HOW CAN TECHNOLOGICAL CREATIVITY BE TAUGHT IN THE SAUDI ARABIAN ELEMENTARY SCHOOL CONTEXT?

A Critical Interpretive Synthesis (CIS) Review

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ABSTRACT

Teaching technological creativity in the Saudi Arabian school context can support the inclusion of technology education in general education. To support this view, the thesis proposes that technological creativity be a topic taught in the elementary school context. The intention is to assist pupils aged six to twelve years to learn how to be creative through planning and carrying out activities. The thesis attempts to introduce the concept of technological creativity to gain insights that can help to enlighten pupils technologically in a way that aligns with Islamic culture. A Critical Interpretative Synthesis (CIS) methodological approach was conducted to identify, select, synthesise, and analyse integrated papers on teaching technological creativity at the elementary school level from 21 developed countries. Papers from a variety of sources, 135 altogether, were selected for the synthesis and to develop a synthesising argument (theoretical framework), derived from constructs generated in the papers included. The text of each of the papers was treated as data and objects of inquiry. This makes CIS different from meta-ethnography (ME) in that it does not aim only at aggregating or summarising findings from studies but rather at developing a clear argument around the chosen topic in order to produce a mid-range theory based on a large, diverse body of literature. The analyses were performed in two major stages: identification, inclusion, analysis and the appraisal of papers; and developing a synthesising argument derived from the synthetic constructs embedded in the integrated papers dealing with the question, how can technological creativity be taught in the Saudi Arabian elementary school context? The synthesising argument provides a new model of interpretation developed from the findings of CIS and the synthesis process. The thesis argues that a true understanding of the benefits of this topic can be achieved through a consideration of the findings of this thesis based on the *critique* of relevant papers drawn from the research literature of a number of developed countries. The research study seeks to encourage the education of pupils through teaching them creative processes and helping them both appreciate and enjoy technology education. Thus the aim includes developing their personality and sense of self-worth. It is also hoped that this research will be of interest to teachers in elementary educa-

tion, curriculum developers, Saudi scholars and future researchers of technology education.

ACKNOWLEDGMENTS

I would like to acknowledge Associate Professor John Williams, my supervisor, for his patience, support, assistance, encouragement, advice and guidance. I extend my sincere appreciation and thanks to him for allowing me the opportunity to make an effective contribution in this thesis, since it deals with a topic that has yet to receive attention in the Kingdom of Saudi Arabia. Thank you for the inspiration you have given me how to become a better technology scholar and for the formative feedback I received during the process of writing this thesis. Being an international student in completely new learning and social environments has had its constraints, so thank you for your very generous understanding in making me feel included and in sharing your rich, valuable knowledge with me.

Foremost, I would like to praise Allah, my Lord, for everything He has given me. I would like to give my praise to Him until He is satisfied, now and always. “Praise be to Allah, the Cherisher and Sustainer of the Worlds; Most Gracious, Most Merciful” (Qur’an 1: 2-3): Praise to Him I say and, better than what I say, praise to Him as He says. It is my hope that He will accept this research as a good deed and make it a useful source to any in need of it. Allah blesses our Prophet Muhammad and the family of Muhammad as He blessed the family of Ibrahim, and He favours our Prophet Muhammad and the family of Muhammad as He favoured the family of Ibrahim in all the worlds, for He is truly the most praiseworthy and noble.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

INTRODUCTION

> Think of it. We are traveling on a planet revolving around the sun, in almost perfect symmetry. We are blessed with technology that would be indescribable to our forefathers. We have the wherewithal, the know it all, to feed everybody, clothe everybody, give every human on Earth a chance. We dwell instead on petty things. We kill each other. We build monuments to ourselves. What a waste of time. Think of it. What a chance we have (Fuller, n.d., as cited in DeVore., Horton., & Lawson., 1989, p. xi).

Humans have always faced a future that demands new, original, creative thinking. Creativity is recognised as the faculty where such new, original thinking is often born and it can be found in a wide range of professions. In the technology education profession, there has been a multitude of responses to creativity (Balchin, 2008; Barlex, 2007, June, 2011; Benson & Lunt, 2011; Christiaans & Venselaar, 2005; Cropley & Cropley, 2009; Davis, 2011; Day, 2011; Demirkan & Hasirci, 2009; DeVore, 1987a; DeVore. et al., 1989; Friedman, 2010; Ghosh, 2003; Good, 2002; Hall, 2011; Heilman, 2011; Howe, Davies, & Ritchie, 2001; Lewis, 2008; Lewis & Zuga, 2005; Middleton, 2005; Myers & Shinberg, 2011; Rutland & Barlex, 2007; Rutland & Spendlove, 2006; Spendlove, 2008; Strzalecki, 2000; Warner, 2010, 2011; Williams, Ostwald, & Askland, 2010; Wong & Siu, 2012; Wu, 2005; Wyse & Spendlove, 2007; Yatt & McCade, 2011; Yeh & Wu, 2006).

There is always the need to prepare the next generation to participate in dealing with new life challenges, even though the challenges are of a very different nature from those faced by earlier generations. In order to do that, however, it is essential to help students develop necessary competences and skills. When students develop their creative abilities at an early age, they can in the future "come up with new ways of approaching situations that have changed" (Mesquita, 2011, p. xvi). The quotation at the start of this chapter emphasises the need to promote the creative ability of students through technology education, helping them to apply their creative abilities for the purpose of solving real socio-technological problems. This research perceives technology education not simply as an accretion of skills and knowledge but rather as "a holistic activity involving pupils' hands, minds, and hearts" (Frost, 1997, p. x). Technology education affords students the opportunity of learning necessary elements of creativity that can help them design new technical means for human and social purposes.

The aim of fostering creativity is an old phenomenon. The desire to get an idea or inspiration is found in many traditions: the Greek, Judaic, Christian and Muslim (Craft, 2001; Shaheen, 2010). More recently in education in general, attention is being paid to the early years of schooling. Indeed, elementary education has received great attention in a number of countries because it is the place where pupils feel more positively about their abilities to contribute to the future (Craft, 1999, 2001, 2003; Good, 2002; Hope, 2010; Howe et al., 2001; Jeffrey * & Craft, 2004; Kerem, Kamaraj, & Yelland, 2001; Lewis, 2008; Eckhoff, 2011). Thus if technology education is to be taught in such a way as to contribute to a student's ability to participate in the challenges of the future, it must embrace the essential elements of creativity.

Chapter One describes my interest in this area, presents a rationale for the research and argues for the necessity of teaching technological creativity in Saudi Arabia. The goal of technology education is to help students build on their personal resources by exploring technology, learn how to be creative through technology and enhance their creative thinking and problem-solving skills which will enable them to play an integral part in society. The purpose of this research is not to critique the curriculum, however, nor to change it. Rather, it aims to discuss the topic of technological creativity and the way it should be taught in Saudi elementary education, using students' creative skills and factoring in a sensitive understanding of the students. The research takes into account cultural differences and endeavours to align the content of this research with Islamic culture and education so it does not conflict with the philosophy of Saudi education.

A good example of this is music education, a subject of study in Western education, where pupils can foster and learn creativity, but is it an appropriate subject that accords with Saudi Arabian culture? According to Islamic values based on the Qur'an and the Sayings of the Prophet Mohammed, the answer is no because music is taboo in Islam. Notwithstanding, pupils still benefit from other areas of education. Technology education is one of the most suitable subjects and is flexible, i.e., it can be aligned with any cultural context. Culture here refers to the culture of the nation and its people, not the culture of the subject, school or classroom. Once technology education is included in the Saudi Arabian general education curriculum, there will be the need to explore such aspects as cognition and technology, and the nature of technology education, assessment, subject and classroom culture, technological practice and society – to name a few of the essential themes of technology education.

1.1. Overview of the Saudi Arabian curriculum structure

The demands of the economy have encouraged greater emphasis on scientific and technological subjects (Rugh, 2002). Recently, The Ministry of Education (2011) and the King Abdullah Bin Abdul-Aziz Public Education Development Project (2010) have aimed to develop general education by making changes to science and technology education:

> By the will of Allah, the year 1434H [2011] should witness the fulfilment of the vision held by the Ministry of Education and Training, which can be expressed in the following manner: Engendering a new generation of male and female youth who embody Islamic values, both theoretical and practical, in their persons, are equipped with necessary knowledge and skills, are endowed with the right orientations, are capable of responding positively to, and interacting with, the latest developments, and can deal with the latest technological innovations with ease and comfort. They should be able to face international competition both on the scientific as well as technological levels and be able to participate meaningfully in the country's overall growth and development. This is to be achieved through an effective and practical system of education capable of promoting young people's potential and predispositions and creating a spirit of action, all this in an education and training environment charged with the spirit of instruction and edification (The Ministry of Education, 2011).

The main objectives of the King Abdullah Bin Abdul-Aziz Project development in general education are:

- Building global standards for various aspects of the educational process and its elements;
- Developing an integrated system to evaluate and measure the quality of education; and
- Developing various elements of the educational process, including:
    - Comprehensive curriculum development that can respond to developments in science and technology and promote knowledge and

professional skills, as well as psychological, physical and mental health for living;

- Improvement of the learning environment configured for the integration of technical and digital models in the curriculum, to be a classroom and school environment conducive to learning in order to achieve a higher level of achievement and training; and
- Strengthening endogenous capacities, creative skills and development (King Abdullah Bin Abdul-Aziz Public Education Development Project, 2010).

The Ministry of Higher Education (2010) indicated the Saudi Arabian educational system as follows:

> **Preschool level**
> This includes education before school entry. It is offered by kindergartens and nursery schools aiming to nourish young children before the age of six. Although it isn't a compulsory level, many people consider it an important step in their children's journey of life.
> **Elementary, Intermediate & Secondary level**
> This level is compulsory and provided freely and spans three sublevels. The duration is six years for primary school, and three years each of intermediate and high school.
> After elementary education, students can attend either high schools offering programs in both the arts and sciences, or vocational schools. Students' progress through high school is determined by comprehensive exams conducted twice a year and supervised by the Ministry of Education (The Ministry of Higher Education, 2010).

Figure **1** provides a diagram which illustrates the structure of the Saudi Arabian general educational system at kindergarten, elementary, intermediate and secondary school levels.

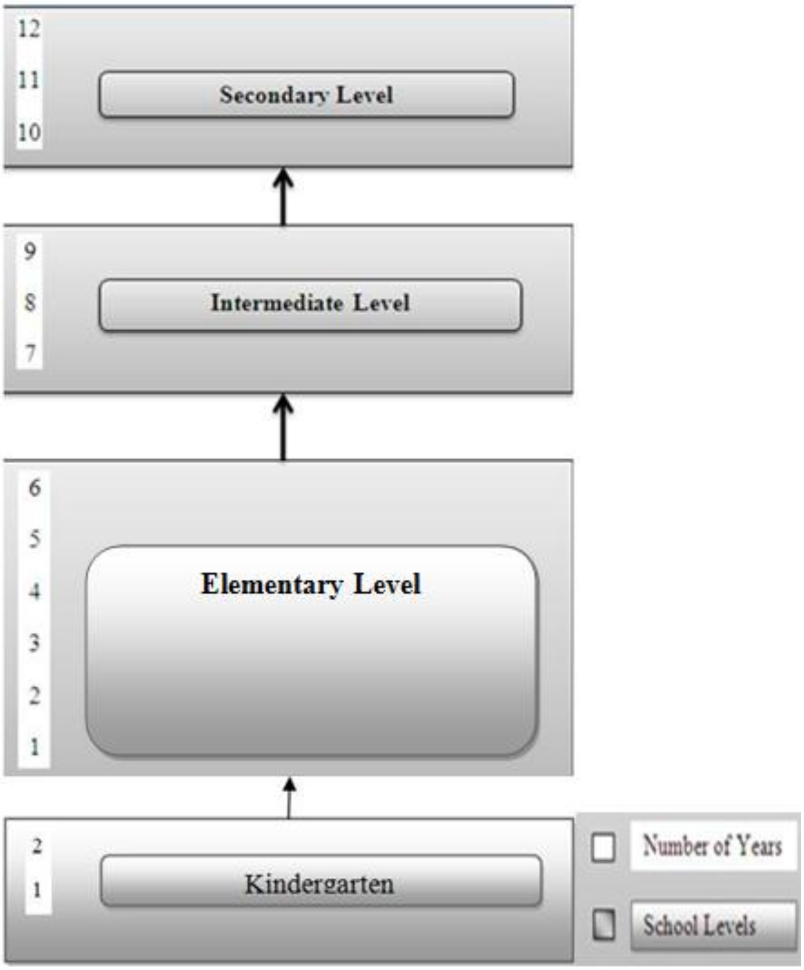

Figure 1. The structure of the Saudi educational system.

General education in Saudi Arabia is divided into four levels: kindergarten, elementary, intermediate, and secondary. The numbers of years for the four levels are: 2, 6, 3 and 3 years, respectively (Siddiqui, 1996) as shown in Figure **1**. Saudi students are required by the government to attend compulsory elementary schooling from the age of six. Before the age of six, when education is not compulsory, learners have the option to enrol in kindergarten for 2 years. The kindergarten is not an official level in general education but parents are urged to educate their children prior to elementary school. Kindergartens are not available to all people throughout Saudi Arabia. People in some urban areas do not have the opportunity to enrol their children in a kindergarten before entering elementary school. Subjects taught at the three compulsory levels from elementary to secondary are indicated below according to the Ministry of Education document:

> The following are the curricula of the various levels of education in Saudi Arabia:
>
> Elementary education: Arabia, art education, geography, history, home economics (for girls), mathematics, physical education (for boys), religious studies, national education and science. A recent attempt to introduce the teaching of English at this level, beginning in the fourth grade.
>
> Intermediate education: Arabic, art education, English, geography, history, home economics (for girls), mathematics, physical education (for boys), religious studies, national education and science.
>
> General secondary education: During the first year, students share a common curriculum. In the final 2 years they are divided into scientific and literary streams. Students scoring 60% must opt for the literary stream. The first year general curriculum includes: Arabic, biology, chemistry, English, geography, history, home economics (for girls), mathematics, physical education (for boys), computer science and religious studies (The Ministry of Education, The Ministry of Higher Education, & Training, 2004, September p. 9).

All schools, both public and private, supervised by the Ministry of Education must refer to the curriculum selected by the Ministry of Education. This means schools cannot edit or change the curriculum but "can only add to the government-approved curriculum, not subtract from it" (Rugh, 2002, p. 45). Not allowing schools to make changes to the government-approved curriculum may hinder student learning because the curriculum assigned by the Ministry of Education might not be suitable for all regions in the country. Teachers should have the right to contribute to the curriculum and make any changes that may positively influence student learning. Students should also be given the right to link the curriculum to what interests them since this would enhance their decision-making and ownership strategies from the early stages of education. Of course, any changes to the curriculum should be discussed with the school's teachers and principal. Learning becomes more than just a set of rules given to teachers to pass on to students. If the Saudi Arabian government, represented by the Ministry of Education, intends to reach the highest levels of competitiveness in different areas, it should seek to benefit from other countries' curriculum, and particularly their teaching methods, strategies and content for both the curriculum and subjects.

1.2. Thesis context

Given these strategies and learning goals and the structure of the Saudi curriculum and learning subjects, as a researcher and teacher I would argue that particularly at the elementary level, it is difficult for students to acquire technological knowledge and skills without a technology subject. The strategies and intended goals of The Ministry of Education (2011) and the King's Project (King Abdullah Bin Abdul-Aziz Public Education Development Project, 2010) do not provide a curriculum framework indicating how these strategies and goals can be achieved at the class-room level. While technological topics and activities can be taught more inde-pendently within an established technology curriculum, there is the option to teach them through science education. An analysis of science textbooks indicated that only grades 5 and 6 may have some technology related topics, whereas grades 1 to 4 focused only on teaching scientific topics, laws and rules in their theoretical forms. Therefore, a *Cross-Curriculum Technology* approach is advocated in this study to allow students to learn technology education subjects in particular. The topic of this research, technological creativity in interaction with all subjects, is not necessarily limited to the science context.

Since many researchers define creativity in various ways, no clear definition of the concept dominates in the literature. Many scholars have contributed their own definitions to the discussion of creativity (Barlex, 2011; Hope, 2010; Rutland & Barlex, 2007; Williams et al., 2010; Yatt & McCade, 2011) and a number of pro-fessionals have defined it in markedly divergent ways. Some believe that a gen-eral view of the term creativity is usually linked to thinking and imagination (Barlex, 2007, June, 2011; Gow, 2000; Heilman, 2011; Howe et al., 2001). In-deed, creativity is recognised as the source which gives rise to creative thinking. The main element is that the final outcome of the thinking process produces a va-riety of solutions to a particular problem.

Creativity is often twinned with innovation. It is treated as "part of an innovation process but whereas creativity is inspired activity, innovation is more about the strategic overview" (Mesquita, 2011, p. xvi). Some researchers connect the defini-tion of creativity to creative thinking and innovation. Creative thinking refers to the cognitive ability to perceive known situations from new viewpoints. Innovation is defined in relation to creativity, "in terms of the uncommon or statistically infrequent, remarkable, and valuable" (Williams et al., 2010, p. 40). These views are discussed further in Section One of the findings in Chapter Three. Nevertheless, a useful definition of creativity can be the ability to generate ideas and possibilities to explore and that employ the imagination. Creativity deliberates and progressively explores a theme for the purpose of generating something new. Creative ideas can be but are not necessarily completely new; they can be based on previous experiences (Roseman & Gero, 1993). When discussing creativity, all its aspects have to be taken into account: the idea, capabilities, society, and the environment (climate) that develops creativity. Technological creativity is also directly affected by the personal traits and abilities of the inventor in whom the creative activity takes place. DeVore (1987a) provided examples of the relevant personal traits. Creative individuals are:

> challenged intellectually by problem situations, self-motivated, willing to take risks, see things unconventionally, focus on identifying the true problem, [have] little regard for social and textbook rules, recognise and respond to societal needs, engage in disorganized thinking, use existing knowledge systematically, resist adverse premature opinions of others, [and are] intense and focused when working on the problem (p. 97).

Key elements of technological creativity are represented in a new interpretive form in Chapter Three. The development of technological creativity and creative products requires domain knowledge, originality, imagination, value and appropriateness. Elements of technological creativity include the creative personality and environment, mental and psychological traits, and the creative process.

This thesis examines work by researchers who have presented a range of perspectives that seem to provide an answer to the question, *how can technological creativity be taught in the Saudi Arabian elementary school context?* The purpose is to show from their writings what types of issues were raised in countries that already have experience teaching technological creativity in their primary school curriculum. The thesis aims to demonstrate what aspects are relevant to the nature of creativity and ways of teaching and learning the creative process and creative thinking in technology education. This focus establishes a context for the thesis through reviewing the topic of creativity in technology education. Literature from the fields of psychology and education is utilised because research into creativity was born first in psychology then developed in education studies which are still new to technology education. The focus has been mainly on contexts in the United States of America and Great Britain but also includes contexts from Malaysia, Saudi Arabia, Turkey, New Zealand, the Netherlands, Lebanon, Hong Kong, Australia, Singapore, Sweden, Canada, Germany, China, Poland, Latvia, Finland, Denmark, South Africa, and Taiwan.

1.3. Rationales

There are two main rationales clarifying the importance of doing this research. The first has to do with the importance of teaching technological creativity. The second concerns the importance of choosing to focus on the elementary school level.

1.3.1. Rationale for teaching technological creativity

"Creativity has been touted as an essential 21^{st}-century skill and is regarded as an integral component of student success" (Eckhoff, 2011, p. 240). Many developed countries have recognised the significance of integrating creativity into their curriculum agenda (Shaheen, 2010). In Section Three of the findings, there is a survey of creativity in the elementary school curriculum of a number of developed countries. Currently, creativity is a subject taught within nearly all school subjects. The focus here is on technology education.

Technology education is a learning area where students' creative skills can be fostered and enhanced and has become a priority in many countries' educational systems which aim to support and foster creative skills and knowledge. In Section Three of Chapter Three, there is an indication of various forms of technology in 19 developed countries' elementary school curriculum. While technology education has been incorporated into many countries' educational systems, this is not the case in Saudi Arabia (Almutairi, Everatt, Davis, & Snape, 2011). Technology education is not in the curriculum as a discrete subject and no clear definition of technology education has been established either in the Saudi general education curriculum or in the Ministry of Education document agenda. Thus students are growing up as did previous generations, not spending time at school learning about technology. For example, no time is given to exploring technological artefacts through activities where students can express their creative knowledge and creative thinking skills. There are technological, economic, social and personal rationales for teaching technological creativity.

Technological rationale

Creativity and technology education have many essential components in common. Technology education is one of those subjects through which students can improve their creative abilities (Lewis, 1999). The technological rationale relates to technological topics taught in Saudi Arabian elementary schools, for example in science where teaching methods neglect application to everyday situations (science textbooks can be found at http://www.nooor.com). Students' interests, backgrounds, and environments remain neglected and little attention is paid to creativity and imagination (Baqutayan, 2011; BouJaoude, 2003). In technology education, the goal is to help students not only to gain technological knowledge and skills but also to assist them to apply technological knowledge and skills to solve everyday problems they may face in their daily lives (Custer, 1999; Fox-Turnbull, 2003; Herschbach, 1995; Hill, 1998). Thus, new approaches are needed to enable the curriculum to meet the challenges of a new social and technological world. Saudi students must learn to become effective and contribute more productively in the workplace in the future by training in and exercising general creative skills (such as critical and creative thinking and activity oriented skills).

Economic rationale

"Creativity is at the centre of discussions on an increasingly competitive global economy" (Bairaktarova & Evangelou, 2012, p. 378). One of the fundamental rationales for integrating technological creativity into elementary education is to improve a country's economic status. In recent times, many countries have been endeavouring to deal with current economic changes. The importance of the knowledge economy is recognised throughout the world, together with the importance of innovation. In the last decade, great interest has been shown in the place of creativity in education. Why should schools teach creativity? There are several answers to the question and a number of reasons for the importance of integrating creativity into the primary education curriculum (Hope, 2010; Shaheen, 2010).

For many nations, creativity in education is intended to address these concerns and includes dealing with life problems and coping with the rapidly changing world. “Government reports, calls for educational reforms, all point to [the] need to provide students with a better education than ever before in order to be successful in this global world” (Bairaktarova & Evangelou, 2012, p. 378).

Social rationale

The social rationale has two aspects. Before illustrating the issues, it is useful to clarify what is meant by the word ‘technology’ and ‘technology education’. Technology refers to the subject in the school curriculum whereas technology education is the philosophical and theoretical grounding for presenting and teaching technology. The first, however, is an issue that requires understanding technology education in Saudi Arabia where people still view it as being limited to computers (instructional/educational technology) as educational tools for supporting the learning process (teaching aid). Students should understand technology education as:

> ...being concerned with studying the relationships between people, technology and their material culture. In its simplest form, material culture is concerned with investigating the relationships between artefact and society. This includes: an understanding of why artefacts are produced, the skills associated with the production of the artefacts, the impact of both the production of the artefact and the artefact itself on society, as well as relevant social and technical systems (Williams, 1996b).

Educational technologies such as computers and more recently cell phones, information communication technologies (ICTs) and telecommunication devices differ from general technology education as defined in this study. Technology education has to do with a broad range of technologies and with developing technological literacy for all citizens. Custer (1999) provided examples of technology:

> …simply a part of living in the modern world. These technologies include a vast array of devices and procedures including digitized kitchen appliances, “smart” house technologies, digital TV, sophisticated transportation systems, biotechnological innovations, and video games, to mention a few (p. 25).

Figure **2** indicates the relationship between the two understandings of technology. It presents educational/instructional technology as a part of technology education and not the opposite.

