioration

Cost benefit analysis to proposed solution
What are the cost of the proped solution?
What benefit(s) does the proposed solution offer to each piller of sustainability?
Do the benefits outweigh the associated costs?

	People	Profit	Planet
Cost	They have to constantly take off the grip and put into another measuring cup/spoon to change. More time and a greater learning curve to use.	People will buy less measuring cups/spoons as they won't lose them. More expensive materials used.	May include some components that are harder to recycle.
Benefit	Less likely to lose them, so less money spent and less time lost trying to find them. Easier to clean. More visually appealing. Intuative expeirence. More comfortable to hold. Due to a more human centred design.	Possibly more customers buying them, as people may reccommend them.	Less consumption, buting lost or missing measuring cups/spoons. Sustainable materials used, be repurpased easily.

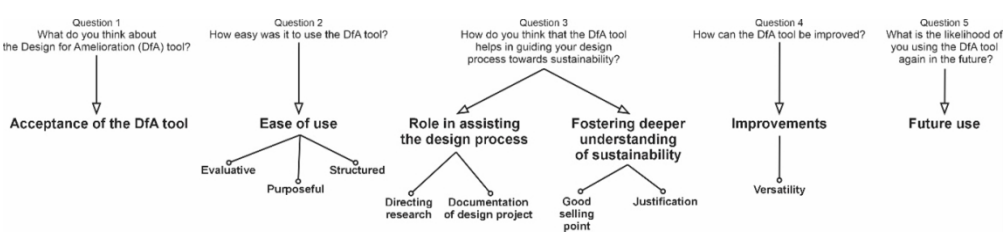
402x272mm (38 x 38 DPI)



Real-World Testing Results Table

	People	Profit	Planet
Improvements	Easier access to essential services and products. Improved community health and well-being.	Growth in local economies through new business models. Increased awareness and adoption of sustainable practices.	Better management of resources and waste. Positive impacts on local ecosystems and biodiversity.
Limitations	Increased costs for users to adopt and adapt to the new solution. Potential resistance or slow uptake from the community.	Initial financial investment may be high and risky. Potential adverse effects on existing businesses and competitors.	Initial resource consumption and environmental impact during the setup phase. Potential for unforeseen environmental side effects.

402x395mm (38 x 38 DPI)



402x85mm (87 x 87 DPI)