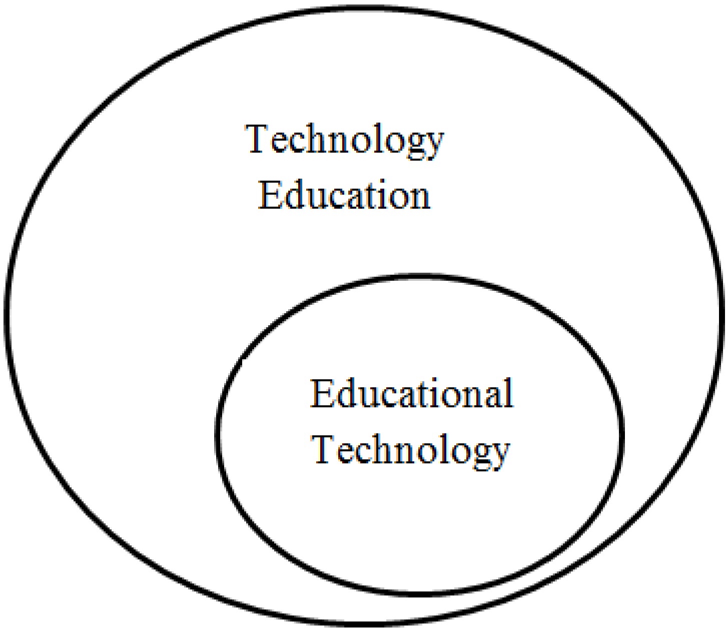

Figure 2. Technology education and educational/instructional technology.

Garmire and Pearson (2006) provided a broad definition of technology which was originally adapted from *The Committee on Assessing Technological Literacy* which viewed technology as:

> …not only the tangible artifacts of the human-designed world and the systems of which these artifacts are a part, but also the people, infrastructure, and processes required to design, manufacture, operate, and repair the artifacts. This comprehensive definition differs markedly from the more common, narrow public view, in which technology is almost exclusively associated with computers and other electronics (p. x).

In addition, students need to understand science and its relation to technology and how they remain different subjects which can both be learned and taught independently, as argued by Custer and Wright (2002):

> Students need to think about technology as tools, as a mechanism for extending human capability, and about how technology is distinct from the study of science and the study of the natural world. So an initial curricular challenge is to conceive of ways to expand students' awareness of the complexity of what is meant by technology (p. 154).

This perception is shared by Sade and Coll (2003):

> …whilst technology and science are inextricably linked, treating technology as an aspect of science fails to take into account the historical nature of technology (e.g. humans were using technology before they understood the underlying science (p. 89).

The second aspect, which may be seen as supporting the teaching of technological creativity, is that most students are influenced and guided by Islamic philosophy in which all subjects must be aligned to fit the philosophy of Saudi society. Indeed, Islamic culture encourages the teaching and learning of technological concepts. There are many indications in different places in the Qur'an which confirm this perception. Examples with respect to both creativity and technology are developed in Section Four of Chapter Three.

Personal rationale

As a technology researcher, my aim in exploring how to teach technological creativity in elementary schools is to focus on the students. I believe that students are the source of their own learning within their own world. Learning is personalised by drawing on their interests and meanings. Students can explore their ideas within technology education and across other subjects. The personal rationale for this study is also to help teachers in elementary education by providing an example of how technology education can be taught and learned through participating in this research and making it a source for later researchers.

In addition, the study allows for the opportunity in the future to conduct similar research in technology education focusing on different areas, for example design processes or manufacturing, and using them to benefit students at elementary schools. From previous discussions on creativity, I would like to provide reasons for its importance for Saudi Arabia these days and link the concept to real life contexts.

It can be understood this way. People in general have different abilities to work hard for achieving something that will benefit their societies. In Saudi Arabia, people are a long way behind the developed world, especially in the disciplines of science and technology. The message I want to convey is that Saudi Arabia should benefit from its current economy by educating students at all levels about how to be productive and have a purpose in life. The school is the prime means for educating students, especially at the elementary school level. The curriculum is the main issue facing both teachers and students in the current educational setting as there is no flexibility in the curriculum for students to choose what they want to learn or to express their personal engagement. This situation has a direct link with the concept of ownership and encouragement identified in the literature (Banaji & Burn, 2007; Benson & Lunt, 2011; Campbell & Jane, 2012) and is a fundamental element of technological creativity.

1.3.2. Rationale for choosing elementary education

As students develop between 6 and 12 years of age, the development of the self occurs. Students become increasingly capable of reasoning. Their development at this age is also characterised by increased well-being, extending their relationships to significant social groups beyond their immediate family, seeking significant role models, and engaging in exploration and imagination.

Gibbs (2006) made a significant contribution to student learning. His discussion mainly concerned students in the early stages of education in pre-school (birth to 6 years of age) and at the elementary level (6 to 12 years of age). This thesis focuses only on the elementary level. His discussion, with respect to teaching and learning in general and not in specific contexts, dealt with appropriate teaching methods in wakening students' spirits and imaginations while "also encouraging them to explore and learn independently" (p. 135). He provides many reasons for educators to always consider student learning at this stage of education because students need to learn specific skills (e.g., developing social skills). Montessori (1966) refers the success of student learning in the early years to what she calls "sensitive periods – a period of increased receptivity for specific learning about specific aspects of the environment which leads the child from the unconscious to the conscious and creative" (Gibbs, 2006, p. 132). An effective teaching method recognises sensitive periods for specific skills to develop and provides opportunities at that time so that students may access this learning. Table **1** illustrates Montessori's suggested plan of student learning development between the ages of 6 through 12.

Table 1: Montessori's second plan of development

Second plan of development (Montessori) characterized by socialization, moral justice, imagination.	**The second plane of development (6-12 years)**
	Socialization is a key feature of this plan of development, along with the further development of imagination, wonderment, and a sense of moral justice. Montessori described this phase of development as the 'metamorphic age' which is characterized by rapid growth in children's minds and bodies.

Source: (Gibbs, 2006, p. 136).

These views assist in the consideration of teaching technological creativity at this age because if students do not learn some technological (or technical) skills at this point, they will lose the chance of learning them. While they can still learn such skills at higher levels in their education, learning may become difficult.

1.4. Thesis objectives

There are five objectives to the thesis:

- Defining and addressing an appropriate meaning for creativity and developing a constructed meaning of technological creativity;
- Exploring how creativity addresses the aims of technology (as a "doing" activity) and how creativity as an educational concept can contribute to the development of student learning in Saudi Arabia;
- Identifying concepts related to the place of creativity in technology in the elementary curriculum;
- Considering future developments and how to improve student learning through creative activities in technology education;
- Developing a religious relevance curriculum design theory which treats technology as a *good deed* activity; and most of all
- Proposing technological creativity as a topic to be taught and learnt in the elementary context in a manner aligned with the philosophy of Saudi Arabian education.

1.5. Thesis structure and outline

This chapter introduces the research and develops the argument for answering the research question developed in Chapter Two.

Chapter Two outlines the methodological approach used in this thesis, the Critical Interpretative Synthesis (CIS). The chapter explores CIS methodology and its approaches to refining the topic of the thesis, the research question, inclusion of papers, determining the quality of the studies included and conducting the synthesis. Contrasts related to the use of CIS in this thesis and justifications of the method are discussed.

Chapter Three presents the results of the CIS and the findings of the included studies in the form of a synthesising argument consisting of a network of synthetic constructs. Data were sought in books, journal articles, peer reviews, document policies, websites and theoretical papers from a range of sources. Due to the extensive length of the included papers, all papers with a summary of their theoretical orientations as well as research approaches and methodological characteristics are presented in an integrative grid table attached as an Appendix to this thesis.

Chapter Four concludes with an overall discussion of previous chapters and presents possibilities, suggestions and recommendations for further research followed by selected concluding remarks.

1.6.Definitions of terms

Table 2 lists terms used in qualitative evidence research – or “individual qualitative research reports” as they are termed – (Paterson, 2012) and other general terms that need to be defined. It is important for the reader to comprehend the meanings of terms when reading through the thesis.

Table 2. Terms and definitions

Terms	Key definitions
Creativity	An independent subject or topic.
Technological creativity	Creativity in the context of technology education
Ontology	- Develops an understanding of what exists. - An assumption about the nature of reality and things which paves the way to epistemological assumptions.
Epistemology	Philosophical background (worldview/basic beliefs) for making decisions concerning what kinds of knowledge are adequate (Gray, 2009).
Paradigm	- A particular way of looking at the world. Paradigms are a mix of certain ontological and epistemological beliefs (Tolich & Davidson, 2011). - A paradigm also denotes understanding knowledge, reality/truth and people, and how they act.
Meta	Used in the sense of “after,” “about,” and “beyond.” (Zhao, 1991, p. 377).
Meta-Synthesis	Refers to studies that come after other studies and may include studies about (or of) other studies. Meta-synthesis often refers to the amalgamation of a group of qualitative studies for developing an explanatory theory or model (Walsh & Downe, 2005).
Critical Interpretative Synthesis	- A methodology for the synthesis of findings of existing qualitative studies. - An approach used to synthesize a diverse body of literature which allows for the integration of qualitative and quantitative research and also theoretical papers (Dixon-Woods et al., 2006).
First order	A first order study examines the real world. A first order study construct reflects participants’ understandings as reported in the primary studies.
Second order studies	Present the interpretations of participants’ understandings made by researchers of primary studies.
Third order studies	A new model of a phenomenon is constructed by synthesizing first and second order studies.
Line of Argument Synthesis (LAS)	The development of a new model, theory or understanding by synthesizing and interpreting first and

	second order themes found in the text.
Papers/studies/sources	The research materials of all types included in the review: activity books, books, articles, chapters in books, online books, primary research studies, and secondary research studies etc.
Pupil(s)	Used to describe children of school age. The word “student” might be more suitable to describe people who are enrolled at a tertiary educational institution.
Coding	The process of collecting research materials and organizing them under particular categories or themes.
Nodes	Meaning units (containers) for organising the research materials around one theme or concept.
Curriculum	A variety of experiences that are formed and made available to the learner through an educational institution by presenting processes of education in viable alternative forms.
Curriculum design	The way the subject matter is conceptualized and its elements are arranged in order to provide direction for curriculum development (Zuga, 1989). According to this definition, curriculum design is the development of the overall picture of the curriculum. The image includes the interactive relationship between essential elements of the curriculum: content, objectives, means, methods and activities.
Curriculum theories	Groups of decisions that result from the study of society, culture and philosophy as well as from the learner and her/his relations and interactions in personal and social contexts. Decisions then reflect the goals and content of the curriculum and determine the relationships between goals, content and teaching strategies and other components of the teaching learning process.
Curriculum development	The development of a curriculum entails putting it all together in a workable package that meets the needs of the teaching situation (Williams, 1996).

CHAPTER TWO: OUTLINE OF THE METHODOLOGICAL APPROACH

2.1. Introduction

This chapter discusses the research methodology utilised for exploring studies that review findings on teaching technological creativity based on Critical Interpretative Synthesis (CIS) approaches. My approach is based on different paradigmatic assumptions, both interpretive and critical. CIS considers the significance of the theoretical orientations of relevant studies on a specific topic more than their methodological characteristics, particularly with regard to the synthesis process and outcome. CIS allows the researcher not only to re-interpret a study's findings but also enables *critique* in order to come up with a new interpretation for policy-making and practice. CIS methodology, data synthesis strategies and procedures are explored.

2.2. Overview of research methodologies

Educational research aims at making choices of suitable methodologies for a particular topic to be investigated using multiple perspectives (Donmoyer, 2006; Gray, 2009; Cohen, Manion & Morrison, 2011). It uses paradigms that allow deeper thinking for understanding ontological and epistemological positions that focus on different aspects. People (including researchers) hold different views in understanding realities, dealing with social issues and exploring relevant knowledge. **Figure 3** is a diagram that illustrates an in-depth view of the elements of the research process: epistemology, the researcher's own worldview (philosophy), selection of an appropriate paradigm to locate his/her philosophy in that paradigm, a decision on the appropriate research approach, then time frame, whether long or short, depending on the selected approach and the decision on methods and data-gathering strategies. The research design connects all of these aspects together. These elements are the main basis for doing a primary research study.

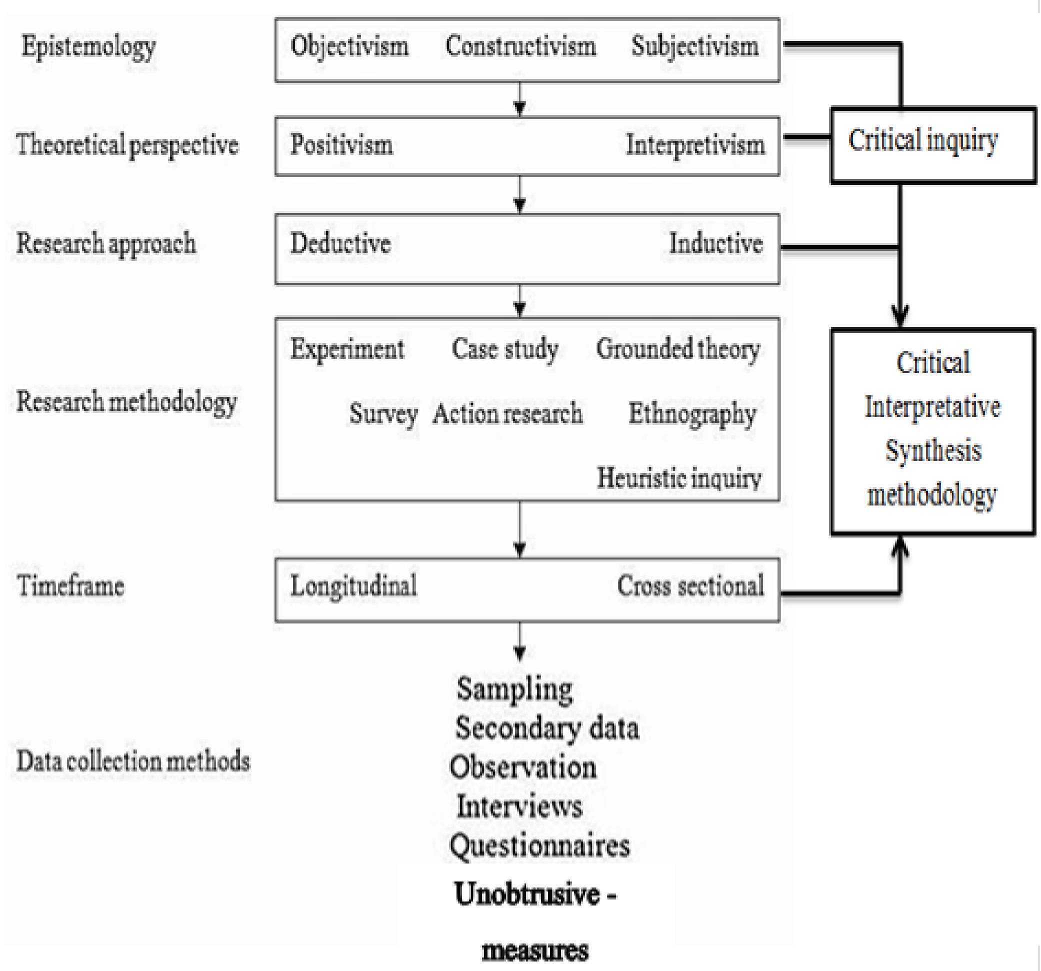

Figure 3. Elements of the research process.

Source: (After Gray, 2009).

Different positions can be taken in epistemology; each individual can see reality in a quite different way. Three general approaches to epistemology are: objectivism (reality is discovered from the external world), constructivism (reality is constructed with the interactions between people and the world), and subjectivism (people impose meaning on the world). These epistemologies identify suitable paradigms by which they can be expressed (indicating how epistemology can be located or viewed in particular ways).

According to Gray (2009), two main paradigms have been commonly debated in the history of educational research: positivism is strongly connected to the objectivist epistemology in that it seeks to discover objective reality/truth. The dominant research paradigm for much of the 20th century was positivism. It was first developed in the social sciences from the 1930s to the 1960s (Gray, 2009). The basic tenet of this paradigm is that the social world exists externally to the researcher. Interpretivisim differs from positivism in that it looks for culturally derived and historically situated interpretations of social life. Each of these paradigms links to a particular methodology and each has its own approach for research, investigation, data collection and data analysis. Commonly used research approaches are the quantitative (deductive), qualitative (inductive) or a mix of quantitative and qualitative (deductive-inductive). These methods deal with the ways people understand reality and this stage can be termed “reasoning.”

For example, deductive reasoning aims at testing a hypothesis. A hypothesis is a testable proposition about the relationships between several concepts. Through the inductive approach, the researcher aims to move from observation to generate theory. The deductive approach typifies positivism (dealing with the quantitative) and relates closely to the concept of reliability whereas the inductive approach strongly emphasises the interpretative aspect (qualitative) and the main question then is validity. Some of the methods for gathering data are shown in **figure 3**, such as sampling, interviews, observation, use of focus groups (for example in action research), documents, unobtrusive measures, to name some of them. Which are used depends on the researcher’s own epistemology and selection of paradigm and also whether the research is to be deductive or inductive. Finally, planning time scales is also an important element of the research process. According to Gray (2009), most research studies are cross-sectional due to time pressure and limitations for researchers in conducting longitudinal research.

Having understood the basic characteristics of the primary research process, there is always the need to develop new methods and allow adaptations of new methodologies. In qualitative research in particular, many methods have emerged based on the traditional interpretive paradigm such as meta-ethnography, first developed by Noblit and Hare (1988). Another is meta-analysis, a statistical method for aggregating empirical (primary) studies and analysing them using a set of procedures. This method has been modified under two names: qualitative meta-analysis and quantitative meta-analysis. However, these are only two examples of many different 'meta' research methods such as meta-study, meta-synthesis, systematic review, meta-summary, thematic synthesis (Barnett-Page* & Thomas, 2009; Dixon-Woods, Agarwal, Jones, Young, & Sutton, 2005; Zhao, 1991; Entwistle, Firnigl, Ryan, Francis & Kinghorn, 2012) and recently CIS, adapted mainly from both conventional systematic review and meta-ethnography (Barnett-Page* & Thomas, 2009; Dixon-Woods et al., 2006). While I was reviewing these different methods I asked the question, where do they come from and under which paradigm could they appropriately be placed? I then created the extension in **figure 3** to develop an understanding of (or an assumption about) these methods, specifically CIS.

Critical inquiry is a new paradigm that provides new insights into the world and differs from positivism and interpretivism. The critical inquiry form of research is "a meta-process of investigation, which questions currently held values and assumptions and challenges conventional social structures" (Gray, 2009, p. 25). Donmoyer (2006) suggests that for changing educational policy, the researcher should use a critical inquiry paradigm because "the critical inquiry perspective is not content to interpret the world but also seeks to change it" (Gray, 2009, p. 25).

It is important to note that the discussion here does not limit critical inquiry as only concerned with secondary research; it was developed basically for primary research. Here I want to focus on combining critical inquiry with CIS, a methodology which aims to review primary evidence research based on the integration of multiple paradigms (qualitative, quantitative, mixed or other research types). I developed the approach linking critical inquiry to CIS based on Gray's (2009) statement that the objective of the critical inquiry perspective is not only to interpret the world but also to change it. Thus like CIS, my approach does not intend simply to bring together data collected from other primary evidence research in a new interpretative form but seeks to go beyond these findings and build a mid-range theory. Mid-range theory does not attempt to explain everything about a general subject but focuses on a subset of phenomena relevant to a particular context. This means mid-range theory can be used as a basis to investigate empirical research questions. Here my intent is not to debate mid-range theory but to show what it is. Similarly, for Dixon-Woods et al. (2006), the purpose of developing their own methodology was to produce a mid-range theory called a *synthesising argument*. Now, it is safe to say that CIS is derived from a combination of the interpretive and critical paradigms, as I argue here, basing myself on Gray (2009) and Dixon-Woods et al. (2006).

As shown in **figure 3**, critical inquiry is placed beside the theoretical perspective which means it is a completely different perspective in terms of its views of the world and of its knowledge base. The arrow linking the critical inquiry perspective with CIS indicates that CIS is an independent research methodology in its own right because it was mainly developed to synthesise multi-disciplinary and multi-method evidence:

> Our experiences of working with a large sample of papers using multiple methods led us to refine and respecify some of the concepts and techniques of meta-ethnography in order to enable synthesis of a very large and methodologically diverse literature. Eventually we had made so many amendments and additions to the original methodology that we felt it was more appropriate, helpful and informative to deem it a new methodology with its own title and processes. It is this approach which we term critical interpretative synthesis (Dixon-Woods et al., 2006, p. 5).

Dixon-Woods et al. (2006) developed this methodology and regard it as a new approach to the whole process of review rather than just the synthesis component (Barnett-Page* & Thomas, 2009). CIS involves an iterative approach to refining the research question, selecting primary studies, applying codes and categories and appraising the quality of primary studies. For example, as in the thesis, the research process had two forms at the outset but after close investigation of the studies included, a level of saturation was reached and new data became confirmatory. CIS "uses aspects of conventional systematic review methodology but the typical staged and linear approach of systematic review is not used" (Flemming & Mclnnes, 2012, p. 63).

> This approach [CIS] is sensitised to the range of issues involved in conducting reviews that conventional systematic review methodology has identified, but draws on a distinctive tradition of qualitative inquiry, including recent interpretive approaches to review (Dixon-Woods et al., 2006, p. 2).

Before justifying the choice of this approach, a representation of the philosophy of this thesis is paramount. As argued in Chapter One, the Saudi Ministry of Education aims to support students to become scientifically and technologically literate future citizens (The Ministry of Education, 2011). However, this research plans to focus on technology education and how technological topics can be taught in the Saudi elementary context. Specifically, I propose technological creativity as a topic for investigation and will then produce a new teaching model for technological creativity to be integrated through technology related subjects. Science was selected, following Lewis (2000) who suggested that for developing countries which do not have technology education as a discrete subject, science (or any other relevant subjects) should be used as a vehicle for delivering technology education specifically for the elementary level. The thesis advocates the technology across-curriculum approach for teaching technological creativity and this for two main reasons: (a) technology education topics can be taught as part of general technology education which allows interactions between science and technology education, (b) this offers Saudi students and teachers in elementary school the possibility of learning about general technology. However, following an analysis of the variety of studies included, I decided not to limit my scope to teaching technological creativity through science. Instead a technology across curriculum approach was adopted which allows for technological creativity to be taught in and linked to any other subjects in the elementary school curriculum.

CIS was found to be an appropriate method for this thesis, making it possible to be more critical about the area of interest with the purpose in mind to produce a practical model for teaching and also for changing current educational policy in Saudi Arabia.

The literature on technological creativity is large, diverse and complex and is listed in the Appendix. A variety of primary and secondary studies includes research that uses qualitative or quantitative methods, some mixed methods, and some presented only a theoretical framework. CIS is an ideal approach which can overcome the problem of focusing on particular studies because it allows for the integration of both qualitative and quantitative research, theoretical studies, curriculum frameworks, policy documents, and political statements (Dixon-Woods et al., 2006). It is my intention to utilise a suitable methodology that allows for this integration in order to draw on a sufficient number of appropriate studies that can answer the research question and inform Saudi teaching practices and educational policy. Hence, the CIS approach is aligned with the thesis philosophy.

As noted, CIS drives the whole research process in that the researcher seeks to explore interpretations of studies in order to re-interpret them and produce a line-of-argument (LOA) synthesis or "synthetic constructs," as they are termed in CIS. Then synthetic constructs develop synthesising arguments, a new comprehensive theoretical framework.

2.2.CIS methodology

While CIS is essentially an adaptation of Meta-Ethnography (ME) and some of its techniques are borrowed from grounded theory (Barnett-Page* & Thomas, 2009), CIS differs from other approaches in that it deals with a large, diverse body of literature. With respect to the relation between CIS and ME, table 3 presents the relationship and differences in the stage processes of each approach and the adaptation of CIS to this thesis.

Table 3. Comparing Meta-Ethnography **phases** and CIS, to the CIS of this thesis

Meta-ethnography phases	**CIS**	**CIS of this thesis**
***Phase 1: Getting started*.** **The phase involves identifying an interest that primary studies might inform.**	Identifying an area of interest	"Teaching technological creativity in the Saudi Arabian elementary school context" was identified as an area of serious interest.
Phase 2: Deciding what is relevant to initial interest.	Searching for studies to be included.	Relevant papers on the area of interest were selected.
Phase 3: Reading the studies. **This phase involves repeated re-reading of studies to identify concepts and metaphors.**	This was not identified by Dixon-Woods et al. (2006) as a separate process.	Not set as a separate process in CIS.
Phase 4: Determining how the studies are related. **Determining the relationship between studies.**	This was not identified by the methodology developers as a separate process.	Not set as a separate process in CIS.

Phase 5: Translating the studies into one another. **Comparison of metaphors/concepts in one study with those in other studies.** **Translations can be reciprocal, refutational, or form a "line-of-argument" (LOA).**	Translating into one another. The concepts, themes, and metaphors used by authors are identified and translated from one study into another to produce a reduced account of the content and context of all studies.	Was not applied due to the large and diverse body of literature but is still possible with small samples. Dixon-Woods et al. (2006) suggested a maximum of 50 qualitative studies for using this technique. Flemming and Mclnnes (2012) used it in CIS methodology but with only 19 qualitative research primary reports, which was manageable for them.

Phase 6: Synthesizing translations. **Secondary translation (not always possible) when translations can encompass those of other accounts producing third order constructs.**	Synthesizing translations Translations compared to determine if either the translations and/or concepts encompass those of other accounts. Through Reciprocal Translation Analysis (RTA), evidence can be transformed into a new conceptual form called a synthetic construct.	
Phase 7: Expressing the synthesis. **Communication of the findings from the meta-ethnographic synthesis in a form appropriate for the audience.**	Evidence from across studies is integrated into a comprehensible theoretical framework called a synthesizing argument. This represents the network of synthetic constructs and explains the relationships between them, with the aim of providing "more insightful, formalized and generalizable ways of understanding a phenomenon" (Dixon-Woods et al., 2006, p. 5).	A synthesizing argument (new theoretical model) consisting of a network of synthetic constructs generated in the findings was developed.

Sources: (Dixon-Woods et al., 2006; Flemming, 2010; Flemming & Mclnnes, 2012; Noblit & Hare, 1988).

Several methodological decisions had to be made in addition to the choice of CIS for this research. First, the decision was made to utilise a ME approach using the *seven phases* (as in table 3) of Noblit and Hare (1988). After having read relevant studies related to research methods, I realised that the rules of ME restrict the researcher to the use of only qualitative primary studies in terms of their methodological characteristics and samplings. This was an issue because the thesis is guided by the research topic.

The meaning of the term *critical* used in this methodology refers to the broader sense of *critique* rather than the more limited sense of a critical appraisal of the selected studies (Dixon-Woods et al., 2006). CIS examines papers primarily in terms of their relevance to either the research topic or question. In this regard, the CIS approach is not different from other approaches like ME. Indeed, the approach was adapted from meta-ethnography but CIS differs in that it allows for the researcher to integrate studies that may have helpful information related to the research topic, as in the case of this thesis, and can inform the final results of the study despite any methodological issues.

Four main reasons for using CIS in this study are: (a) CIS allows the researcher to be more *critical* about the phenomena which inform policy and practice (b) it focuses on extracting concepts and themes from studies even if they have methodological biases (this is crucial in the data synthesis process stage). An additional very important reason is that (c) it synthesises the data using a line-of-argument (LOA) approach which means there is no need to re-interpret first and second order constructs in the selected studies because they have already been discussed in the studies (Barnett-Page* & Thomas, 2009). The LOA synthesis is termed in CIS a “synthetic construct” where the approach treats second and third order constructs the same way. Figure 4 indicates the relationship between first, second and third order constructs (Schutz, 1973).

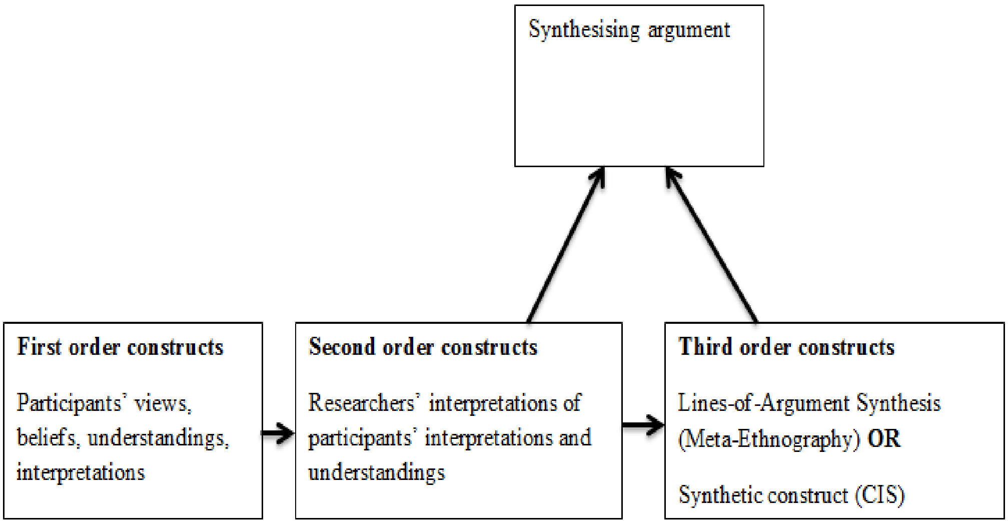

Figure 4. A synthesising argument's relation to first, second, and third order constructs.

Source: (After Flemming, 2010; Flemming & Mclnnes, 2012; Schutz, 1973).

In addition, (d) CIS also explicitly recognizes the voice of the author of the review. For these reasons I decided that CIS is the most suitable methodology for use in this thesis. Although the research questions have two different issues, they are related: how to teach creativity through technology, and then how to teach technological creativity, as a technological topic, through existing subjects. This requires an integration of studies that might not contain direct data on teaching technological creativity but are still relevant in terms of the final outcomes as argued by Dixon-Woods et al. (2006), taking into consideration the complex learning situation in Saudi Arabia which requires a significant number of theoretical papers to inform educational policy and practice.

2.3.Methods

There are five stages towards the completion of the CIS analysis process as shown in Table 4. Stages 1, 2, 3, and 4 are the focus of this chapter. Stage 5, the core of the thesis, is developed in Chapter Three. Thus, procedures outlined in this section present four primary stages towards the whole CIS process review. First, the section explains the identification of an initial review question and its development (Stage 1), then methods for searching studies and determination of the quality of studies selected (Stage 2 and 3), summarising included papers (Stage 4), data extraction and conducting the synthesis (Stage 5). Stage 5 presents the findings in a new theoretical framework model developed for the Saudi Arabian elementary school context. The organisation outlined above and indicated in table 4 simply intends to clarify the process of the thesis.

Table 4. Stages and key processes involved in the CIS of the thesis.

Stage	Key processes involved in CIS
1	Identification of an initial review question (which can be modified as the study proceeds)
2	Searching and sampling papers
3	Determining the quality of included papers
4	Summary of papers included (presented in table form in the Appendix due to the extended length of the texts)
5	Analysis of papers included: generating a new theoretical framework model for planning implementation

Source: (After Ring, Ritchie, Mandava, & Jepson, 2011).

2.3.1. Identifying an initial review question and its development

This first step requires the researcher to identify a topic of serious interest which would benefit from being explored through the synthesis of the selected studies (Dixon-Woods et al., 2006). Teaching technological creativity was chosen as the area of interest as proposed in Chapter One.

Question development

In the ME approach, question formulation involves:

> … identifying the intellectual interest that qualitative research might inform … qualitative approaches are the preferred strategy when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context (Noblit & Hare, 1988, pp. 26-27).

The specific review method chosen is determined by the research question guiding the inquiry (Dixon-Woods et al., 2006). The question that is of interest and how this question is framed will be derived from the researcher’s epistemological beliefs and paradigmatic orientations as to what can be understood about the world and how this understanding can be acquired. Dixon-Woods et al. (2006) made it possible for the researcher to modify the research question(s) according to the final results of the studies. This is another advantage of using CIS because the main aim of its review is to inform policy and practice. The development of the review question in CIS differs from that in a systematic review where the research question is highly designed. Accordingly, at the outset there was one main question: *how can technological creativity be taught in the context of science teaching in elementary education in Saudi Arabia?* And two sub-questions may be added: *how can creativity be taught through technology education?* And *how can technological creativity be taught through science education?* After the final analysis of the studies and generation of the theoretical framework model, I decided to reduce these questions to one major question which was aligned with the findings of the studies themselves and the synthesis process of CIS: *how can technological creativity be taught in the Saudi Arabian elementary school context?*

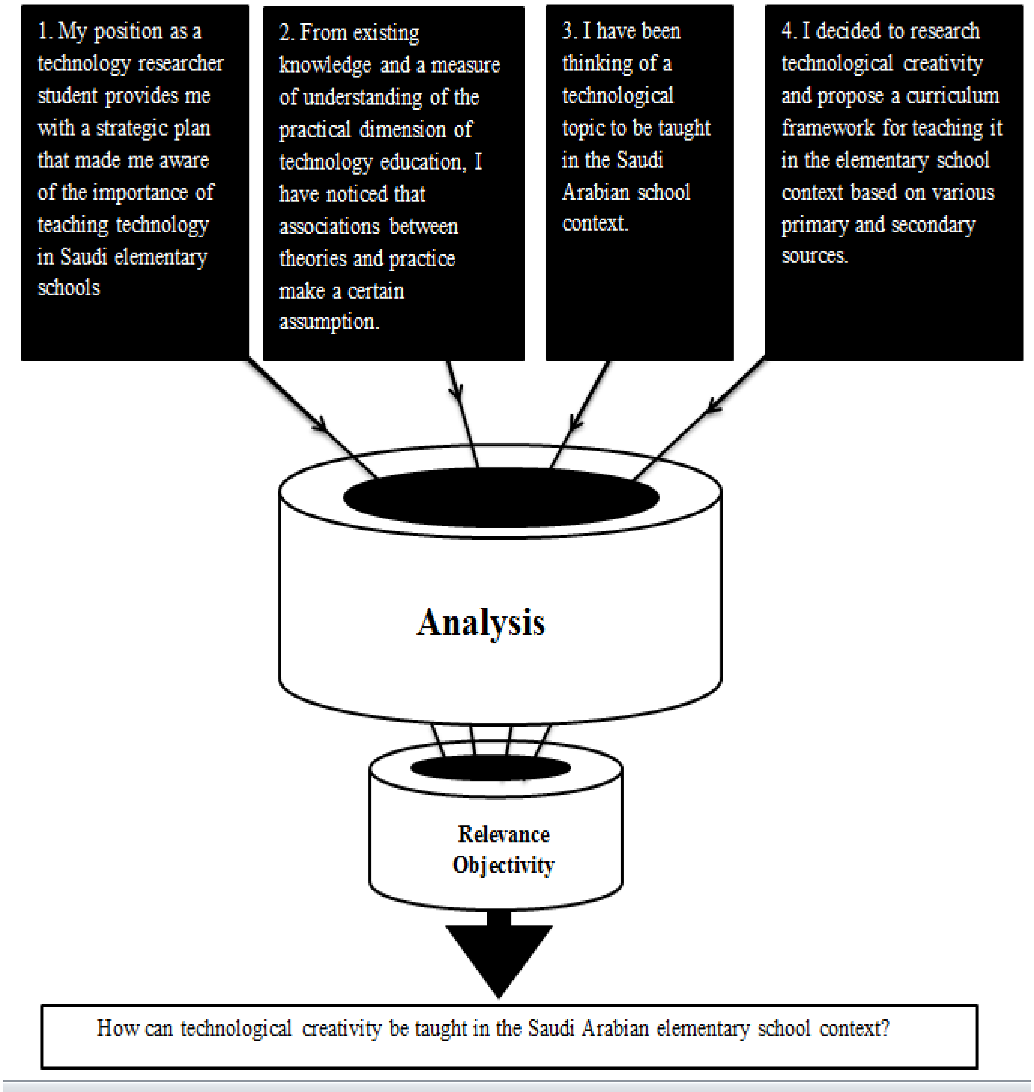

Figure 5. The process for identifying the research question.

Within CIS, question formulation involves "reflection on the approach taken by meta-ethnography, with the posing of a question that identifies an area of interest, not a specific hypothesis" (Flemming & Mclnnes, 2012, p. 67). Dixon-Woods et al. (2006) claim that although the research question is not set *prior* to the identification of relevant primary studies, this does not mean the researcher cannot pose a particular question before conducting CIS. Research questions may not be the same as those raised in the studies included in the review but they are similar to those in primary studies which have focused on the topic of creativity in design and technology education. The only difference between the question dealt with in this thesis and those raised in the primary studies is the context in which technological creativity was developed. I formulated the research questions in relation to the area of interest (teaching technological creativity), then specified two sub-questions as part of the context for answering the questions. Dixon-Woods et al. (2006) claim that the research question can be reformulated and aligned with final findings and outcomes of the research. "The approach we used to further specify the review question was highly iterative, modifying the question in response to search results and findings from retrieved items" (Dixon-Woods et al., 2006, p. 3). This does not mean a research question cannot be determined prior to the review but it should not be a specific hypothesis. This is what makes CIS different from a systematic review where the question is identified before the review and becomes the anchor for the review from which its parameters are set (Dixon-Woods et al., 2006; Flemming, 2010; Flemming & Mclnnes, 2012).

Having stated how a research question can be formulated within CIS, the research questions in this thesis do not constitute a specific hypothesis, i.e., my focus is on how technological creativity can be defined, taught and learned in the broader context of teaching technology at the elementary level. The question then is, "how can I inform my intellectual interest by examining a set of studies?" (Noblit & Hare, 1988, p. 27). Adopting the ME and CIS methods, Noblit and Hare (1988) and Dixon-Woods et al. (2006) claim that intellectual interest develops as studies are read. This does not happen through the synthesis process but through effort in synthesising relevant studies.

2.3.2. Searching for studies

A variety of research strategies were used to identify the studies on teaching technological creativity focusing on the elementary context. Studies were searched for in electronic databases, books, e-books, technical books, websites, conference papers (PATTs), and reference lists from initial studies. No time limit was set when searching.

The first step in the process was to manually search books, book chapters, and technical books known for publishing in the area of technology education. Five books, 15 chapters in published books, 6 technical books and 115 online journal articles were selected on the topic of creativity, drawing from materials in psychology, education and technology education. Due to space limits for illustrating all studies, overview samples of articles, their titles, authors, nationalities, source types, focus and year of publication are attached in the Appendix. This search process was carried out prior to the use of electronic databases. I then began searching online by accessing electronic databases using relevant terms for searching. There were many studies on the topic of creativity. Even though I specified that I was looking only for creativity within technology education, the search yielded results dealing with creativity in other disciplines as well, such as psychology, social psychology, special education, requirement engineering (RE), music, and education in general. Supporting studies from psychology and education were found because, as many researchers argue, creativity has a psychological element which cannot be ignored when viewing creativity in other subjects, as is the case in this research. Applying them was important.

In this process of inclusion and exclusion, I have only included studies that have direct relevance to the area of interest, technological creativity and its teaching applications, tools and techniques. This phase requires the researcher to identify studies on the topic. I then established broad inclusion criteria and considered the selected studies. The goal was to identify studies on the topic which meet the following criteria:

Studies were included if they:

- Were written in English;

- Published and/or peer-reviewed in journals on technology education;
- Focused on technological creativity or on how to teach technology through elementary subjects; and
- Were considered papers relevant to the topic.

After deciding what to include, 64 studies were selected for inclusion in the meta-synthesis process.

2.3.3. Searching outcomes

Twenty-five studies were identified prior to searching for further studies in electronic databases. These 25 met the inclusion criteria because they are well-known published papers in technology education. The studies focus on technological creativity, its processes, elements, and applications for teaching with particular focus on the elementary and lower secondary education levels. I have argued, furthermore, that CIS considers the relevance of papers to a thesis and is not concerned with methodological characteristics. Some of the sources were technical (activity) books which are not considered research studies but their theoretical orientations are relevant to the topic and question. For electronic databases, there was a very large number of studies on creativity which required reading the abstract to discover what was relevant. Drawing on these abstracts, 115 papers were identified, 76 of them dealing with creativity in other subjects such as psychology and education, and a few had to do with educational technology. However, the 76 were excluded. A total of 64 primary studies were included for the synthesis process. Figure **6** indicates the criteria used in the process of inclusion and exclusion.

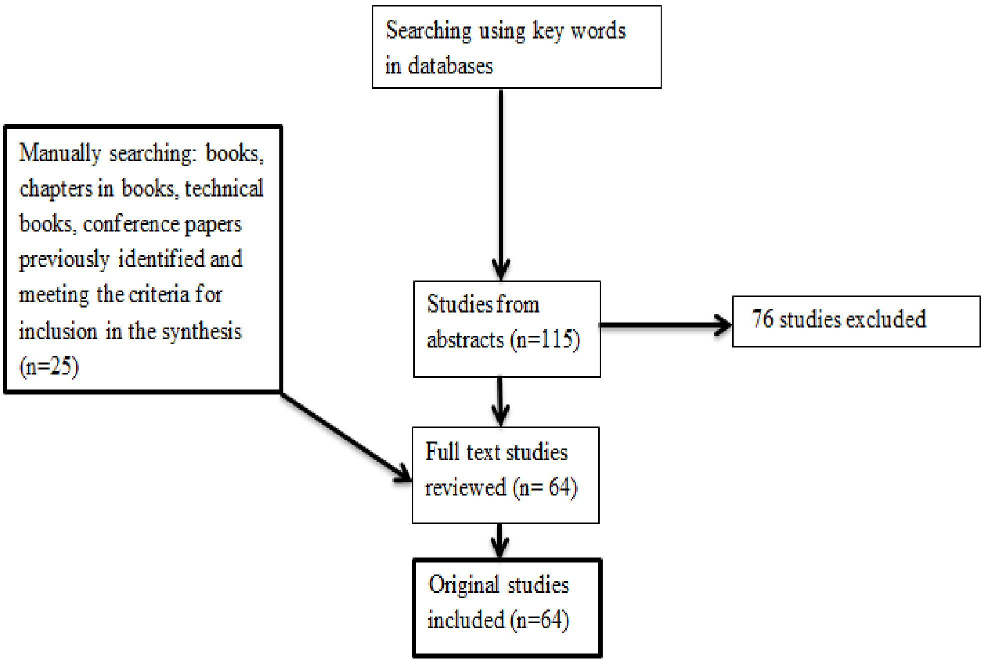

Figure 6. Process of inclusion and exclusion.

Because CIS is an iterative and reflexive approach by nature, new papers were found and integrated to bring the number of included papers to 135 as identified in the Appendix.

2.3.4. Determination of quality and credibility check

Appraising primary studies is a contentious matter in the history of qualitative research and not just in CIS (Dixon-Woods et al., 2006). Dixon-Woods et al. (2006) specified two ways for ensuring the quality and credibility of the studies. “First, we decided that only papers that were deemed to be fatally flawed would be excluded. Second, once in the review, the synthesis itself crucially involved judgments and interpretations of credibility and contribution” (p. 4). The authors argued that the concepts and themes of the primary studies should all be relevant to the research topic and question. As in their CIS study, they found that a few papers were excluded as “fatally flawed, because even weak papers were often judged to have potentially high relevance” (p. 4). The purpose of the developers of CIS was to include all papers that can contribute to the theoretical development of the synthesis topic, even if they provided less weight within the synthesis (Annandale, 2007; Atkins et al., 2008; Dixon-Woods, 2006, 2011; Dixon-Woods et al., 2005; Dixon-Woods et al., 2006; Noblit & Hare, 1988).

However, Flemming and Mclnnes (2012) claim that "the most common approach to appraisal has been in the form of structured checklists" (p. 71). Accordingly, I drew on the methods of Dixon-Woods et al. (2006) and Flemming & Mclnnes (2012) for appraising the quality of the studies. I developed a specific tool for identifying primary and secondary research, their focus, content, methodologies, and criteria for inclusion. Table **5** illustrates a sample of one source using the identification research tool (Papers Research Identification Tool).

Table 5: Papers Research Identification Tool

Paper No. 1	
Reference	Howe, A., Davies, D., and Ritchie, R. (Eds.). (2001). *Primary design and technology for the future: Creativity, culture and citizenship*. London: David Fulton Publishers.
****Source**	Secondary
Major construct	About primary design and technology, written for those who are concerned with the education of students aged 4-11 years.
Methodological characteristics	An interpretive review which examines the place of creativity in design and technology, and possible and practical approaches to teaching design and technology. These concepts are illustrated from case studies made in primary schools.
Decision to include in CIS	Yes. While this source is secondary and not primary, it provides insights into how creativity can be taught at the primary school level. The source also established strong links between design and technology and other subjects in the primary curriculum. It emphasises the "learning across curriculum" approach which is of particular relevance to the Saudi learning situation.

After having read and re-read all the papers, the process of synthesis and the development of the theoretical framework model were completed and a decision was made to include all papers because they were relevant to the research question and the topic. The Studies Research Identification Tool was discarded and a new table which groups all information needed about each paper was created. The table, presented in the Appendix, consists of five columns: paper number, author, date and country (column one), title of papers (column two), focus – including themes –, the concepts' main constructs generated in the studies (column three), research approach and methodological characteristics (column four), and publication/data sources (column five).

2.4.Source limitations

One of the limitations to this CIS was the number of papers included in the review on Saudi education. There was not even one in-depth study either on creativity, technological creativity or technology education. Moreover, the synthesised studies did not deal directly with the question how technological creativity can be taught through science (it is the aim of this thesis to answer this question). Researchers focused on defining creativity and its processes and discussed pedagogy relating to design and technology in countries that already have these subjects in their school curriculum. A number of researchers, however, contributed to the discussion of how technological topics can be taught and learnt through science. Indeed, there were a number of articles that discussed teaching technological creativity through Science, Technology, Engineering and Mathematics (STEM) subjects but they still lack information on strategy and learning plans. I limit my discussion to the included papers and do not generalise the idea on the basis of other research not utilised in the thesis.

2.5. Data extraction

The role of data extraction in qualitative research synthesis requires formal evaluation (Dixon-Woods et al., 2006). For studies that involve participants and have explicit research designs, Dixon-Woods et al. (2006) noted that data extraction aims to assist in identifying characteristics of research participants, methods of data collection and analysis, and the findings of the selected studies. For all included studies, data extraction involves specifying the titles, categories and subcategories of the studies themselves. For this thesis it was difficult to conduct this formal data extraction because the documents were very large and included both primary and secondary studies. This type of data extraction may require further formal evaluation. Nevertheless, after reading through the studies, an overall summary is provided in the table in the Appendix. It is important to note that at the beginning, particularly when reading the studies, a highlighter pen was used as an informal method for summarising the documents. Then in aggregating the papers Endnote X6 software was a helpful tool for creating a library of the papers included. NVivo 10 was used to extract and organise themes and categories from the papers by creating nodes based on the headings used in the integrated papers and to code relevant data to those nodes. NVivo 10 was useful software in collecting the data relating to constructs, a task which was too difficult to accomplish using traditional methods.

2.6. Conducting the synthesis

The manner of conducting the synthesis is detailed in the next chapter (Findings) and presents the findings of CIS as well as the findings of the included studies in the form of a *synthesising argument.* This involves a new understanding of the phenomena being transferred into a new and comprehensive theoretical framework to inform the Saudi Arabian elementary school context. The argument is developed around the final topic of the research question: *how can technological creativity be taught in the Saudi Arabian elementary school context?* The theoretical framework model contains a set of connected synthetic constructs and sub-constructs generated in the integrated papers. Synthetic constructs refer to the construct orders identified by Schutz (1973) as indicated previously in **Figure 4** and include first, second and third order constructs. As stated previously, first order constructs present first-hand information from real life situations (taken directly from participants' views and beliefs). Second order constructs present the researchers' own interpretations and understandings, seen as descriptive and subjective in nature (Flemming & Mclnnes, 2012). Third order constructs are termed "line-of-argument synthesis" in ME. The equivalent term in CIS is "synthetic construct," which consists of second and third order constructs.

A synthesising argument is the output of the synthetic constructs (both second and third orders). CIS does not distinguish between second and third order constructs. Both form the synthesising arguments which are the new research form emerging from both the findings of the primary and secondary studies and the CIS synthesis process. Flemming (2010) explains that CIS is a two-stage process for developing output: the assembly of 'synthetic constructs' which results from the transformation of the underlying evidence into a new conceptual form, and the creation of a ‘synthesizing argument’.

However, Flemming (2010) uses CIS in a different way from that of Dixon-Woods et al. (2006). Flemming conducted his study by integrating 19 diverse materials, a mix of qualitative and quantitative. No theoretical papers were included and he employed a reciprocal translation analysis (RTA) which is impossible to use with a large number of diverse papers. Having understood this issue, in their study *The use of morphine to treat cancer related pain: A working example of critical interpretative synthesis,* Flemming and Mclnnes (2012) maintained that there was no indication “in the development of CIS that discrete synthesizing of synthetic constructs and synthesising arguments is not possible or indeed desirable” (p. 79). While it would be useful to establish synthetic constructs as a new theoretical form developed from the selected papers and then create a new theoretical model in the form of a synthesising argument, it was difficult to conduct the synthesis in two different forms in this thesis because of the variety of sources (qualitative research, theoretical papers, technical books, books, activity books), primary and secondary, and also because no other similar papers exist in the literature on technological creativity with respect to Saudi Arabian education. Consequently, this research study offers a unique presentation in a new context that can definitely inform educational policy and practice in Saudi Arabia.

2.7. Reflecting on and justification of methodology

Recent developments in the review of qualitative evidence research have led to new inquiry into interpretative synthesis methods, such as critical interpretative synthesis, grounded theory synthesis, meta-ethnography, meta-interpretation, meta-summary, qualitative cross-case analysis, meta-analysis, meta-synthesis, systematic review and thematic synthesis. Each of these methods has its strategies for identifying, interpreting and synthesising qualitative material. They have provided understanding of continuous developments in interpretative and qualitative methods. The reasons for the establishment of these meta-methods can be found in the different purposes of researchers for reviewing evidence grounded in the literature and in their purpose of presenting new theories suitable for informing practices such as the use of CIS. ME is the most widely used of the methods mentioned because of its *clear* processes in reviewing only qualitative research. Approaches other than CIS have been used only in qualitative evidence research where researchers who need to integrate other types of evidence, such as quantitative, had to use two approaches: one for synthesising qualitative research and the other for synthesising quantitative research. Booker's (2008) doctoral thesis "*A comparative study of extended meta-ethnography and meta-analysis based on the fundamental micro-purposes of a literature review*" is a good example of this.

2.8. Considering other methods

Qualitative meta-analysis, meta-synthesis and meta-ethnography have also been considered. I had to reject these methods due to their restricted roles, none would allow in-depth exploration to be undertaken that would be informative for the Saudi Arabian education system. For example, a traditional literature review would be unlikely to uncover diversity in the methodologies. More importantly, it would not look at studies and their data in an in-depth, critical and interpretive way.

Figure 7 shows the organisation of the thesis process in its final form, starting with an introductory chapter consisting of the background, thesis context, rationale for teaching technological creativity in Saudi Arabia, an outline of the thesis structure, and definitions of related terms. Chapter Two explains CIS as the methodological approach used to conduct the synthesis process. It discusses four stages as shown, and the stage 5 findings (developing a critical interpretive synthesis) are presented separately in Chapter Three. The final process summarises the content of the thesis and its organisation (the findings of the CIS synthesis process and the findings of included papers), presents a conclusion which highlights an overview of the thesis, suggests further research needed in Saudi Arabia and in technology education, and offers a recommendation for future researchers who may use CIS in technology education.

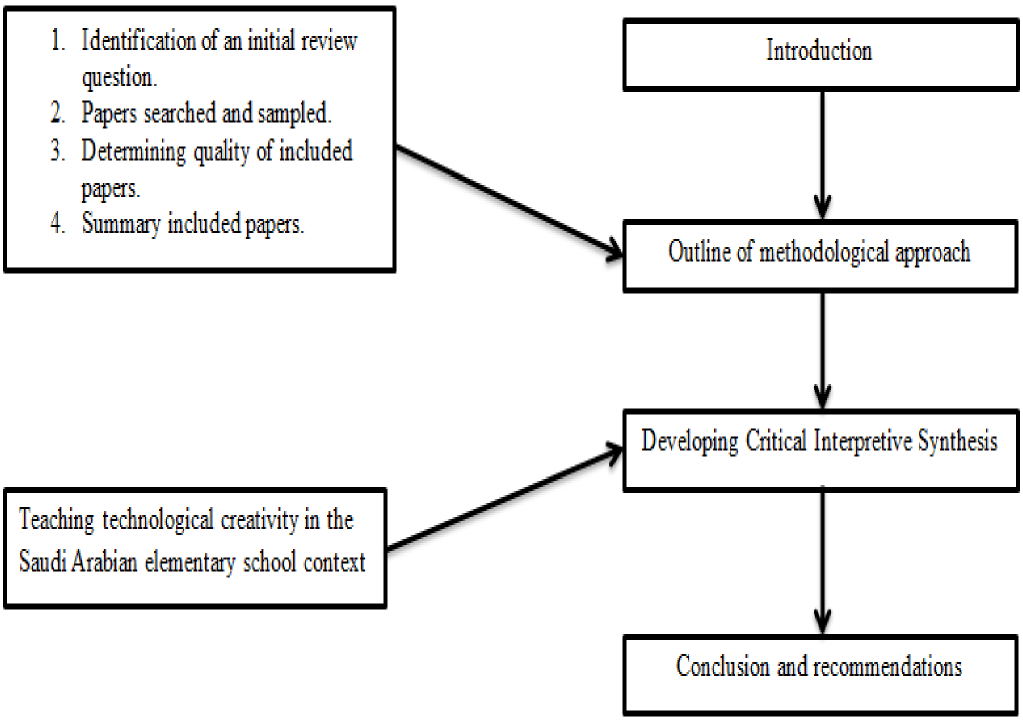

Figure 7. Organisation of the process of this research.

2.9.Conclusion

This chapter explored CIS methodology and the analysis techniques adapted from ME to allow inclusion of a large, diverse body of studies on technological creativity. The chapter began by developing a general understanding of research paradigms in educational research. Next, specific consideration was given to CIS methodology which, as this chapter has argued, emerged mainly from the critical inquiry paradigm because the critical inquiry perspective concerns all “meta” research methods and CIS is one of them. The methodology, developed from ME, is still new. CIS is a methodology and not only a method for synthesising data. Methodology usually refers to the paradigm which drives the whole research study whereas the method refers to the synthesising/analysing component. However, I presented an identification of the topic of interest and research questions linking this to the development of synthesis procedures that include all relevant papers. A detailed discussion followed on the development of questions and methods for searching, including the strategy used for searching studies and for the inclusion and exclusion criteria process, outcomes of searching, determination of quality and credibility, and data extraction. Particularly in view of the large and diverse number of studies included, CIS offers new possibilities for this thesis.

The effectiveness of the studies presented in this research will show the potential for using CIS when there are calls for decision and educational policy-making.

CHAPTER THREE: DEVELOPING A CRITICAL INTERPRETIVE SYNTHESIS

3.1. Introduction

The review develops an understanding of technological creativity, and presents key dimensions of creativity and their relationships in constructing technological creativity. I explore the pedagogy of technological creativity together with relevant pedagogical suggestions how creativity can be integrated into the elementary curriculum. A religious context of creativity in relation to Islamic culture is developed. This chapter presents four main sections.

The first section presents definitions of creativity from various philosophies. It identifies three themes: the complex nature of creativity associated with the many approaches to creativity in psychology and education in the past few decades; a historical review of the research development of creativity; and a construct meaning of technological creativity.

The second section presents key dimensions of technological creativity: creative product requirements (originality, imagination, value and appropriateness), and elements of technological creativity (domain-knowledge, creative personality and environment and the creative process). Different ways of theorising about creativity in different disciplines illustrates how the emphasis placed on the nature and role of technological creativity depends on the basis on which creativity has been analysed in relevant fields.

The third section views creativity within the technology education teaching and learning contexts. The section generates a curriculum framework model where technological creativity can be implemented in the Saudi Arabian elementary curriculum.

In the fourth section, a religious context of creativity in relation to Islamic culture is developed with respect to the ways in which technological creativity can contribute to pupils' cultural and religious education, and the ways in which different cultural contexts can be used for technology education activities in schools.

Following Chapter Two, the data are synthesised and I explore in more depth the synthesising argument, a new form of interpretation critiquing the pedagogical stance regarding technological creativity. Evidence of commonality across studies was recorded in order to re-conceptualise findings and allow the production of a mid-range theory. This theoretical model added an element that goes beyond the synthetic constructs developed on the basis of included papers.

The findings presented in this chapter emerged in an attempt to answer the research question: *how can technological creativity be taught in the Saudi Arabian elementary school context?* Undertaking synthesising arguments means that new knowledge was brought to bear on existing material. Practically speaking, the development of synthesising arguments means evidence derived across studies was integrated into a comprehensible theoretical framework. This represented the network of synthetic constructs and explained the relationships between them with the aim of providing a more insightful way of understanding the phenomena. It is important to note that the analysis of the findings in this chapter took one form, as argued in the previous chapter, and all papers were treated as objects of inquiry. This means that not only the findings located in those studies (e.g., the results sections of the included papers) but also each text of each individual paper was treated as a synthetic construct. Thus, this chapter was developed directly from the papers in its final critical form under newly created categories.

3.2. Section one: Developing an understanding of creativity

The synthesis process began by trying to construct a meaning of technological creativity. All the studies discuss similar definitions identified by other research studies and this was a common characteristic. The definition of the National Advisory Committee on Creative and Culture Education (NACCCE, 1999) is one example. Little research examines the history of the topic of creativity (Bairaktarova & Evangelou, 2012; Craft, 2001; Hennessey & Amabile, 2010; Surkova, 2012; Warner, 2010). I limited my discussion to the included papers and do not generalise the idea on the basis of other research not utilised in the thesis. Four papers provided a clear indication of the subject's history so they were used to support my research.

"What is creativity?" is a common question to which all the papers provide answers in various ways. Based on findings concerning the many different definitions and views of creativity, three major categories were identified in order to develop an understanding of technological creativity: the complex nature of creativity, research development, and definitions of creativity. Then a constructed meaning of technological creativity is developed.

3.2.1. Complex nature, research development and definitions of creativity

Creativity has its special part to play in assisting people to meet the unpredictable changes of the future. Historically, it has been an area of interest in many fields including education, psychology, religion, economy, technology (design), science, and engineering. The importance of creativity is evidenced by on-going research in those domains. Milgram (1990) (p. 215, as cited in Hill, 1998), remarked that "it is an idea whose time is still coming – an idea that is still in the process of becoming". Research on the topic of creativity was first initiated by Guilford in the 1950s (Guilford, 1950; Vidal, 2007) or 1960s (Hill, 1998) and was under-researched until the mid-1990s. Burton (2010) commented that:

> The starting-point for the development of modern creativity studies as a distinct academic field was the address to the American Psychological Association by J.P. Guilford (its then President), in 1950, which identified creativity as an area of study in its own right, distinguishable from the study of intelligence, and of particular importance to the development of science and technology (p. 495).

Lubart and Georgedottir (2004), Sternberg (2005) and Lin (2011) provided holistic views of research development in psychology, as did Craft (2001); Jeffrey * and Craft (2004) in education, and DeVore (1987a); DeVore. et al. (1989) and more recently Bairaktarova and Evangelou (2012), Warner (2010, 2011); Williams et al. (2010) in technology education. These studies review the history of the research of creativity since its first recognition in the 1950s. In the field of psychology, Lubart and Georgedottir (2004) aver that the reason for the complexities of the notion of creativity is due principally to the many approaches used:

> …for example, one popular division was proposed by Rhodes (1961) who identified the '4 P's' of creativity: the creative product, the creative person, the creative process and the creative environment…another line of attack has been to study creativity within one or another sub-field of psychology. Thus, we find the cognitive approach, the social-psychological approach, the developmental approach, the cross-cultural approach, the psychoanalytic approach…in the last twenty years; several authors have sought a more integrated conception of creativity in which different approaches, different pieces of the puzzle come together (p. 24).

After 1950, the topic of creativity became a fresh, rich research area in psychology when Guilford (1950) launched it more than half a century ago with a presidential address to the American Psychological Association. Then until the 1990s, the topic remained under-researched despite its increasing significance. After 1995, the subject of creativity exploded in interest for many psychological researchers who focus on researching new aspects of creativity (Sternberg, 2005). Lin (2011) described the status of contemporary research theorising creativity as still unclear:

> …some psychologists believe creativity to arise from unconscious drives, while some psychological researchers defined creativity as a syndrome or a complex. Some other researchers deem creativity as thinking skills, a product of creative thinking, or personal qualities. The varied views and definitions of creativity imply different research approach to creativity (p. 150).

In education, creativity has developed in four different stages from the 1950s to the present:

1. In the 1950s, the focus was on the individual, on genius and giftedness, and on the personality of the person who creates. As a result of this trend,
2. The 1960s concentrated on a measurable outcome and tests of creative ability related to cognition;
3. Then in the 1970s the emphasis shifted to connecting creativity with imaginativeness and the need to stimulate creativity; and
4. Finally, during the 1980s, researchers looked toward environmental conditioning and social theory to understand the concept of creativity. Following this fourth line of reasoning, researchers began to focus more on the creativity of ordinary people within the education system (Saebø, McCammon, & O'Farrell, 2007, p. 207).

Currently, research involves several areas which should be accounted for systematically in all domains. Areas such as the characteristics, personality traits or dispositions of a creative person, stages of the creative process, characteristics of the creative product or outcome, the nature of the environment and climate, the nature of the creative imagination, perception, intuition, assessment of creative work, learning styles, pedagogical framings, teaching applications, and nurturing and fostering creativity (Surkova, 2012). Bairaktarova and Evangelou (2012) present three major overlapping phases of research on the topic of creativity: "technological innovation in the first wave of research; rebellious, unconventional ideas in the second; and recognized work of major significance in the third" (p. 380). Table **6** summarizes the three phases and their development stages.

Table 6. Phases of research on the topic of creativity

Phase focus	Development
Technological innovation	• Started with Guildford 60 years ago; • Creativity as a whole was defined as "technological inventiveness." • Creativity research was motivated by a desire to identify and encourage the development of technological inventiveness and other traits to insure survival in future wars; • This work is primarily psychometric and aims to produce tests that would be independent of IQ and would predict creativity. This research and development included an educational component; however, education was generally not its main focus.
Rebellious and unconventional ideas	• Took more than a decade after the 1950s to change the field's definition of creativity; • Creativity research produced a diversity of topics, a variety of research methodologies and theoretical frameworks; • Conceptual frameworks emphasize the dynamic and interactive nature of creative activity; • Developmental theories determine the qualitatively distinct nature of creative advances in thinking; • Evolutionary frameworks argue for random or chance causes for creative advance; and cognitive approaches that emphasize processes common to all forms of thinking have appeared in the last 2 decades.
Work of major significance	• Creativity research produces more recognized work of major significance.

	• This work targets extreme forms of creative accomplishment in contrast to the Guildford emphasis on lower-level creativity.
Moving the focus of research from the abilities or personal qualities of the individual creator to the conditions that support, inhibit, constrain or enable creative work to take place	Creativity located in its social, cultural, historical, and evolutionary context also preoccupies scholars.

Source: (Bairaktarova & Evangelou, 2012, pp. 380-381).

The growth of research on creativity areas is very important for our survival simply because there are many everyday problems that need to be solved and no specific solution can be identified before the emergence of problems (Surkova, 2012). Consequently, research will continue to take many forms in identifying new insights about creativity in all fields of study. In technology education, Warner (2010) claimed that problems associated with research on creativity in the field of psychology should serve as important guidelines for researchers in technology education. Creativity within the domain can help to address needs such as how the creative performance can be assessed and improving teachers' competence in teaching design and problem-solving.

Researchers have used various approaches in defining creativity with respect to their fields of study, including psychology, education and recently design and technology education (Barlex, 2007, June, 2011; Ghosh, 2003; Gibbs, 2006; Han & Marvin, 2002; Hope, 2010; Lin, 2011). The majority reflect the National Advisory Committee on Creative and Culture Education's (NACCCE, 1999) definition of creativity as an "imaginative activity fashioned so as to produce outcomes that are both original and of value." An analysis of the literature shows that the definition is limited to the product. It is like an evaluation of the creative product rather than a reference to the creative process, environment or person. Clearly, the definition comprises three elements: the first relates to the creative person exercising their imagination in the activity in order to produce a creative product. The next two elements are related to the product which reflects the outcomes of the process, task or activity. However, NACCCE's definition was not the only one available but was the one most commonly debated in the literature, particularly English language literature. Researchers have developed their definitions based on it.

Amabile (1997) defined creativity a bit differently, viewing it as "the production of novel, appropriate ideas in any realm of human activity, from science, to the arts, to education, to business, to everyday life" (p. 40). Other researchers, furthermore, have supported this idea and add that "creative ideas and actions depend upon knowledge of the domain – whether it be mathematics, human relationships, science, drama, etc." (Craft, 1999, p. 138). Rutland and Spendlove (2006) provided a description summarising much of the literature and affirmed that current insights into the research indicate that:

> …there is still generally a lack of consensus over the meaning of the word creative. In some cases the word is used to describe a product, in others a process, sometimes a personal quality and at other times a social quality (p. 143).

Creativity has received increasing attention, particularly in psychology and education in the past twenty years (Craft, 1999, 2001, 2003; Hennessey, 2003, 2004; Hennessey & Amabile, 1998, 2010; Lubart & Georgedottir, 2004; Runco, 2004a; Runco, 2004b) and recently in technology education (Balchin, 2008; Banaji & Burn, 2007; Barlex, 2007, June, 2011; Benson & Lunt, 2011; Campbell & Jane, 2012; Caney, 2006; Christiaans & Venselaar, 2005; Clinton & Hokanson, 2012; Cropley & Cropley, 2009; Davis, 2011; Day, 2011; Demirkan & Hasirci, 2009; Friedman, 2010; Ghosh, 2003; Gifford, 2009; Good, 2002; Hall, 2011; Howe et al., 2001; Lewis, 1999, 2008; Lewis & Zuga, 2005; Mesquita, 2011; Middleton, 2005; Myers & Shinberg, 2011; Rutland & Barlex, 2007; Rutland & Spendlove, 2006; Warner, 2002, 2010, 2011; Webster, Campbell, & Jane, 2006; Wong & Siu, 2012; Wu, 2005; Wyse & Spendlove, 2007; Yatt & McCade, 2011; Yeh & Wu, 2006).

These papers from psychology, education and technology education present weighty evidence that relates to the topic of technological creativity and its pedagogy. Attention is largely directed to understanding creativity in relation to a specific domain or context: how creativity can be defined, how it can be taught within a particular context, and how it can be assessed.

Researchers have also defined creativity and its elements with respect to their particular domains. This development links with the concept of domain-general and domain-specific creativity. Nguyen and Shanks (2009) have investigated studies of researchers focusing on general and specific domains of creativity in relation to teaching, measuring and assessing students' creative abilities. Domain-general education aims at training and developing students' general creative skills whereas domain-specific education focuses on teaching creative skills in particular contexts. For example, in technology education important creative skills include problem-solving, higher order thinking, convergent and divergent thinking, inventing, troubleshooting, procedure, design (Custer, 1999; Middleton, 2005; Williams et al., 2010). Williams et al. (2010) describe creativity as having three different aspects: reverence for particular abilities held by individuals, the particular processes and the particular outcomes:

> These three aspects of creativity refer to different approaches to creativity; that is, they refer to creativity as psychological, philosophical or ontological phenomenon, as practice, and as a characteristic of artefacts. The interconnectedness between these three different approaches and the often uncritical use of the term 'creativity' as a singular, heterogeneous concept lies at the centre of the problem of defining creativity (p. 26).

In a similar way, Howe et al. (2001) define creativity with their suggestion that three main components form the meaning of creativity: imagination, originality and value. The authors define creativity in a directly technological context. Their definition was developed particularly for an educational context in accordance with the NACCCE definition, perhaps because the latter's definition was the result of an agreement among the NACCCE's committee members who:

> …had agreed upon what they called a 'stipulative' and 'indicative definition: stipulative in that it stipulates four characteristics of the creative process, and indicative in that it points to features of creative processes that the committee wished to encourage for educational purposes ... The four

> characteristics were imagination, purpose, originality and value (Hall, 2010, pp. 483-484).

Indeed, the research mentioned has focused on these four components for providing a construct meaning of creativity: imagination, originality, purpose and value. The imaginative and originality elements are discussed under creative product requirements because the creative product has to be imaginative and original. They are also discussed in the category of creative personality because imagination is more concerned with the individual's mental ability and the level of awareness that the unconventionality of his/her actions is deemed imaginative.

Originality is more concerned with the degree to which an outcome is original and useful in an educational context. Originality is an aspect which is essential in any creative process to ensure that the new idea falls appropriately under the term creativity, otherwise it is a usual, not creative, idea. Thus, all creative processes have to be original (new/novel/unexpected). Creative processes have to be for a purpose. Craft (1999, 2003) links this element of the definition to 'what is appropriate' and 'what is inappropriate' when speaking of the creative product (e.g. a criminal can be creative). The fourth element of the definition, as proposed by NACCCE (1999), is that creativity has to be of value and this component is relevant to culture, education and technology education because it requires a judgment about whether or not an outcome is of value. "Values can be economic, environmental, safety, etc." (Middleton, 2005, p. 69).

Ghosh (2003) adds a narrative view to the effort to define creativity which he relates "principally to human behaviour and the problem-solving ability" (Ghosh, 2003, p. 256). Technologists (Custer, 1999; DeVore, 1987a; DeVore. et al., 1989; Friedman, 2010; Lewis, 2008; Lewis & Zuga, 2005; Williams et al., 2010) agree with this statement because problem-solving is treated in design and technology as an aspect of the design process, which is treated as a creative process. Ghosh (2003) refers to human behaviour because according to Lubart & Georgedottir (2004), "creativity represents an important facet of human behaviour, which is potentially relevant to nearly every domain of activity (e.g. artistic, scientific, economic, religious and everyday life domains)" (p. 24).

Secondly, the problem-solving ability is central because historically, according to Blake and Giannangelo (2012), creativity and problem-solving have been linked in various ways. That:

> problem-solving is creative is obvious to anyone who includes the ability to change one's approach to a problem, to produce ideas that are both relevant and unusual, to see beyond the immediate situation, and redefine the problem or some aspect of it (p. 303).

Thus, the narrative view linking creativity to problem-solving allows the identification of two forms: creative problem-solving (CPS), and technological problem-solving (TPS). These forms are similar but also different in terms of the strategies and processes in identifying, processing and verifying appropriate solutions. CPS and TPS are essential elements for the development of life. They are further explored in Section Two.

3.2.2. A constructed meaning of technological creativity

Terms frequently used with technological creativity are: design, innovation, invention. Are they synonymous? Distinguishing between design, innovation, invention and creativity is important and is another way of understanding what they mean for the process of technological creativity.

Design is an independent field of technology education and it is the element which distinguishes technology education from other fields such as engineering. Design implies engineering, technological and scientific knowledge, skills and experience such as knowing the nature of materials or forms used in designing something useful to solve a particular social or personal problem. Problem-solving is the core of design but design means more than problem-solving as it involves a "whole process of producing a solution from conception to evaluation. This includes elements such as cost, appearance, styling, fashion and manufacture" (Yatt & McCade, 2011, p. 45). Custer and Wright (2002) explained clearly what design is, its activities and the relationship between it and creativity:

> The designed world is a product of human creativity and volition. There are numerous ways that the products and structures that make up the designed or human-built world come into being. These activities are often described using terms such as troubleshooting, research and development,

> innovation, invention, experimentation, and engineering. All of these techniques involve creativity, problem-solving, critical thinking, and decision-making. Commonly these approaches are grouped under a term called design (p. 161).

Thus technological creativity is a product of design. The statement confirms that creativity is seen as a tool or procedure within design. Just as “creativity is a silent process” (Lewis & Zuga, 2005, p. 66), so is design. The aim of the design process is to identify a concept, give it form, structure and function; this is the core of design as a human activity (Clinton & Hokanson, 2012). Design sees creativity as an essential element of the design process referring primarily to the seed idea, whereas design itself is conceived of as the holistic term that encompasses multiple processes, such as interpretation and measurement, imagination and communication, and design judgment. Design is thus seen as having a broader scope than most views of creativity. This way of differentiating between design and creativity is not to say creativity is limited to a particular procedure but it can also have a wide range of designs. In short, technological creativity relates to a design product that is original, imaginative, valuable and appropriate.

There is a definition of creativity that refers to achievements and innovations of the highest order (AbuJarad & Yusof, 2010). Studies which examined creativity have also investigated the related terms, innovation and invention. Hall (2010) presented innovation and invention as metaphorical dimensions of the NACCCE’s definition of creativity. His suggestion is useful for shedding light on definitions of innovation, invention and creativity as all are linked and contribute to technological creativity. To clarify, innovation is about the overall strategy whereas creativity is the first step to innovation. Invention refers to the product being invented or to the small unit of a problem-solving process. Innovation can be described as a general process which “is the introduction of new things, ideas or ways of doing something” and, “is the process of both generating and applying such creative ideas in some specific context” (AbuJarad & Yusof, 2010, p. 308). An invention is something that has been invented, it is one of the outputs of creativity that brings the creative idea into existence. Wu (2005) defined invention as a form of thinking activity which solves problems by making use of the laws of natural science. He views the term invention and its relation to technological creativity as "the breakthrough of technical unit or recombination of a fixed technical unit, which has fulfilled the demands of creativity, solved the bottleneck of technical issues, or carried commercial benefits to a certain goal" (p. 134). Without creativity there is no innovation. Rutland and Barlex (2007) put it this way: "Creativity is one of the basic constituents of innovation…you can have creativity without innovation but you cannot have innovation without creativity" (p. 141). Technological creativity then is the central key for innovation. It is "the first step in innovation, which is the successful implementation of those novel, appropriate ideas" (Amabile, 1997, p. 40). A novel idea is a new/unexpected idea which has not existed or been realized yet.

Clearly, the term creativity is used to reflect a psychological view of creativity at a personal level whereas innovation is used to reflect a business/market view of creativity at an organisational level (Rutland & Barlex, 2007). However, one clear definition of technological creativity was found:

> Technological creativity defined as the means by which individuals apply science to accomplish tasks in faster and better ways and, as a result, improve the overall quality of their lives, plays a crucial role in this ever-expanding age of knowledge (Yeh & Wu, 2006, p. 213).

Wyse and Spendlove (2007) defined it as "a person's capacity to produce new or original ideas, insights, restructurings, inventions, or artistic objects, which are accepted by experts as being of scientific, aesthetic, social, or technological value" (p. 182). Plsek (1996, as cited in Balchin, 2008) defined it as "the ability to use imagination, insight and intellect – as well as feeling and emotion – in order to move a particular set of ideas towards an alternate, previously unexplored state" (p. 32). One of the roles of technology teachers is to put the definition of creativity into operation using technological contexts (e.g. design processes).

Based on the research, creativity is a complex concept that is used in many contexts and is not exclusive to any one domain which makes it difficult to define. It is difficult to limit creativity/the creative process to one approach or theory since creativity cannot be analysed as a deliberate process but is rather a process of mind in making connections between different elements and themes (Demirkan & Hasirci, 2009). Thus, arriving at one in-depth definition, technological creativity can be described as a concept and tool. As concept, it is the first step in the innovation process for producing something original, imaginative, appropriate and of aesthetic, technological, social, environmental, educational and cultural (and religious) value. Both creativity and innovation can be defined as activities that lead to producing an original and valuable product for society. Hence, technological creativity can also be seen as a practical tool that can help to solve technological problems and lead to the adoption of possible solutions. Technological creativity is also a human trait reflected in knowledge and skills, levels (individual/social), types, and stages.

3.3. Section two: Key dimensions of technological creativity

In order to produce a technologically creative product, three major themes were identified through the analysis of studies: domain-knowledge, creative product requirements and stages of creative process. This section focuses on these key dimensions which form the elements of technological creativity.

3.3.1. Creative and technological knowledge

In the debate about domain-general and domain-specific creative knowledge, the findings show that creative knowledge can be of two types: general knowledge of related disciplines (i.e. technology, science, language, mathematics) and specific knowledge which is technological. The knowledge I refer to here has a strong relationship with the human mind and pupils must acquire such knowledge at the elementary school level. Heilman (2011) provided two examples of knowledge – conceptual knowledge and procedural memory.

> For example, knowledge of propositional language includes the ability to speak, understand, read, and write, the ability to calculate using numbers, the use and understanding of directions and routes, and the recognition of peoples' faces. Procedural memories are memories of how to perform a learned skill, such as riding a bike, hitting a golf ball, using a power tool, or operating the controls of an automobile (p. 122).

"Creativity cannot proceed in a knowledge vacuum" (Lewis & Zuga, 2005, p. 75) – it is a fundamental aspect of creativity. Knowledge is necessary "in order to transfer skills learned in one domain to another domain, i.e., you cannot be creative on a violin if you have never seen or played one before" (Saebø et al., 2007, p. 208). Emphasising knowledge and how it has been neglected in technology education, Lewis and Zuga (2005) declared that:

> Beyond cognitive strategies that are known to yield novel products are the concomitant factors that support creativity, notably the importance of domain knowledge, problem posing, and problem restructuring. We have learned from the literature that domain knowledge is fundamental to creative functioning ... And yet, this is an area of the design discourse in technology education that receives almost no attention… while there is a place for the teaching of domain-independent design, where the context is everyday functional knowledge, it is necessary that children be challenged with design problems that reside in particular content domains, such as electronics, manufacturing, or transportation. Children are more likely to arrive at creative solutions when they puzzle over such problems if they are first taught the supporting content knowledge (p. 75).

Other researchers support this idea that it is important for the creative person to have a good basic understanding of the knowledge and way of thinking of the domain (e.g. technology education or any subfields in the domain such as designing) in which the creating takes place. Two types of knowledge are explored: creative knowledge – general and specific, and technological knowledge – conceptual and procedural. The two are important for teaching technological creativity (Bitter-Rijpkema et al., 2008; Christiaans & Venselaar, 2005; Davis, 2011; Demirkan & Hasirci, 2009; Herbert, 2010; Hope, 2010; Howe et al., 2001; Lewis & Zuga, 2005; Middleton, 2005; Saebø et al., 2007).

Creative knowledge is defined by Herbert (2010) as "the object of desire where a person acquires knowledge without knowing how to look at it" (p. 135). She identifies three types of knowledge: imaginary (conscious), symbolic (unconscious), and know-how (physical). According to her, imaginary knowledge is knowledge of the ego. The ego is made up of a large network of energised nerves. Ego creativity is the foundation for conscious creativity. The second type of creative knowledge from a psychological point of view has a symbolic dimension. It is the unconscious knowledge of the subject. The third type of knowledge is the knowledge of the body which is also unconscious. It is also called silent/quiet or *tacit* knowledge as in the domain of technology. It can be observed, for example, "in physical skills such as riding a bike, hitting a hole-in-one or knocking a nail into the wall with a hammer" (Herbert, 2010, p. 2).

Similarly, Middleton (2005) presents three types of knowledge involved in the act of designing (creative knowledge): visual knowledge (producing and using mental images that are in some way isomorphic to objects in reality), verbal knowledge (producing and using abstract propositions (such as in descriptions of processes), and tacit knowledge (can be derived from previous knowledge or physical action). Webster et al's. (2006) findings recognise the importance for both teachers and students of having a theoretical understanding of technology (technological knowledge). Wyse and Spendlove (2007) maintained that for enhancing creativity, teachers should "support domain specific knowledge: pupils need to understand as much as possible about the domain (often subject area) that they are doing the creative work in" (p. 183).

The combination of creative and technological knowledge with their subtypes is recommended to the particular audience of the thesis – Saudi teachers and pupils. Before teaching technological creativity, teachers should have an understanding of the nature of technology and technology education. Developing an awareness of the nature of technology education, its sub-fields and its relationship to science education, is of major relevance to teaching technological creativity. Technological creativity as a topic area is cultivated over time and depends on students having a very good knowledge in the domain. It must be the role of elementary education to start providing appropriate creative knowledge in technology education by introducing children to a range of materials, experiences, possible solutions and ways of working that will sustain them when facing new challenges. Knowledge of materials, elements and mechanisms is required. A teacher's role will be to decide which knowledge would be useful for students and to provide methods for introducing them in a relevant way.

3.3.2. Four creative product requirements: originality, imagination, values and appropriateness

It has been largely agreed in much of the literature that in order to come up with creative products, a number of requirements must be met. These required elements are originality, imagination, value and appropriateness.

Originality relates to something different, not existing before, and is often seen as part of the process of engaging in problem-solving activities. Originality "refers to the tendency to produce unusual solutions to problems" (Ghosh, 2003, p. 256). Fisher (2004) divided the degrees of originality into three levels: individual, social, and universal. **Table 7** presents three levels of the degrees of originality.

Table 7: Degrees of originality

Levels	Degrees of originality	Examples
Individual	Being original in relation to one's previous thoughts, words or deeds	I have not thought of or done this before
Social	Being original in relation to one's social group, community or organization	We have not thought of or done this before
Universal	Being original in terms of all previous known human experience	No-one has thought of or done this before

Source: (Saebø et al., 2007, p. 208).

Originality involves new concepts, useful and related to the solution of specific problems and the re-installation of known patterns of knowledge in a unique form in a given situation. The source of technological creativity, according to the views of many technologists, is described as a process of mind in making connections between varied elements (Hennessey, 2003; Nguyen & Shanks, 2009; Surkova, 2012). Original creative products are also seen to have an imaginative aspect. Imagination is a feature of the creative activity. It "involves the generation and harvesting of novel ideas and associations between them" (Nguyen & Shanks, 2009, p. 657). DeVore. et al. (1989) related this feature (or strategy) to the "mind" rather than the "brain":

> …because the mind is something that is a holistic blending of logic and emotion. The brain, however, has physical mass and is composed of matter in the form of chemicals, cells, water, and so on. The mind cannot be seen or measured. The brain, on the other hand, is a physical thing, that can be seen by using X-raying techniques (p. 22).

The mind is responsible for the imaginative process. Imagination then is the ability to generate ideas and possibilities, to create new ones which may be but are not necessarily based on previous experiences – creative ideas can be purely new. Roseman and Gero (1993) reject this view and argue that "it is not possible to initiate a creative process from nothing." They insist that "any new structure must be produced from some starting points or foundation" (p. 122). Here I would like to link the discussion with the concept of mind-storming (or brainstorming). Researchers classify this as a technique for enhancing creative thinking. It gives the individual the opportunity to think free from any pressure or negative effects. The aim of mind-storming is to detect hidden creativity and to uncover a creative solution to the problem. Imagination is also considered a learned skill or mental exercise which can be enhanced through schooling:

> The skills or mental exercises developed by educators to improve Type B creative abilities include brainstorming, visualization, and imagination, thought experiments, examination of opposites, mind mapping, lateral thinking, problem reversals, questioning, imitation, metaphorical thinking, assumption smashing, fuzzy thinking, forced relationships, synaptic ideations, and storyboarding … these tools help us understand and improve our Type B creativity and can be useful in the classroom (Gow, 2000, p. 32).

Mind-storming can also be viewed as a general tool based on real world knowledge used by humans to reflect on situations that are beyond their experience (Kind & Kind, 2007). This emphasises the need to restructure or create new habits of mind – up-to-date habits of mind (Perkins, Jay, & Tishman, 1993; Williams, 2011). A habit of mind is something natural to the person and it develops as he/she grows. "As the mind moves in thought from one moment to the next, it is channeled by habit. This becomes especially true as we grow older. These habits of mind determine how we choose among many possibilities" (Gow, 2000, p. 32). These habits of minds lead the person to act or behave in a certain way. According to Gow (2000), Perkins et al. (1993), and Williams (2011), these habits concern human mental processes which affect the activity of the creative mind. Dispositions are the teachable theories associated with good thinking skills. Perkins et al. (1993) and Williams (2011) described a disposition as a psychological element and they agree upon two components: inclination and ability. "Inclination is the person's tendency toward a certain behavior … Ability refers to the capability to engage with the disposition" (Williams, 2011, p. 90). An example of inclination is: "a person with an inclination toward critique will tend to be critical when confronted with a situation in which he or she can respond in that way" (Williams, 2011, p. 90). Examples of ability are:

(1) "A person with the ability to be open-minded knows how to go about it: resisting the impulse to decide quickly, listening to evidence for rival points of view, and so on" (Perkins et al., 1993, p. 4).
(2) Or "a person with the ability to critique will know how to question with purpose, isolate elements, and perceive patterns and consequences" (Williams, 2011, p. 90).

Perkins et al. (1993) also identify the factor of sensitivity. For example, "a person sensitive to the need for open-minded thinking will notice occasions where narrow thinking, prejudice and bias are likely and open-mindedness called for" (p. 4). This component of the dispositional theory of thinking is discussed under the mental and psychological traits of the creative person sub-section. The imaginative aspect of technological creativity lies behind making connections between previously unconnected ideas. In order for a person to be imaginative, he/she must be aware of the unconventionality of his/her actions. In addition, other researchers believe that it is possible to initiate a creative process from nothing using the imagination, which calls for a person skilled in divergent thinking. Technological creativity, as defined previously, can produce an imaginative, novel (original/new/unexpected), useful and appropriate idea.

Imagination and originality, however, require divergent thinking skills whereas for usefulness and appropriateness there is the need for convergent thinking skills and knowledge of the domain. Both types of thinking are creative. In fact, divergent thinking skills are needed for extraordinary types of creativity whereas convergent thinking usually concerns ordinary creativity so the emphasis falls on the first type of thinking which is divergent (viewing creative thinking as an open-minded activity). Varied forms of creative thinking have been identified; these include divergent thinking (multiple ideas in response to a given proposition), problem identification, and evaluative thinking (judging the value of an idea) (Clinton & Hokanson, 2012; Plucker & Renzulli, 1999). Divergence is a characteristic of creativity. Lewis (2008) categorised Guildford's 16 divergent production factors into four main categories:

1. Fluency (the ability to produce a number of ideas).
2. Originality (the ability to produce unusual ideas).
3. Flexibility (production of a variety of ideas).
4. Elaboration (the ability to establish ideas) (p. 263).

The difference between divergent and convergent thinking is that in teaching technological creativity, the focus should be on enhancing divergent thinking skills in students because these have more to do with originality/novelty and imagination (Williams et al., 2010). Figure 8 shows creative thinking skills with a bit more clarification in relation to teaching and learning.

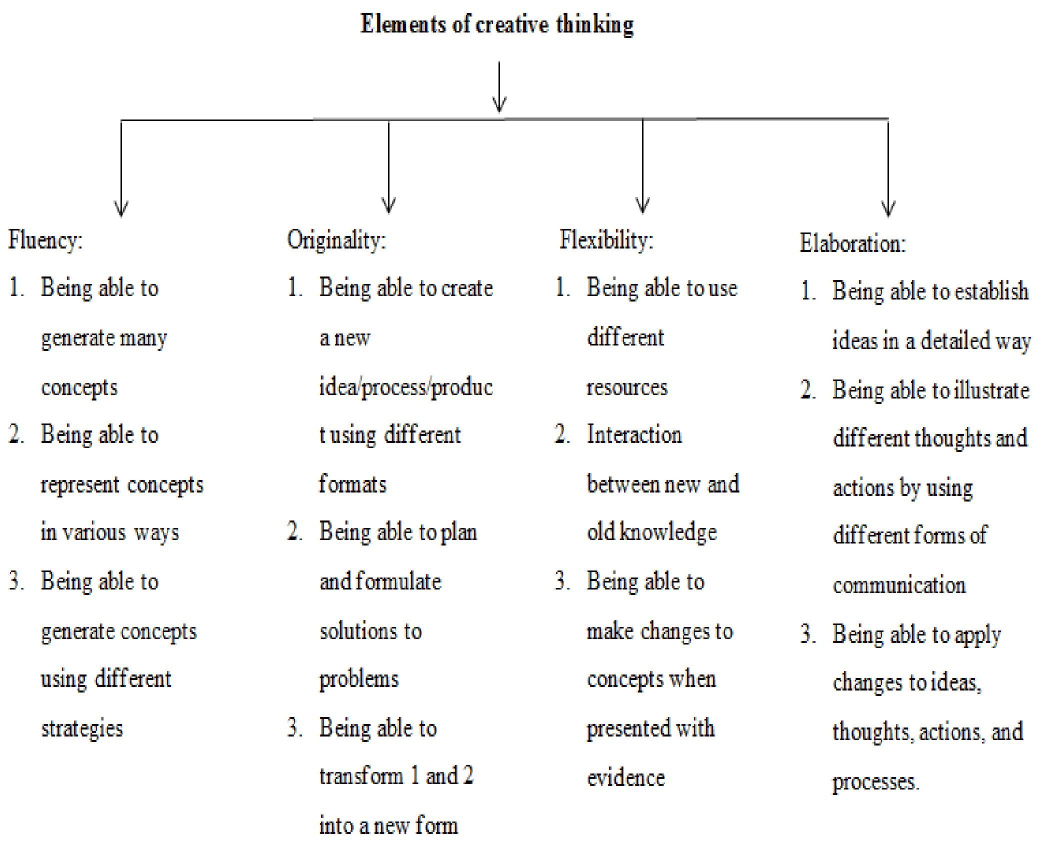

Figure 8. Elements of creative thinking.

In evaluating any creative product, these elements of creative thinking are usually found. Flexibility refers to stored information which is rearranged to look at issues from several angles. Fluency has to do with prolific production and the rapid generation of units of information, using words consistent with the question *what*. Originality refers to an exclusive idea. It is not intended that the concept have no connection with familiar ones but the person presents it in a new way or arrives at the theory of organised ideas. Originality in the end is part of the creative personality. Intellectuals who are characterized by authenticity are more open-minded, mentally and emotionally. To these three elements of creative thinking, some psychologists add other elements such as interest (the new thing can be useful to the community) and social acceptance, i.e., the idea accords with the values of society.

Creativity in general has been linked to gifted people in the first order (Hennessey, 2004). Two types are identified: people with high creative capabilities and people with high intelligence. The characteristic that distinguishes the two types is that the first has the ability to direct his/her thinking in several directions and the results might clash with social norms and values and its regulations. This type is difficult to deal with in a familiar institution or organisation. People of this type are rare. By contrast, the second type differs from the first in that his thinking can be influenced and organised to accord with social rules and a curriculum or school. Examples of this second type are intelligent students who get high grades and succeed in their studies. Both these types can display technological creativity but both also are subject to the motivational element/orientation.

Value is an important characteristic which has the same importance to technological creativity as to originality and imagination. The creative product is evaluated in terms of its value(s). The product should be of social, educational, economic and/or environmental value. This is a generality concerning all creative products but the role of value in an educational context operates in two ways: the value of the final outcome/product together with the effectiveness of the creative process, and the educational value of the process and product (Howe et al., 2001). These modes of assigning value will be influenced by the beliefs held by teachers and pupils in a particular community. For example, in Saudi Arabia Islamic values must be referred to in every aspect of people's lives. These values have various levels of acceptance. Different groups and communities may hold a range of different belief systems where they can clarify and develop their unique values and beliefs: groups and communities might not have the same level of values and beliefs in Islam. Examples of values that are common in any society are human nature, social problems, religions, environmental issues, the economy and the relationship between them. Hence, the creative product should be of one or more of these values because products in general must be accepted by the cultural and social norms that lie at the root of that society. This leads to identifying the concept of appropriateness as it relates a cultural and ethical event to technological creativity. This consideration is examined further in Section Four.

3.3.3. Elements of technological creativity

*3.3.3.1. **Creative personality and environment***

Herbert (2010) argues that most creativity research currently carried out by cognitive psychologists focuses on the motivational, personal and psychopathological factors of the creative process. Major noteworthy themes generated in the literature are: motivation, the creative climate (psychological climate – encouragement), and personal factors and conditions.

> Most – if not all – people have a personal experience of being creative or experiencing something that is perceived as being creative. Hence, creativity is, at least in a limited way, a personal concept that reflects past experiences. Knowledge, familiarity, ideas, values, practice and attitudes (Williams et al., 2010, p. 2).

The personal aspect of creativity is of major importance. Thus, the personal dimension needs to be identified, as do some of the specifications for personal creativity. A meta-analysis of the personal dimension of creativity was carried out by Feist (1998) which led him to conclude:

> Empirical research over the past 45 years makes a rather convincing case that creative people behave consistently over time and situations and in ways that distinguish them from others. It is safe to say that in general the creative personality does exist and personality dispositions do regularly and predictably relate to the creative environment (Herbert, 2010, p. 79).

Personality characterised by technological creativity is associated with aspects such as risk taking, originality, playfulness, sensitivity, and a preference for complexity. All are cited in the research. In addition, the character traits of self-confidence, effectiveness, self-promotion, self-control and intrinsic motivation, are all necessary for technological creativity. A broad example is given by Vidal (2007) who identified three types of creative personality in terms of the person him/her-self (subject) and the product (object).

(1) The creative person is a problem solver (subject) who tries to solve a problem (object) in a creative way (e.g. computer scientists, engineers, mangers, advisors).
(2) Second, the creative person is an artistic individual who creates a new piece of art in close interaction between the person and creative environment.
(3) Third, the creative person adopts creativity as a lifestyle "being creative at work, at home and everywhere" (e.g. inventors, artists, mode designers) (p. 411).

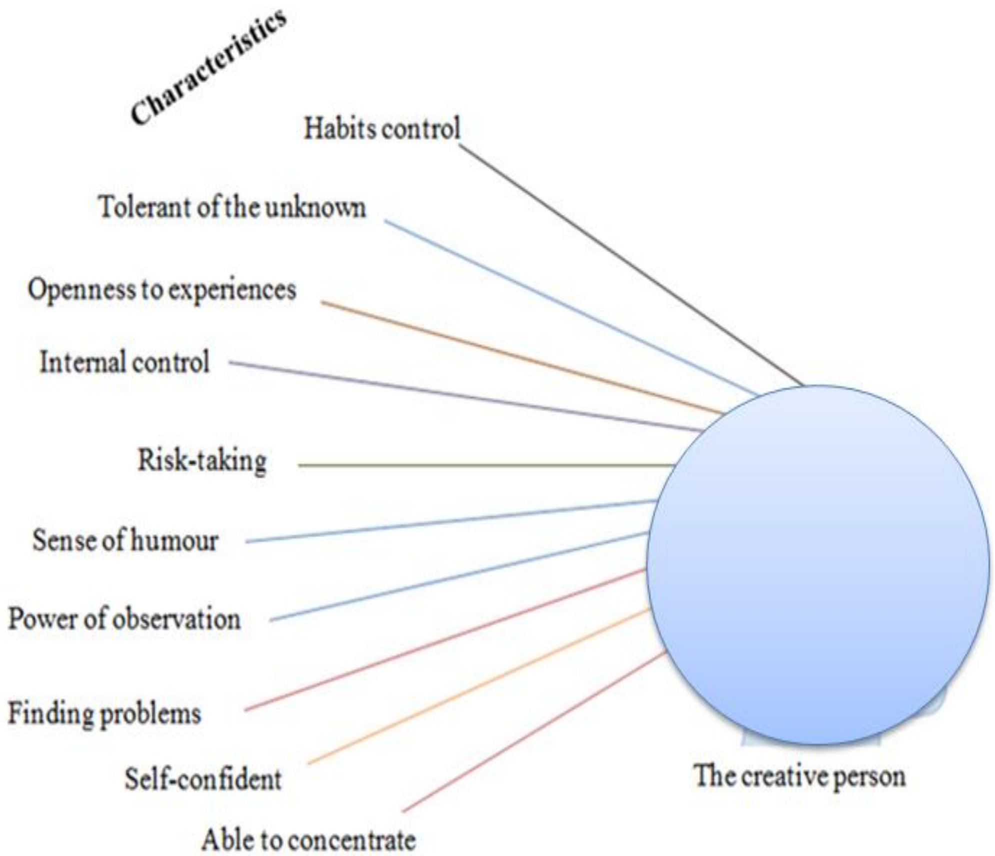

Figure 9. Characteristics of the creative person.

Source: (DeVore, 1987a; DeVore. et al., 1989).

There is no single specification for creativity but anyone can develop the ability to be creative because he/she can make a conscious effort to think and act differently (DeVore. et al., 1989). Further, the authors discussed different characteristics of the creative person and suggested that such personalities involve high intelligence in (a) putting different ideas together and recognising their value, (b) having divergent and convergent thinking skills. These skills and the balance between them have been a major obstacle in the creative design process. In an educational context, Amabile (1996) treated motivation and the social environment as the two main elements responsible for the success or failure of the creative activity (or process).

Two main traits were identified: mental traits and psychological traits. It was mentioned previously that the basis of technological creativity depends on creative thinking – divergent and convergent thinking. Researchers place the emphasis on divergent over convergent thinking since the first produces various solutions to a problem whereas the second has only to come up with a particular solution to an identified problem. Nevertheless, both are still important to consider when teaching creativity.

Mental and psychological traits

Intelligence: The link between creativity and intelligence is strong – they have similarities and differences. If intelligence is treated as part of the creative process, then it is different from creativity because the latter is a more specific concept than that of intelligence. This means it is not necessary for the creative person to have a high degree of intelligence. The converse is also true. The highly intelligent person is not necessarily creative. It seems that when intelligence plays a minor role in the creative process, other traits of the creative person intervene decisively. IQ is a requirement for technological creativity (DeVore. et al., 1989), there must be a minimal acceptance for technological creativity and if this condition is met, creativity then relies on other factors, mental and psychological. It should be noted that there is a minimal difference in intelligence between technological creativity and other fields of creativity (e.g. scientific, linguistic, artistic etc.). For instance, it was observed that the degree of intelligence required for technological creativity, e.g., inventing devices, is relatively lower compared to the desired degree in science (e.g., physics). Similarly, the degree of intelligence required in literary creativity is relatively higher than in domains like drawing, science or technology.

Sensitivity to problems: The creative person shows sensitivity to the presence of a thought-provoking problem requiring a solution. For example, as Herbert (2010) noted in relation to scientific creativity, asking questions is one of the methodologies that is important to creativity. Not all people may have this trait and some might find it easy whereas others might find it difficult. Sensitivity might depend on other factors as well such as motivation, thinking and the interests of the creative person.

Deploying divergent thinking: An individual’s ability to direct newly identified concepts in more than one direction at the same time (e.g., having the ability to think divergently) which becomes more difficult with the increased number of elements that the mind must deal with while engaged in the thinking process.

The ability for evaluating identified concepts: Ideas should be relevant to the problems identified so the creative person must evaluate unrelated ideas to ensure that attention is paid only to suitable ideas. For example, the degree of control should not negatively affect the basic elements of creative thinking (fluency, flexibility, originality and elaboration) because if the degree of control is extensive, this can prevent an individual from interacting with authentic elements. Evaluation is responsible for the emergence of mind-storming in that it allows training technological creativity.

Psychological traits: The psychological traits of the creative person are self-reliance, confidence, isolation, sensitivity, independent thinking, psychological insights, and the weakness of the superego (i.e., belonging to the community). In contrast with doing and making following a plan or specific set of procedures, the creative person usually acts in a sudden manner where he/she has no commitments to social norms, ethics, or values (especially in relation to creativity in other domains such as the arts). In technology education, the creative environment (or *press*) is a holistic support system that enhances the physical and psychological environments. Both are important to the process of technological creativity. The physical environment refers to the provision of materials, tools, textbooks, and classroom equipment to support physical environment. The psychological environment comprises support from friends, teachers, colleagues, the administration or management of a school to support the psychological environment of creative students. Thus the psychological environment here differs from motivation. Even motivation is psychologically constructed but the encouragement pupils receive from their teachers and families can lead to creative potential. The creative environment is discussed in Section Three, *Pedagogy of technological creativity,* because it has to do mainly with classroom equipment, the amount of space, decoration, and providing materials so pupils can work more independently.

3.3.3.2. ***The creative process***

Technological creativity has been introduced in the form of creative processes of design (Barlex, 2007, June; Christiaans & Venselaar, 2005; Clinton & Hokanson, 2012; Webster et al., 2006). Design explains the nature of the technical function (of technology, designing) and presents some strategies which enhance the creative abilities of students. Design might seem to be the same as creativity because:

> …design is the first step in the making of a product or system. Without design, the product or system cannot be made effectively” ... From a design perspective … creativity is a sub-component of the process of design, referring primarily to the seed idea, whereas design is conceived of as the holistic term that encompasses multiple processes, such as interpretation and measurement, imagination and communication, and design judgement (Warner, 2002, p. 116).

Research describes design as the creative process which is at the heart of technology education (Williams et al., 2010). It is described as “the task of creating the form of something unknown, the ability to imagine, to see in the mind’s eye” (Rutland & Spendlove, 2006, p. 143). The creative designing activity “involves pupils carrying out a range of activities to being ideas from the mind’s eye into reality in response to peoples’ needs and wants” (Rutland & Spendlove, 2006, p. 144). Technology researchers have produced a variety of models of the creative process. For example, DeVore. et al. (1989) suggested six main stages of the creative process:

1. Motivation (the creative person is motivated and interested in creating something),
2. Preparation (a time for setting the action plan, collecting tools, materials, sources),
3. Manipulation (new ideas are generated and this stage includes three strategies: mind-storming, sketch-storming and model-storming),
4. Incubation (allowing the subconscious to illuminate elements and direct the mind to a possible solution),
5. Illumination (this stage depends on other stages of the creative process and may require the person to revisit the manipulation stage to search for an appropriate solution), and
6. Verification (the new ideas created are put into practice).

Wallas (1926, cited in Mesquita, 2011) presented five stages:

1. Preparation,
2. Incubation,
3. Intimation ("the creative person gets a "feeling" that a solution is on its way" (Mesquita, 2011, p. xvii) ,
4. Illumination and
5. Verification.

Basadur et al. (1982, cited in Mesquita, 2011) "proposed a three-stage model comprising problem finding, problem-solving (generating as many ideas as possible) and solution implementation" (p. xvii). Amabile (1983) suggested a five-stage model:

- The problem (task presentation),
- Preparation (the creative person reactive a data),
- Generation,
- Validation (verified the new ideas),
- The assessment of the outcome (Mesquita, 2011, p. xvii).

Hill (1998) identifies four stages of creativity in the design process: (a) preparation (identify and understand the problem and produce solutions); (b) incubation (the periods for allowing subconscious thought); (c) illumination (the emergence of the idea); and (d) verification (testing the idea and forming a workable solution). In addition, Shneiderman (2000, as cited in Nguyen & Shanks, 2009) provided three different views of the creative process:

- Inspirationalist (the steps of problem understanding – “Aha!” moment),
- Structuralist (problem-solving strategies and selection of alternative solutions as well as generating and evaluating the ideas), and
- Situationalist (incorporating the communication of the creative ideas within teams; this emphasises “the role of the human and social environment and professional domains in the creative collaborative process”(pp. 657-658).

In their discussion of creativity and the design process, Williams et al. (2010) suggest differentiating between people who view the design process as a descriptive, linear model and those who describe the design process as an integrative system through which problems and solutions, sub-problems and sub-solutions co-evolve. Examples are Atkins et al. (2008) and Demirkan & Hasirci (2009). However, when making this distinction, Williams et al. (2010) explain the reason for viewing design processes in relation to creativity as associated with the distinction between routine and non-routine design processes. These can be applied to both the design process and design product. Table **8** clarifies the difference between them in light of Williams et al.’s way of dividing the creative design processes.

Table 8. Types of creative process in designing

Type of design process	Characteristics
Routine design processes	- They are not considered different from previously produced designs in their class in any substantive way - Proceed within a well-defined space where all the design variables and their possible range are known and the problem is one of instantiation - Are predictable - Evolve through pre-defined stages in a linear fashion
Non-routine design processes	- They are recognized as being different from previously produced designs in their class in some substantive sense - Their nature is ill-defined. At least one function, structure or mapping will be unknown at the start of the design project - The ill-defined nature of this type of design process (stability and monotonicity are problematic) can be overcome by introducing new elements, operators, requirements, structures, and potential solutions throughout the process - A division is made into innovative and creative design processes:

	Innovative	Creative
	- **Results in products/processes that display solutions that were not previously known…due to change in the values of existing design variables** - **Involves generation of new/alternative subtypes**	- May incorporate innovative design but it involves a substantial difference … due to the introduction of at least one new design variable - Generates entirely new types

Source: (Roseman & Gero, 1993; Williams et al., 2010).

Roseman and Gero (1993) argue that creative processes cannot be purely new, as discussed; they must be produced from a starting foundation (*starting points*). Their two approaches to defining the creative process are:

1. To start from existing elements and create new ones; and
2. Configure new elements from basic building blocks.

Williams et al. (2010) maintained that Roseman and Gero (1993) approaches are not directly linked to creativity but "are different methodologies used to support the designer in the development of the creative products" (p. 16). Webster et al. (2006) identify four phases in the creative process: preparation, incubation, illumination and insight. "To come up with an idea, and to give form, structure and function to that idea, is at the core of design as a human activity" (Nelson and Stolterman, 2003, p. 1, as cited in Clinton & Hokanson, 2012, p. 116). Processes are engaged to explore technological knowledge (e.g., procedural and conceptual knowledge) from an integrated theory and practice perspective. The reason for linking the discussion to technology processes is because they bear some resemblance to the stages of creativity (Clinton & Hokanson, 2012). Hence based on the above literature, five key strategies that construct the process of technological creativity were identified: motivation, manipulation, incubation, illumination and verification. These five strategies are considered responsible for the complexity of the creative process in technology education. While these strategies have been demonstrated in literature for many years, they are represented here in a coherent order and in a new form looking at the overall process of technological creativity as a *voltage source*.

Motivation is “to work on something because it is interesting, involving, exciting, satisfying, or personally challenging” (Amabile, 1997, p. 39). It plays an essential part in the creative process and the success or failure of the process depends on the motivational energy of the person. According to Hennessey (2004), for creative people it is not enough to have a deep conceptual understanding or high levels of skill. She claimed that if individuals are learning to reach their creative potential, “they must approach a task with intrinsic motivation - they must engage in that task for the sheer pleasure and enjoyment of the activity itself rather than for some external goal” (p. 201).

There are two types of motivation: intrinsic (internal) motivation and extrinsic (external) motivation. The first type is the motivation to do something for the task itself partly for enjoyment where a person feels free of external control. According to Amabile (1997), the three components of intrinsic motivation are: a sense of competence, mastery and a sense of control. Intrinsic motivation is an internally controlled, highly individualised process. It is found when the person gets the sense that he/she is playing rather than working. This feeling assists the creative person to engage or express him/herself in the creative activity.

In contrast, extrinsic motivation is externally controlled. Much of the literature focuses on intrinsic motivation because it is more closely associated with the creative process. The person should feel free and have his/her own interests to link to the creative task. Figure **10** represents the role that motivation plays in the creative process. The diagram shows that the creative process depends on the motivation of the person. If he/she is motivated and interested in creating something, then other elements in the creative process are valid. On the other hand, if he/she is not sufficiently motivated or interested in designing and making something, then the creative process is not valid because motivation is not at work. A simple way of describing the role of motivation, as this thesis proposes, is through seeing technological creativity as a voltage source.

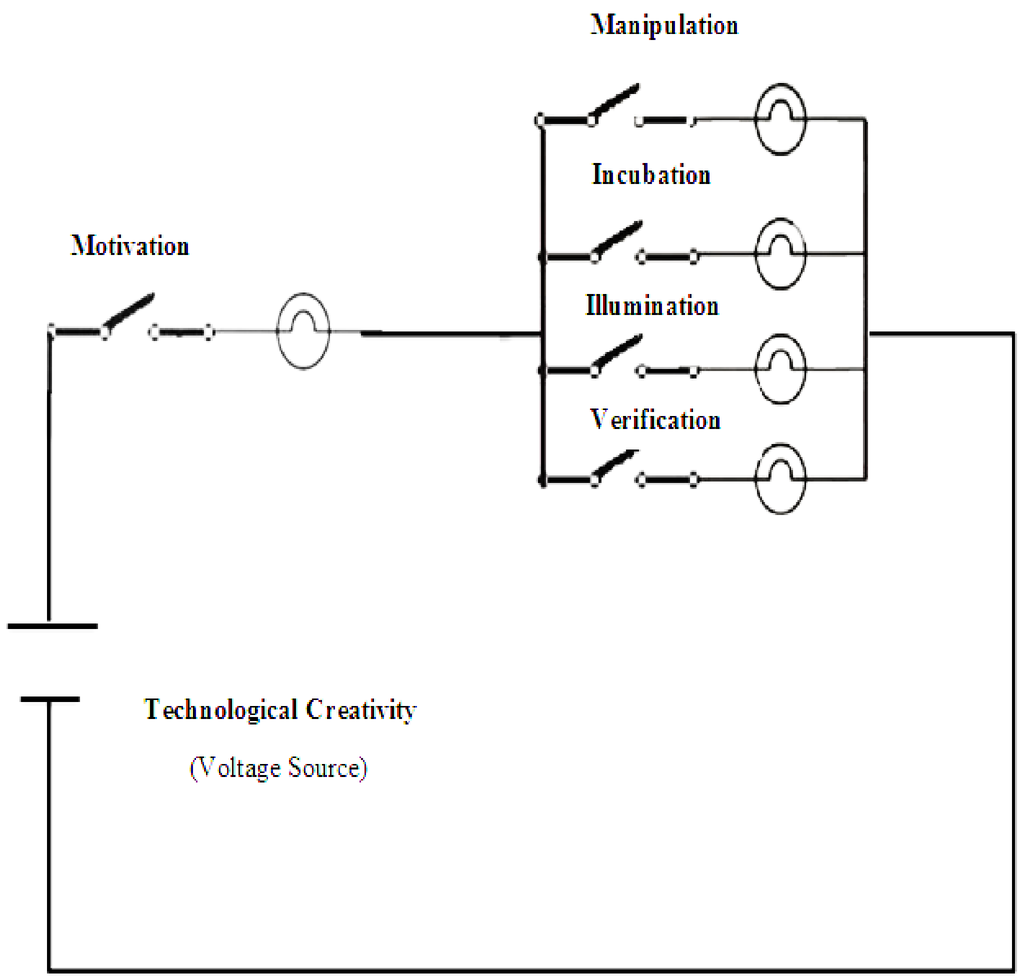

Figure 10. The role of motivation in the creative process.

The diagram represents technological creativity as a voltage source which consists of one necessary open gate, motivation, which is essential for allowing the creative process to happen. If motivation is at work, the creative person can easily proceed to what he/she planned to create. The person may have a general concept about making or designing something but is not motivated enough to start creating. The motivated person may already have something in mind, for example solving a personal or social problem. The various theoretical perspectives on motivation confirm that the creative person must want to do something or create something new based on previous experiences or knowledge (Roseman & Gero, 1993). He may create something purely new; this possibility is not accessible to every person but to some who are more motivated or have a great desire since "desire is the energy source that powers the creative process" (DeVore. et al., 1989, p. 5) to produce something new. However, given this emphasis on motivation indicated in the diagram, the person can then go through the stages of the creative process – manipulation, incubation, illumination and verification – explored previously from research. These are the four key strategies for technological creativity. These provide a general understanding of the role of motivation in technological creativity processes. This discussion reflects the importance of intrinsic over extrinsic motivation because intrinsic motivation is pressure free, giving the person space and time to link his/her thought to the task.

Lessons learned from social psychologists (Amabile, 1997; Hennessey, 2003, 2004; Hennessey & Amabile, 1998, 2010) indicate that both intrinsic and extrinsic motivations are strongly affected by the organisational environment, and by social and cultural events. This means that if the creative person is still interested in creating something for its own sake, there are still external (extrinsic) factors influencing the intrinsic motivation of the creative person positively as well as negatively. Hennessey (2003) refers to the differences in the way researchers view the role of motivation in creativity, adopting different cognitive explanations.

A common and effective cognitive explanation of the role intrinsic motivation plays in the creative process was identified from a number of studies specifically relevant to pupils at the elementary school age. The cognitive explanation shed light on the situation where, prior to doing classroom tasks, pupils were introduced to those tasks as work or as fun activities. Recent empirical research on motivating pupils learning technology at the elementary school level provides a true, clear explanation of the influence of intrinsic motivation and how pupils have effectively contributed to the technological task. “The children were very interested and perceived engaging in the task as being ‘fun’ with 33 comments in 30 booklets” (Campbell & Jane, 2012, p. 8). This relates to the discussion about the levels of creativity: individual or social (group). While there are convincing arguments about whether creativity is the result of individual or social actions, a number of papers confirm that creativity cannot be the result of individual actions alone. This indicates that social and cultural events must be included with the psychological aspect which sees creativity mainly as a process of mind alone.

Creative Problem-Solving (CPS) and Technological Problem-solving (TPS)

As previously noted, Ghosh (2003) proposes that creativity relates principally to problem-solving abilities. Middleton (2005) provided a rationale for the importance of a problem-solving approach in design and technology education and observed that:

> designing is a particular form of problem-solving where it is possible to both explain some of the processes by which successful designing occurs, and to draw on these processes to suggest strategies design and technology teachers may employ to assist their students' creative thinking" (p. 65).

One of the ways to study creativity is through solving real life problems (Barak, 2007; Hill, 1998; Lewis, 2008). In the technology context, Hill (1998) argues that technological problem-solving must be set in the context of 'real-world' problems and 'real' human needs. In her discussion about the place of authenticity in technology education, Fox-Turnbull (2003) declares that teachers of technology should link taught topics to children's real life experiences. She clarified what she means by 'real' life experiences and discusses levels of what real problems students should learn at school:

> ...real to the students may be real to their own lives, or real to situations that they may encounter in the future workplace. The second level is real to technological practice, reflecting the practice of practitioners as much as it is practicable in the classroom situation (p. 2).

First, it is of major relevance in understanding CPS processes to demonstrate human problem-solving theories developed in psychology. The Elsevier article "Roeckelein (2006) discusses theories of human creative problem-solving processes. Table **9** summarises these theorists' views of creative problem-solving processes.

Table 9. Human problem-solving and creativity stage theories

Theorists	Problem-solving process
Allen Newell (1927-1992) and Herbert Alexander Simon (1916-2001)	- The fundamental characteristics of the information processing system - The problem space - The structure of the task environment - The nature of the problem-solving process Characteristics: the heuristic value of this theory is relevant to theories of learning, perception, and concept formation.

Karl Duncker (1903-1940) Duncker was the first person to propose the notion of functional fixity/fixedness in problem-solving (e.g. the inability to find the solution to a new problem because one attempts to use old methods that are not suitable in the new situation)	- The establishment of the general range of the problem and its possible solutions - Functional solutions - Specific solutions Characteristics: 1. The mental process involved in creative thinking leads to a new solution, invention, or synthesis in a given area dealing with a particular problem; 2. Creative solutions typically employ preexisting objects and/or ideas, but uniquely create new relationships between the elements used, such as new social techniques, mechanical inventions, scientific theories, or artistic creations.
Graham Wallas (1858-1932)	Proposed that the following four stages comprise the successive phases/operations that may be observed in the general process of problem-solving including creative thinking: - Preparation: setting the appropriate mental conditions for solving a particular problem (e.g., mastering the techniques of one's art/skill and includes all the random and direct/formal educational exposures that the person has experienced. Preparation for the scientist in problem-solving seems to be a more deliberate process than it is for the artist or poet); - Incubation: characterized by creative thinking while the problem is turned over in one's mind; - Illumination/inspiration/insight: the process of understanding the meaning and significance of a pattern or the overall solution to a problem (via aha or eureka revelatory experience or feeling); and - Verification: this phase is characterized by hard work wherein the individual attempts to "materialize" all that has occurred previously in the unseen thought processes. Thus, the "creative act" is a combination of knowledge, imagination, timing, and evaluation.
John Dewey (1859-1952)	- Suggestion: set of propositions/definitions concerning the particular issue at hand; - Translation: transforming any difficulties into "well-defined problems" where the starting position or initial state, the permissible operations, and the goal/end state are specified precisely and clearly; - Framing of a hypothesis: specification of potential cause-effect relationships within the framework or domain of the

	issue/problem at hand; - Reasoning: application of formal rules of logic or some other rationality-based methodology to the proposition, such as deductive or inductive reasoning); and - Testing: submission of the resultant reasoned/stated hypothesis to formal test and assessment conditions and devices.

Source: (Roeckelein, 2006).

A major approach technologists have been focusing on for nearly forty years is problem-solving, particularly with respect to teaching design. Technological creativity focuses on technological problems, but what technological problems do pupils need to learn? Custer (1999) argued that a distinction in problem-solving must be made in relation to different academic disciplines because problem-solving can assume a number of very different forms. Technological creativity focuses on solving technological problems and technologists stress the significance of teaching creativity for solving technological problems as these are the key elements to teaching technological creativity.

Custer (1999) categorized problems in general, according to the goal (or motivation) of a particular activity, into three classifications: social/interpersonal problems, natural ecological problems, and technological problems. Technological problems are derived from various contexts which can involve social, environmental, mathematical, scientific and/or technical aspects. Technological problems are different than, for example, scientific and mathematic problems in that technological problem-solving often involves social norms and values. The problems do not necessarily arise from considering the individual/society's needs but originate with inventors and engineers pursuing a technical possibility rather than in response to a request by people (Barak, 2007).

Custer (1999) identified four major categories of technological problems that should be part of the technological literacy of all students: invention, design, trouble-shooting, and procedures. These categories of technological problems and examples indicate what Saudi pupils should acquire at the elementary level because they can expand pupils' perceptions and understanding of what technology and design are, involving them in acquiring knowledge and skills and teaching them something about what kinds of technological problems they should learn. I believe these can be seen as starting points for them to learn about technological creativity. Table 10 indicates these four categories with illustrative examples.

Table 10. Examples of basic technological problems.

Category	Description	Examples
1. **Invention**	- Occurs when abstract ideas are transformed into physical objects or processes. - Processes/objects that exist in the imagination of creative people.	- First electric light bulb (Edison) - The moving assembly line (Gifford) - Interchangeable parts - Wheel
2. **Design**	- Using sets of established principles and practices within certain constraints to accomplish an intended purpose.	- When architects design buildings - Everything people experience and use in the man-made world represents a product at some level of design
Design professionals include engineers, interior designers, architects etc.		
3. **Trouble shooting**	- Occurs when things go wrong - Must be done to locate the cause and fix the problem	When : - A lamp fails to light - A door sticks or squeaks - TV reception is poor - A virus invades a computer
4. **Procedures**	- Have to do with planning or following instructions - Occurs when technicians and fabricators make planning decisions about the order of action	- Cutting - Drilling - Assembling - Installing - Printing …etc.

Source: (Custer, 1999, pp. 27-28).

Hill (1998) argued that a problem-solving approach is "a demarcation from what is typically found in schools; [the aim is to] design, make and appraise cycles based on closed design briefs that are teacher assigned and unrelated to the students' world" (p. 203). The problem-solving process is an appropriate option to link creativity to technology education. Lewis (2008) identified two approaches of problem-solving within design:

(a) An approach in which students are presented with an open ended problem that requires them to ideate such that multiple possible solutions emerge. These solutions are evaluated and a product is realised based on the chosen solution strategy; and
(b) An engineering design approach which is taught in terms of tacit knowledge and trial and error, and more in terms of analysis and prediction (p. 257).

Lewis (2008) argued that problem-solving processes along with divergent thinking, a combination of both, metaphorical thinking, and analogical thinking processes are among the pedagogical strategies that seem to stimulate the inventive urges of students at the elementary level. However, there seems to be agreement in the literature that problem-solving and divergent thinking processes are well suited when teaching technological creativity because both support the production of original ideas where it is possible to be open-minded about other possible solutions.

The findings of research literature critiqued in Section One and this section confirm that technological creativity can be taught. In the next final section, a proposed new context is developed for the intended audience with a new form of interpretation.

3.4. Section three: Pedagogy of technological creativity

> … to reflect our technological world, with a strong focus on design, ranging over domains such as power and energy, construction, manufacturing, bio-technology, and communication technologies…the basic potential of the subject to help students uncover talents not touched by other subjects remains an enduring goal. Increasingly the potential of the subject for simulating creativity in children is being explored (Lewis, 2008, p. 256).

This quotation captures the core need for enhancing and fostering creativity in specific contexts or domains (e.g. technology education, design in particular), a position supported by DeVore. et al. (1989), Howe et al. (2001) , Lewis (2000, 2008), Barlex (2007, June, 2011), Benson and Lunt (2011), Hill (1998), Rutland

and Barlex (2007) and Wyse and Spendlove (2007) , to name a few. In education, Craft (2001) clearly demonstrated this view when she noted that:

> …[after 1950] there followed a large amount of research which attempted to test and measure creativity, to pin down its characteristics and to foster it through specific teaching approaches (p. 6).

Lewis (2000, 2008) argued that technology (design) as a context for creativity is an important area of research as it has been developed as a construct in technology education which aims at developing students' technological literacy. Through creativity students can learn the creative knowledge and skills needed in design and technology education which will positively influence pupils' learning. The exploration of an appropriate technology context for the pedagogy of technological creativity based on related technology literature and research constitutes the main rationale for this thesis and will answer the research questions. The following sub-sections provide an appropriate conceptual framework for the question, *how can technological creativity be taught in the Saudi Arabian elementary school context?*

3.4.1. Creativity and technology education in the elementary context of the developed world

In the general curriculum documents of many developed countries, creativity has been recognised and its place in education identified, as shown in

Table 11. **Table 12** indicates the many different forms of technology education in the educational system of 19 developed countries. Illustration of both technology education and creativity are very significant for the educational policy-making committee in Saudi Arabia. A variety of methods was used to develop both tables. For **Table 12**, the data used were based on Williams (1996a) study exploring international approaches to technology education. Then a number of other studies were studied to provide an up-to-date view of the various forms of technology education from a number of developed countries. Neither table provides an exhaustive view but rather each serves to support the main argument of this thesis.

Knowing how technology education been integrated into these countries' curriculum is essential because in the history of Saudi Arabian education, even though technology education has taken the form of vocational and technical education in higher secondary schools and in technical institutions after the secondary school level, technology education has not been recognised or considered at the elementary school level. By taking advantage of these different approaches to technology education in different forms and made up of different elements, Saudi Arabia can learn from these countries' history and experience of teaching technology education. At the same time, Saudi Arabians can develop their own technology education linked to and aligned with Saudi Arabian social, cultural, and religious needs. Technology education, so to say, is a flexible subject that has many learning areas and sub-areas, each of which can contribute to pupils' learning. Making technology education a compulsory subject in Saudi Arabia is an urgent need if the country is really willing to assist its people, not only pupils at school but at all educational levels, including extra-mural adult students.

Table 11: Creativity in general curriculum documents of some developed countries.

Country	Learning goals and creativity
USA	The goals of restructuring the schools are to provide students opportunities to learn and apply strategies for creative thinking.
Canada	Creativity outlined as creative thinking; the learning goal is to enable students to use creative thinking skills to develop or invent novel, constructive ideas or products. The national curriculum defines an educated person as healthy, independent, creative and moral.
UK	Three major developments in the place of creativity in the elementary school curriculum in the UK have been established: • The National Advisory Committee on Creative and Cultural Education's (NACCCE) influential report "All our futures" (NACCCE, 1999) argued for the need to foster creative development in all pupils. • The introduction of 'creative development' as one of the seven Early Learning Goals promoted an emphasis on the role of imagination in children's learning. • Inspired by "All our Futures," the Department for Media, Culture and Sport (DCMS), the Department for Education and Skills (DfES) and the Arts Council's Creative Partnerships initiatives were established to 'provide school children across England with the opportunity to develop creativity in learning and to take part in cultural activities of the highest quality".
France	Lower secondary schools are expected to develop in children a taste for creativity.
Germany	Emphasis of primary education is placed on developing "children's

	creative abilities."
Sweden	The government's national development plan for preschool, school and adult education (1997) stated that education should provide the conditions for developing creative skills.
Netherlands	The principle on which primary education is based is "creative development."
Australia	The second educational goal for young people is to become successful learners, confident and creative individuals, and active individuals.
Korea	The National Curriculum defines an educated person as "healthy, independent, creative and moral."
Japan	The school curriculum has included the development of creativity since the Second World War. The Japanese National Council on Educational reform (NCER) has outlined the development of creativity as the most important objective of education for the 21st century.
China	In China, creativity has become an important component of education since 2001 and its development has become a "priority."
Singapore	The Ministry of Education is to foster "enquiring minds, the ability to think critically and creatively." It has included the "thinking schools, learning nation" (TSLN) program designed to develop thinking skills and creativity in students. This was in response to leading industrialists and entrepreneurs signaling that staff in Singapore "are 'conforming' [rather] than 'independent' and not curious enough." The Singapore Ministry of Education website states that they expect of their young to be "creative and imaginative". According to Singapore's primary curriculum, creativity is among the eight core skills and values.
Hong Kong	The education policy proposal includes creativity as "higher order thinking skills." Educational reforms are being carried out in preschool, primary and secondary education in which the development of creativity is being given "top priority."

Source: (Barlex, 2011; Shaheen, 2010; Wyse & Spendlove, 2007).

Table 12: Technology education in the educational systems of 19 developed countries.

Country	Forms of Technology Education
USA	Technology education is defined as "the comprehensive curriculum area which has an action-based instructional program concerned with technology, its evolution, utilization, significance: its organization, personnel, systems, techniques, resources and products; and their combined social and cultural impacts." Forms of technology education are: technology as skills with particular emphasis on tool skills, technology as a form of motivation that uses hands on and project activities to add interest to other subjects, technology as a subject in its own right, technology as an end in itself that provides conceptual frameworks for integrating content and skills learned in other subjects, technology as a guiding theme that provides organizers for what students are to learn, technology as a perspective or philosophical viewpoint that includes a set of higher-level problem-solving skills. Now, the content of technology is defined as what

	every student should know and be able to do in order to be technologically literate provided in *Standards for Technological Literacy: Content for the Study of Technology*.
Finland	Technology education began as handicraft education as in many countries around the world. Technology education is a compulsory subject for all students. Technology education is defined as "the understanding of the functions of technical instruments, equipment and machines and their controlled and skilful use in order to create products and services." Technology is restricted to the technology occurring mainly in the everyday living environment of the pupil. Cognitive activity is seen as the basis of manual skill development. Thought and planning presuppose practical skills. The type of skills needed in everyday life are emphasized, such as creativity and criticalness, ability to cooperate, responsibility, ability to find things out independently and to arrive at justified conclusions. Currently, the content of technology offered as an optional subject is in many schools based on students' choices –what they want to produce for themselves. Technology education in Finland now puts great emphasis on the motivation of students.
China	Technology education exists at primary school level in vocational and technical education or integrated with general science education. A minimum of two hours per week of science and technical education is required for all elementary school students. Currently, school technology education in Mainland China is embedded as part of a curriculum area titled "Integrated Curriculum of Practical Activity (ICPA)." ICPA, mandated as a required curriculum area for both primary and secondary schools, was initially composed of four curriculum sub-areas. Two of these are (1) information technology and (4) labour-technical education. Information technology has come to develop into a separate school subject of its own and has been given high priority by schools, governments, and society at large because of its perceived importance in contemporary education as well as in national and international economic competitiveness. Labour-technical education (LTE) has been officially recognized as a school subject in primary and secondary schools since 1981, although it has been available in a variety of forms and under other names.
Korea	Technology is a compulsory subject for all students, the goal of the subject being a basic understanding of the technical aspects of society. The subject is called technology/industry.
Sweden	Technology education is a compulsory subject in grades 1-9. A 1993 proposal for changes described technology as comprising technological components (tools, machines, systems, etc.) and technological skills and knowledge.
The Netherlands	A new curriculum framework was established in 1993 where the attainment targets for technology education were divided into three domains, each having various subdomains: (1) technology and society: daily life, industry, professions, environment. (2) dealing with technical products: working principles, technical systems, control technology, using technical products. (3) making functional workplaces: preparation of work, design, making and reading technical drawings, working with materials, control of workplaces.

Canada	Canada is comprised of 10 provinces and 3 territories. Each province/territory is responsible for (1) envisioning and implementing its own elementary school curriculum (2) establishing policy on what are core/compulsory and complementary/elective courses (3) envisioning how the study of technology factors into school curricula and graduation requirements. Elementary school curricula across regions are not consistently inclusive of the study of technology, and one finds the study of technology at the secondary school level known by many different names, for example, technological education, technological studies, technical studies, technical education, technology education, practical arts, vocational education, and career studies. The different names represent different grade levels, philosophical underpinnings, and purpose for the curriculum area.
France	Technology education curricula are the result of consensual constructions that, in the absence of clearly defined epistemological references, reflect the uncertainty linked to their creation. As a result, the teaching of technology differs vastly according to four teaching approaches: the production of artefacts, the study of existing technological artefacts, the study of the job market and world of work, and the study of how and why technological artefacts are developed and used.
UK	Scotland: Technology studies have the following goals: (1) to encourage the acquisition of problem-solving skills (2) to develop pupils' ability to apply a systems approach to practical problem-solving (3) to allow pupils to comprehend the evolutionary nature of technology and the effect of technology on the quality of life (4) to highlight the role of technology in manufacturing. England: "Design and Technology" is the name used in the curriculum. All curriculum subjects are defined in terms of attainment targets which are further defined by statements of attainment: processes based, content, skills, and processes which are to be covered during each of the four stages of schooling. They are built around four areas: (1) developing and using artefacts (2) working with materials (3) developing and communicating ideas (4) satisfying needs and opportunities. The subject "design and technology" has two attainment targets: designing and making. Northern Ireland: Under the name "Technology and Design," the subject aims to enable pupils to become confident and responsible in solving real life problems, striving for creative solutions, engage in independent learning, achieve product excellence and social consciousness. The subject "technology and design" does not further specify attainment targets.
South Africa	New changes in the curriculum made technology a compulsory subject for the first 9 years of education, Grades 1 to 9. The subject has two aspects – design and information technology. The inclusion of technology education aims at enhancing the technological nature of society, international recognition as a significant aspect of the curriculum, national economic problems, possibilities for personal development in cognitive skills, and creative thinking and problem-solving. Current development in the school curriculum aims to take the form of a 'design approach,' as in the UK and Commonwealth countries such as Australia and New Zealand. In fact, the approach currently implemented is more a "craft" approach with the Science Technology Society (STS) approach grafted on. The main reason

	behind this might be the complex nature of South Africa's education policy formulation and implementation as with its curriculum theories.
Japan	Technology education takes a general form. Technology-related subjects in the elementary school include drawing/handcrafts, home making, science, and life environment.
Botswana	Technology education borrowed the concept of design and technology from the UK and placed it in an appropriate local context. Four major skills are identified: enquiry and exploratory skills, communication, manipulative and evaluative skills, and discriminatory skills. Design and technology is a compulsory subject in lower secondary schools.
Nigeria	In elementary education, technology education involves students in making, repairing and assembling technical objects. Objectives are (1) to provide a basis for development in Nigeria (2) to prepare students for life (3) to provide training in logical and scientific reasoning (4) to develop students whose daily activities will centre round manual work (5) to stimulate curiosity and creativity and develop problem-solving abilities.
Germany	Technology education aims to provide a functional knowledge about technical devices and processes, to teach technology- specific methodologies, for example creativity, co-operation and communication, and to develop evaluation and assessment capabilities.
Taiwan	Technology studies can be indicated by technical subjects. The last review of the curriculum's technical subjects reduced them to two, domestic technology and living technology. Living technology includes studies in technology and life, information and communication, construction and manufacturing, and power and energy.
Mauritius	Public education is considered to be a replica of the British system. Mauritius promoted design and communication technology in secondary schools, based on the British approach. Technology subjects are called design and communication, and design and technology. In design and technology, students are expected to design and produce artefacts whereas in design and communication, emphasis is put only on the two-dimensional representation of the students' design ideas.
Australia	Technology education provides for the needs of all students to experience and learn about technology. A number of trends have been identified as being common in technology education: (1) Recognition for a general type of technology education to be a core and compulsory subject for all students in lower secondary studies (2) The lagging behind of developments in technology at the primary school level compared to those at the secondary level. (3) Vocational education has traditionally been the domain of colleges of technical and further education (TAFE) where students would attend after the compulsory years of secondary schooling but this is changing with secondary schools increasingly offering vocational courses and TAFE colleges becoming more involved in general education. Currently, the new Technology Key Learning Area was defined as including industrial technology, information and communication and technology, home economics, business, agriculture, and media. The last ten years have seen the implementation of technology education in primary schools. The practice of technology has been modified

	where technology education is equated with the more narrowly defined ICT.
India	The core of technology education at school level in the Indian context is design and technology (D&T) activities that use a variety of skills and draw upon the knowledge of key concepts traditionally taught within other disciplines.
New Zealand	An initial plan for implementation was made in the early 1990s and a plan for full implementation in 1999-2000. Technology is defined as a purposeful activity aimed at meeting needs and opportunities through the development of products, systems, and environments. It takes place within specific contexts and constraints and is influenced by value judgments. General aims of technology education in the Technology in New Zealand Curriculum are to develop: (1) technological knowledge and understanding (2) an understanding and awareness of the interrelationship between technology and society, and (3) technological capability.

Sources: (Ding, 2009; Dugger, 2009; Forret, Jones, & Moreland, 2002; Ginestie, 2009; Hill, 2009; Jones, 1998; Kananoja, 2009; Natarajan & Chunawala, 2009; Rasinen, 2003; Stevens, 2009; Williams, 1996a).

For Saudi Arabia, the topic of creativity is no different than for technology education – there is no emphasis on creativity in the curriculum agenda. Indeed, recently in the development of general education, the Ministry of Education has mentioned many times its intention of assisting pupils to be creative, which is a very similar goal to that of assisting pupils to learn technology, of course without explicit learning goals or strategic plans for either.

Teaching technological creativity must depend on the curriculum, no matter how great this dependence. Teachers and pupils should follow the curriculum set by experts and assigned by the Ministry of Education in order for them to acquire learning. But is education effective when there is no flexibility in the curriculum? If not, why for many years have Saudi schools failed to pay attention to pupils' creativity? Simply because the school curriculum still relies on the same standards in use for at least the last thirty years. It is quite safe to say that the current elementary school curriculum stifles the creativity of students as there is no scope for pupils to show their interests or the relevance to them of taught subjects. Similarly, teachers have little opportunity for using creative teaching methods, approaches and strategies. This perception becomes obvious by comparing the old and new general education curriculum documents. Curriculum developers and educational policy makers should understand that this type of curriculum is not valid in the 21st century, particularly for practical subjects. This critique does not mean that the government should change the curriculum – "*it is easier to change the location of a cemetery, than to change the school curriculum*" (Woodrow T. Wilson, n.d., as cited in Spendlove, 2008, p. 57) – but rather should integrate into it practical subjects such as technology education which can connect the learning process to other subjects. For example, technology education can easily be combined with subjects like science or art or even language which is important in a technology classroom for communication.

The focus in Saudi has been on promoting cognitive abilities and memorization (Al-Sadan, 2000; Baqutayan, 2011; BouJaoude, 2003). These strategies are important but do not help pupils to learn critical or creative thinking skills which are of major relevance and significance, not only to their education but in the future in the workplace. It is not an easy task to teach practical subjects which may involve topics like technological creativity in the current school curriculum but the Ministry of Education should begin to consider the research evidence. Developing an awareness of the importance of technology education among teachers and pupils is a good starting point. Most importantly, teachers, for instance, should know what promotes creative products, introducing pupils to the characteristics of creative people and/or through studying the history of technological creativity and innovation.

Science and technology in the Saudi educational context

The Ministry of Education (2011) defined a general understanding of science and technology as the use of knowledge, skills and resources to meet people's future needs. However, science has its own constraints in the current curriculum, such as the amount of time allocated each week (2 to 3 sessions with a duration of 45 minutes), the laboratory, and classroom equipment. Table **13** indicates subjects and lesson periods per week.

Table 13. Subjects and lesson periods per week

Subject	No. of lessons by grade					
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Islamic Studies	9	9	9	9	9	9
Arabic Studies	9	9	9	8	8	8
Social Studies	–	–	–	2	2	2
Science	2	2	2	2	3	3
Mathematics	4	4	4	5	5	5
Artistic Education	2	2	2	1	1	1
Physical Education	2	2	2	2	2	2
Total hours per week	28	28	28	30	30	30

Note: Each lesson lasts 45 minutes.
Source: (Saudi Arabian Cultural Mission, 1991, p. 28, as cited in Al-Sadan, 2000, p. 148).

Learning in technology education has different purposes than science education (DeVore, 1987b; Skolimowski, 1966) and includes the ability to use technical skills and knowledge and gain understanding in a range of contexts at school, at home and, long term, in adult life including work (Lewis, 2000, 2008). In technology, the objective is to seek effectiveness, not exploration and investigation, which is the aim of science. Many technologists have already examined science and technology in terms of knowledge and progress (Herschbach, 1995; Ihde, 1997; McCormick, 1997, 2004) and in technology education knowing and doing are always emphasised together.

However, the purpose is also to develop students' awareness of the implications of the development of science and technology on societies and individuals. Science teachers (in Saudi) should be aware of the differences between the two subjects as well as their relationships. Teaching technological creativity through science can take a general form by making connections between subjects where possible, as proposed by Lewis (1999, 2000), Barlex (2007, June, 2011), and Sharkawy, Barlex, Welch, McDuff, & Craig (2009).

Technology is better taught as a separate subject. The supporting rationales are: (a) for technology transfer; (b) human development and (c) promoting skills and competence. These can bridge the technological gap between developed and less developed countries. Lewis (1999, 2000) investigated the problems of developing countries who do not have technology in their curriculum and suggested the possibility of teaching technology topics in other related subjects through two approaches: *technology as reconstituted industrial arts* or *technology across curriculum*. Lewis (2000) developed these approaches particularly for the inclusion of technology education in primary and secondary subjects. The technology across-curriculum approach has taken different names such as learning across-curriculum or teaching a general type of technology. Teaching technology across the curriculum is well suited to the elementary school as (Lewis, 2000):

> Science could be an important vehicle for teaching children in developing countries about technology, in the primary school as well as in the secondary. The challenge would be to find in everyday life, situations that provide opportunities to show the interface of science and technology. Food preservation and fermentation are examples of such opportunities. Principles of physics can be shown to underlay flashlights. Electron flow can be taught in connection with simple electric circuits. Principles of electricity, thermodynamics, and mechanics can be explored through practical technological applications such as small engines and bicycles (p. 176).

This approach is well suited to Saudi Arabia, at least at present, because (a) the subject context which would be used to teach technological creativity does not have to rely on specialist teachers, as teachers tend to be generalists; and (b) it could be taught in available facilities (Lewis, 2000).

Science as an example

> Despite the fact that before the 1950s, the majority of technological inventions and innovations did not rely on scientific theory for their development, scientific theory is becoming increasingly the foundation of technological development…this connection between science and technology inspired science educators to ask themselves "whether technology-centred activities afford a learning environment that scaffolds students' learning of science…Leading national organizations of science education responded to the need of addressing the relationship between science and technology when shaping science standards and curriculum (Sidawi, 2007, p. 269).

The purpose of the statement above is to develop a general understanding of the relationship between science and technology. The case of the Saudi curriculum necessitates this, as technology is not a taught subject, and the focus of this research is consequently teaching technological creativity through science. There is therefore a need to discuss science and technology, focusing on their related aspects and differences. The relationship between science and technology can be developed through the consideration of the nature of knowledge or/and progress. For example Skolimowski (1966) claimed that:

> …It may be argued that in the pursuit of technological progress we often bring about scientific progress as well. It should be observed, on the other hand, that scientific progress may and indeed does facilitate technological progress. Discoveries in pure science, regardless of how abstract they appear at first, sooner or later find their technological embodiment. These two observations lead to a conclusion that perhaps neither scientific nor technological progress can be achieved in its pure form…it should not prevent us from analysing these two kinds of progress separately …if we are permitted to divorce scientific progress from technological progress when examining the nature of science, we should be equally permitted to divorce technological progress from scientific progress when examining the nature of technology (p. 376).

In the technology related literature, there are many ways to explore the connections between science and technology as well as their differences in terms of their goals, problems, settings, purposes, knowledge and progress (DeVore, 1987b; Ihde, 1997; Mawson, 2003; McCormick, 1997, 2004; Moreland, Cowie, Jones, & Otrel-Cass, 2008; Ropohl, 1997; Sidawi, 2007; Williams, 2000), e.g., through a consideration of their processes or through their domain of knowledge (Skolimowski, 1966; Williams, 2000). Commenting on the differences between science and technology, Skolimowski (1966) referred to the notion that "the basic methodological factors that account for the growth of technology are quite different from the factors that account for the growth of science" (p. 374). Simply put, exploration, investigation, seeking truth/reality and the development of knowledge are the core of science, whereas technology aims to create a reality based on people's designs (Skolimowski, 1966). Technology, however, does not seek reality because it is not an instrument for investigating reality nor is its aim to enlarge the domain of knowledge and the acquisition of truth. He presented science as a means to knowing reality: "in science we are concerned with reality in its basic meaning …on what there is" (p. 374), whereas "in technology we produce artifacts; we provide means for constructing objects according to our specifications.

In short, science concerns itself with what is, technology with what is to be" (p. 375).

Skolimowski (1966) also differentiated between scientific and technological progress: "the end of the scientific process is the end of science" (p. 374). The overall focus in the scientific process is to improve theories and increase knowledge. While the technological process provides the means for producing new and better objects of the same kind, technology seeks usefulness/effectiveness. The technological process produces useful objects that can be further developed.

Finally, Williams (2000) referred to the individual knowledge of general life skills, such as planning, observing, reporting, evaluating, and communicating, whether they are science or technology, "when they are contextualised, when they are accompanied by scientific or technological knowledge, and set in the context of a scientific investigation or a technological design" (p. 27). However, this is not the place to divorce science from technology but to marry them in order to pave the way to teaching creativity through science. Science cannot be technology and technology cannot be science but this does not mean that it is not possible, for example, to teach science through designing technology (Sidawi, 2007) or the reverse. Lewis (1999, 2000) has suggested that it is appropriate in developing countries to teach technology through agriculture science, science, art or any other related subjects through what he called the *technology across-the curriculum approach*.

There is a further need to align technology education (within the current science curriculum) with creativity in the education agenda. By aligning technological creativity with science, it will be possible to enable pupils to be creative through design "as the means to critique existing products and the uses of technology" (Barlex, 2007, June, p. 107).

An analysis of the Saudi Arabian curriculum document, however, demonstrated that there are no given strategies on teaching technology education or linking science to technology; for instance, linking facts and concepts to practice and applications. The science curriculum has its own problems relating to teaching methods where pupils learn scientific laws and rules that should be subject to evaluation and experiment.

This problem has brought to light another constraint having to do with facilities – the physical environment. It was indicated in Section Two that the physical environment is of major significance for teaching technological creativity (Myers & Shinberg, 2011). As in teaching any other subject, teaching technology education requires a curriculum and clear learning objectives, materials, content, qualified teachers, school and classroom facilities, and interaction between society and the environment (Hall, 2011). To make this happen, an analysis of the surveyed research and literature indicated that the question posed can be answered by considering the *technology across-curriculum approach* as a vehicle for teaching the topic in interactive pedagogy with other subjects. It was the intention to use science as a vehicle subject to teach technological creativity but after analysing textbooks (which can be found at www.nooor.com) along with a possible time frame, the idea was rejected for two main reasons. First, as Almutairi et al. (2011) stated:

> …science textbooks of Years 1 to 4 do not support teaching Technology Education as the contents focus only on life systems, the human body, and environmental issues. In Years 5 and 6 a few topics could help students to develop their skill in Technology, but only if these topics were linked to this concept" (p. 9).

Secondly, technological creativity can be taught in/with other subjects such as art in that pupils can learn drawing techniques using different kinds of materials. What was found in the literature about specifications of creative teaching in science education seems to serve as well for technology education. Kind and Kind (2007) summarised good creative teaching and bad traditional teaching with specific characteristics as shown in **Figure 11**.

'Good' creative teaching		'Bad' traditional teaching	
Student-oriented	v.	Teacher-oriented	(Melar, 1993)
Group/team work	v.	Individual work	(Marazzi, 1999)
Cooperative learning	v.	Individual learning	(Anderson, 2001)
Explorative tasks	v.	Close-end tasks	(Saxon et al., 2003)
Open-ended problems	v.	Closed problems	(Schamel & Ayres, 1992)
Open investigations	v.	'Recipe' work	(Sallam & Krockover, 1982)
Hands-on teaching	v.	Lectures	(Shymansky & Penick, 1981)
Outdoor activities	v.	Classroom activities	(Boss, 2001)
Project work	v.	Lectures	(Mackin, 1996)
Issue-oriented	v.	Concept oriented	(Penick & Yager, 1993)
Teachers taking risks	v.	Teachers playing safe	(Tamblyn, 2000)

Figure 1: Contrasts commonly found in science education literature between creative and traditional teaching.

Figure 11. Contrasts commonly found in science education literature between creative and traditional teaching.

Source: (Kind & Kind, 2007, p. 4).

The instructional situation in Saudi Arabia needs an essential focus on basic technology education strategies. Such technology education is still new and its introduction and inclusion in the educational system might need a great deal of time. Here, I only present a conceptual framework consisting of developing curriculum design theories that can serve the inclusion of technological creativity. Based on the findings, I also demonstrate appropriate resources and materials as a sample, such as the use of activity books and online materials. Tools, techniques and assessment are also explored in light of what might be suitable for teaching technological creativity in the on-going curriculum. Nevertheless, the pedagogical aspects identified from the findings are not exclusive, i.e., they do not examine every element of creativity in terms of teaching and learning.

3.4.2. Teaching technological creativity in the Saudi Arabian elementary context

Having outlined an understanding of technology education and creativity in the educational context of some developed countries, an answer to the thesis question is provided under the following categories and based on an adaptation of supportive data from the included studies in relation to teaching and learning. First, a close consideration of suitable curriculum design approaches for the Saudi Arabian context is presented. Then, the rest of the section develops a conceptual framework on teaching technological creativity applications, tools, techniques and assessment. These aspects should inform the situation in Saudi Arabia.

Supportive curriculum design theories

Research findings have emphasized five curriculum design theories that should be considered in a school curriculum design, namely theories based on: (a) rationalist academic discipline, (b) competencies (Williams, 1996b) or technical (Zuga, 1989), (c) intellectual processes (Biddulph & Carr, 1999; Johnson, 1992; Williams, 1996b), (d) personal relevance and (e) social reconstruction (Biddulph & Carr, 1999; Williams, 1996b; Zuga, 1989, 1992). One or more of these theories can be utilised when designing a technology curriculum (Biddulph & Carr, 1999; Hill, 1997; Johnson, 1992; Petrina, 1992; Zuga, 1989, 1992).

These theories can be applied to the Saudi Arabian school context. Each theory consists of a group of decisions that result from the study of society, culture and philosophy as well as from the learners and their interactions in personal and social contexts. The decision then reflects the goals and content of the curriculum and determines the relationships between goals, content and teaching strategies and other components of the teaching-learning processes. Each of these curriculum design approaches has different objectives. For example, intellectual processes aim at developing the thinking skills of students which is the essence of the problem-solving process. Personal relevance aims to satisfy the wants and needs of students and promote their motivation and confidence levels. This is an essential element for teaching technological creativity which aims to make students interested and highly motivated. Personal relevance is termed a humanistic learning theory (Biddulph & Carr, 1999) because of its consideration of pupils' different abilities and interests.

Given that technology is not a discrete subject in Saudi Arabia, this fact can help curriculum developers place technological creativity into the elementary curriculum. In addition, this research suggests one more approach to be aligned with the philosophy of Saudi education, namely the religious relevance approach. In Section four of the present chapter, a discussion of the Islamic rationale in relation to the topic of technological creativity is developed. Thus, there are six curriculum design theories for the technology curriculum.

1. Religious relevance theory: seeing technology as a good deed activity

Islam is the religion in Saudi Arabia and the two main law sources are the Qur'an and the Sayings of the Prophet Mohammed (or Hadith in Arabic). The majority of people in Saudi Arabia are influenced and guided by Islamic law in all affairs of life. There is a religious rationale to teaching technological creativity which can assist in understanding that technological creativity has had its own history for many centuries. The rationale could take the form of seeing creative technology as a good-deed activity. A Saudi perception of creation is understood this way. Allah has created human beings ("Now let man but think from what he is created! He is created from a drop emitted, proceeding from between the backbone and the ribs: Surely (Allah) is able to bring him back (to life)!" (Qur'an 86:5-8)), and has asked them to colonize, reconstruct and invest what He has provided them on earth. "It is He Who hath produced you from the earth and settled you therein" (Qur'an 11:61). The quote may be used to demystify the significance of a "doing" aspect in people's lives, to reconstruct earth by working and being involved in practical activities drawing on scientific and technical means. For instance, the story of Zul-Qarnain is an example of how people can benefit from using materials and various technical means to serve human needs. Allah has mentioned throughout the Qur'an that people's responsibility is to do good deeds:

> We bestowed Grace aforetime on David from Ourselves: O ye Mountains! Sing ye back the Praises of Allah with him! And ye birds (also)! And We made the iron soft for him, (commanding) "Make thou coats of mail, balancing well the rings of chain armour, and work ye righteousness; for be sure I see (clearly) all that ye do." (Quran 34: 10-11).

The Qur'an places emphasis, for instance, on manufacturing. Here are some examples:

- Textiles and knitting:

> O Children of Adam! We have bestowed raiment upon you to cover yourselves (screen your private parts) and as an adornment; and the raiment of righteousness, that is better. Such are among the *Ayat* (proofs, evidences, verses, lessons, signs, revelations, etc.) of Allah, that they may remember (i.e. leave falsehood and follow truth) (Qur'an 7: 26).

- Food technology:

> And We shall provide them with fruit and meat such as they desire" (Qur'an 52:22). Allah also says: "Do they not see what We have created for them of what Our Hands have created, the cattle, so that they are their owners. And We have subdued them unto them so that some of them they have for riding and some they eat. And they have (other) benefits from them, and they get (milk) to drink. Will they not then be grateful?" (Qur'an 36:71-73). And from the fruits of date-palms and grapes, you derive strong drink and a goodly provision. Verily, therein is indeed a sign for people who have wisdom (Qur'an 16: 67).

- Fishing technology

> "Lawful to you is (the pursuit of) water-game and its use for food – for the benefit of yourselves and those who travel" (Qur'an 5:96).

- Diving industry/technology, pearl and coral:

> And to Sulaiman (Solomon) (We subjected) the wind strongly raging, running by his command towards the land which We had blessed. And of everything We are the All-knower. And of the Shayatin (devils from the jinn) were some who dived for him, and did other work besides that; and it was We Who guarded them (Qur'an 21: 81-82). He also says: "He has let loose the two seas (the salt and fresh water) meeting together. Between them is a barrier which none of them can transgress. Then which of the Blessings of your Lord will you both (jinn and men) deny? And His are the ships going and coming in the seas, like mountains (Qur'an 55: 19-24).

- Pharmaceutical manufacturing

Honey was mentioned in the Qur'an as a food element and also as a therapeutic element:

> And your Lord inspired the bees, saying: "Take you habitations in the mountains and in the trees and in what they erect. Then, eat of all fruits, and follow the ways of your Lord made easy (for you). There comes forth from their bellies a drink of varying colour wherein is healing for men. Verily, in this is indeed a sign for people who think (Qur'an 16: 68-69).

Accordingly, planting a tree is a good deed, protecting the environment (e.g. cleaning and recycling) is a good deed, and using sources (iron, wood) or any other resources available to people to build (e.g. houses, hospitals, schools) is also a good deed. According to this perception, teaching technology to pupils so they learn how to design and make things is also a good deed. There are many inventions that have been created to serve people which are still in use and will remain for many more centuries. DeVore. et al. (1989) mentioned examples of geniuses from the history of technology: Thomas Alva Edison, 1847-1931, patent no. 223,898, electric lamp; Alexander Graham Bell, 1847-1922, patent no. 174,465, telegraphy; Orville Wright, 1871-1948, and Wilbur Wright, 1867-1912, patent no. 821,393, flying machine; Charles Goodyear, 1800-1860, patent no. 3,633, improvements in rubber fabrics; Henry Ford, 1863-1947, patent no. 1,005,186, transmission mechanism. In addition, no one would reject recent inventions of recent technologies and devices such as computers, telecommunication and communication devices, which are all good deeds if people use them appropriately. They have served people for many years now and there will continually be new forms of technology developed over a period of time.

The key point is that there is a religious rationale supporting teaching technological creativity in Saudi Arabia and this is based on the Qur'anic context. A religious awareness of the importance and influence of technology (positively in the case of this research study) on people's lives needs to be considered because once students gain the understanding that creating and designing things can benefit their society, they will accept it as an essential part of their culture, not only as an essential part of education.

In addition, time is an important factor for Saudi educational decision-makers to consider if there is a real intention to enhance students' creative abilities. Creative processes will not stop. "There are probably as many processes of creativity, invention, and innovation as there are people in the world" (DeVore. et al., 1989, p. 4). There are many studies on innovation and creativity in the history of technology, especially in the second half of the 20th century, because technological creativity at the highest level is one of the most significant aspects for human development and for the changes that have taken place in history and in human societies. Changes wrought by technological creativity throughout the history of technology did not happen through planning but through the work of creators.

2. <u>The academic rationalist discipline-based theory</u>

This is the most widely used theory in educational curricula and it is the content which drives the subject. It provides the core for instruction as its underlying principles and objectives aim for knowledge of the subject (technology education). The academic rationalist approach structures curriculum content to develop knowledge of technological method and its elements. It considers technology a discipline and the aim of technology education is to teach pupils practical-based skills, doing as well as knowing. This approach makes technology education an independent subject which interacts with other disciplines in the curriculum but its objective is to teach technological knowledge. Technological knowledge is procedural knowledge and includes design and problem-solving. However, the approach has to do with technological knowledge in the first place.

3. <u>The competencies-based theory</u>

The competencies-based approach differs from the academic rationalist approach in that the first focuses more on an activity-based or technically-based curriculum where pupils engage in the task. Thus it is a behaviour-focused approach which is more highly structured than one derived from analysis. Identification of behavioural outcomes becomes the means for creating the curriculum. One of the virtues of the competencies-based approach is that it prepares pupils to carry out specific tasks and is based on an analysis of processes/tasks. This approach has no place in an ill-defined curriculum but would suit a well-defined technology curriculum. It might best suit the upper secondary level and technical school after high school (vocational and technical education). Hence, it might not be suitable for an elementary curriculum.

4. <u>Intellectual processes theory</u>

Intellectual process is the mental operation where one acquires new knowledge and applies it, and includes the control of the mental processing that is required for knowledge acquisition and use (Johnson, 1992). Zuga (1989) links this approach to the goals which develop critical thinking and the ability to use the acquired knowledge for solving real problems, and to other processes that encourage working cooperatively. An analysis of the approach confirmed its effectiveness for teaching technological creativity because the elements of intellectual processes rely on the mind – on activities where skills and creative thinking are important. For the successful implementation of this approach, it must be applied to content which represents the domain of knowledge. Thinking processes, skills, critical thinking, creativity, cognition and metacognition are the main characteristics for developing an intellectual process approach (Johnson, 1992; Williams, 1996). These elements are the essence of the intellectual process approach that aims at developing thinking and higher order thinking skills in pupils' learning.

Saudi curriculum developers and teachers need to implement this approach as it help pupils to critique decisions related to technological problems. Technology education always aims to develop pupils' thinking skills, for example, to be used for the acquisition and application of knowledge. In addition, cognition and meta-cognition are connected. Cognition is the knowledge or the theoretical frame that pupils need for engaging in activities. Metacognition is the strategic thinking that occurs prior, during and after the thinking activity process (Johnson, 1992; Zuga, 1989). Thus, attention should be paid to the relationships between the cognitive knowledge domain and intellectual processes. It is argued that deep understanding of technological knowledge is required for successful learning because the relationship between the content component and the intellectual process is the same in doing as it is with knowing.

The application of intellectual processes should reflect on the content. The given aspects of intellectual processes must be the major objectives for intellectual processes curriculum design. The structure of the application should focus on goals for developing pupils' abilities and thinking skills. These goals are that pupils can acquire understanding and awareness of the nature of thinking and their mental capabilities, use thinking skills with increasing independence and responsibility, have an understanding of the different subjects related to technology (e.g. science, mathematics), and link the learning process gained to real world situations (Zuga, 1989). While this curriculum approach offers possibilities for the Saudi learning setting for teaching technological creativity or any other technology topics, it must meet two requirements: intellectual processes must refer to knowledge content, and the approach may require a special methodology for assessment.

5. Personal relevance theory

The analysis of various papers used emphasised the pupils' needs and interests. Personal relevance theory can appropriately link to the ownership and control construct identified by Benson and Lunt (2011) and Caney (2006). The theory encourages individuality and freedom and pupil-centred play. Personal relevance is grounded in humanistic theory (Biddulph & Carr, 1999; Petrina, 1992) and is meant to achieve personal goals. It is an integration of the cognitive, creative, aesthetic, moral, and vocational dimensions of being human. The overall aim of this design theory is to involve pupils by allowing them to create their own curriculum which derives from their personal problems, interests, and wants. Considerations of what is practical for the welfare of pupils, community and society along with the cultural and historical perspectives are essential characteristics of this design theory. It encourages the development of comprehensive experiences with the integration of thoughts, actions and goals in the social settings. Based on their own experiences, pupils will be assisted in recognising the relationships between their experiences and broader problems and patterns in life.

According to Williams (1996b), personal relevance emphasises unity because units integrate pupils' thoughts, emotions, and actions with purpose, the means-ends continuum, and the environment. Units present themselves as both project and problem and pupils draw on diverse types of inquiry, knowledge and other resources to assist in their resolution. The process of determining unit types is something negotiated between pupils and teachers and these units also focus on aspects of pupils' lives. Emphasis is placed on linking abstract concepts to real and personal themes inherent in the pupils' lives. The approach is 'learner-centred' with a focus on the individual needs and interests of the pupils. In the design theory overview, the goal is to enhance the idea of ownership and control in pupils by putting the control of the curriculum into the pupils' hands instead of those of subject matter specialists and allowing pupils to integrate the information which they choose.

An emphasis on this theory for teaching technological creativity is important because when pupils feel that they can make decisions in choosing what to learn, they will be encouraged and their motivation level will be enhanced. Personal relevance also may help in achieving self-actualization and self-direction in the world at a variety of levels (Craft, 2003).

6. Social reconstruction theory

The concept of social reconstruction aims at advocating an orientation towards a social reconstruction curriculum which, it is believed, will encourage pupils to structure and improve society. Any learning theory should be sociologically based. Social reconstruction theory consists of two major premises towards society change and this change involves the reconstruction of education in a society and the use of education in reconstructing the society (Hill, 1997; Zuga, 1992). Consequently, the purpose of this approach is to allow opportunities for pupils to alter the structure of society through a democratic process where pupils can practice relevant skills such as problem-solving with focus group welfare. Learning structure based on this curriculum design approach is seen as an active process where knowledge is acquired through activity and experience that interacts internally with society. According to this approach, creative processes are not limited to mental status but lie behind the experiences and relationships (Cropley, 2006; Zuga, 1989).

The social reconstruction design theory is practically oriented. Thus one recommendation is to develop the interface between social issues and the content structure of technological topics, for example technological creativity. It is the responsibility of curriculum developers/planners in Saudi Arabia to use an appropriate structure for the topic that incorporates technological concepts and a historical framework. Through the structure, topics were identified and operationalized so that the main emphasis in the classroom becomes a focus on social problems. Zuga (1989, 1992), Hill (1997), Williams (1996b) attempted to focus on the social goals of technology education by identifying content and selecting appropriate social problems and activities to complement the content. With respect to teaching technological creativity, a social reconstruction theory is becoming increasingly important because the research of creativity in the past focused on the individual level of creativity. Now, the shift is more towards the social level of creativity because the creative process usually occurs in a social system rather than in a person's mind (Cropley, 2006).

Having identified the six supportive curriculum design theories, the competence-based approach was excluded. This thesis suggests the addition of the religious relevance approach because, as it been mentioned throughout this research, people, including pupils in Saudi Arabia, are guided by Islamic law. Thus, proposing a religious relevance approach would encourage teachers and pupils to consider teaching and learning technological topics as *a good deed* activity.

Teaching applications

Research focuses on two applications of creativity within the educational context: *teaching creatively* and *teaching for creativity* (Barlex, 2007, June, 2011; Burton, 2010; Craft, 1999, 2003; Howe et al., 2001; Rutland & Barlex, 2007; Rutland & Spendlove, 2006; Saebø et al., 2007). Teaching for creativity (experimental creativity) deals with the forms of teaching that are specifically aimed to develop students' creative thinking. The aim is to enhance pupils' own creative abilities. Teaching creatively (professional creativity) focuses on the teacher, teaching approaches, the development of materials as teachers attempt to make students interested, motivated, excited and effective. This is an easy way to determine types of creativity when planning for teaching technological creativity, experimental and professional.

The first focus is fully on the creative learning process whereas the second is on making the learning environment suitable for teaching creatively. However, the first application of creativity refers to creativity in learners and is an aspect of student learning that has always been recognised as important. The second application relates to teaching approaches and the curriculum and professionalism of teachers in the classroom. These two types determine general strategies for creativity in education and, hence, technology education. These two teaching applications can be combined into one main application – teaching for technological creativity – because teaching creatively is a part of teaching for creativity. So teaching for technological creativity should integrate essential components of both into one main application.

Teachers were the focus of nearly all the papers. These stressed the importance of having good knowledge and skills in the domain itself and knowing how to teach students creativity in design and technology education classrooms by having their own strategies to succeed in locating creativity in new teaching approaches. Important concepts include, for example, intrinsic motivation, providing and encouraging, supporting cognitive situations to enable risk-taking, making the physical environment as stimulating as possible, and introducing artefacts to students in the classroom. All these promote creative thought and allow students the autonomy to cope with varied tasks and problems, valuing, praising and rewarding creative acts, and attempt risk-taking. The strategies are designed for teachers. It is important for teachers not only to consider these strategies but to use their creative teaching methods and ideas to promote student learning, not an easy task for all teachers of technology (Balchin, 2008).

How do implicit theories support teachers teaching technological creativity?

Implicit theories are derived mainly from psychology and generated in literature related to psychology (Dow, 2006). Psychological researchers claim that people hold what are called implicit theories, which are important to consider when teaching technology. Dow (2006) defined them as those "sets of beliefs or assumptions that we are not necessarily fully conscious of and that we may even find hard to put into words… [Implicit theories] have an enormous impact on how we act and react in everyday situations" (p. 254). Implicit theories is also defined as "the constellations of thoughts and ideas about a particular construct that are held and applied by individuals" (Runco, 2004b, p. 14). Researchers (Dow, 2006; Runco, 2004b) discussed the importance of implicit theories for learning. It would be useful to limit the focus to what implicit theories can offer for teaching technological creativity.

Dow (2006) researched implicit theories in education generally, and in the design and technology education classroom specifically, and within creativity especially. She emphasised the elementary level of education because "it is generally believed that implicit theories are formed at very early stages in our lives…Primary school teachers in particular have an important role to play in the kinds of implicit theories children develop about such things as the nature of knowledge" (p. 255). In a technology classroom, implicit theories can affect the way teachers teach and the way they deliver their messages to students. The theories can positively determine how knowledge is constructed and evaluated. Dow (2006) specified areas in technology education which implicit theories can affect. She argued that implicit theories can have a major effect on teaching creativity through what teachers think about instrumental theories of intelligence and behaviour or theories that are related to creativity, “a construct which is considered central to the teaching design” (p. 259). Implicit theories should be considered as an aspect of teaching technological creativity because of the concern that teachers be aware of their own implicit theories and so contribute effectively to the learning process and the way teachers use teaching methods to deliver technology topics in the classroom. Having stated the importance of implicit theories, these are another factor for primary teachers in Saudi Arabia to take into account.

Rutland and Barlex (2007), Rutland and Spendlove (2006) and Barlex (2011) represented three theoretical framework models for teaching creativity that are generated in research. The first feature is specific to one technological area related to domain relevant features (a set of practices associated with an area of knowledge, for example design and technology or other subjects such as science, mathematics). The other two features are generic, “used to explore creativity within other domain areas of the school curriculum process – relevant features (influencing, controlling the direction and progress of the creative process, and social, environment features (macro/micro environmental, social and cultural issues)” (Rutland & Barlex, 2007, p. 143). Barlex (2011) commented on the importance of integrating these specific criteria in a technology classroom when it comes to teaching creativity and suggested that “these features must be presented in a classroom if pupils are to be creative” (p. 106). Rutland and Barlex (2007) further identified four specific criteria for teaching creativity within design and technology:

1. *The concept or idea* – has the designer proposed a concept that is original, novel, feasible, useful, will function etc.?
2. *Aesthetic creativity* – has the designer made proposals about those features of the product that will appeal to the senses, for example, sight, hearing, touch, taste and smell? Is there something about these proposals that is particularly novel and attractive?

3. *Technical creativity* – has the designer made proposals about the way the product will work and the nature of components and materials required to achieve this? Is there something about these proposals that is novel or elegant?
4. *Constructional creativity* – has the designer made proposals about the way the product will be constructed and the tools and processes needed to achieve this? Is there something about these proposals that is novel or original? (pp. 143-144).

For the use of one subject informing purposeful activity in another subject. This strategy/approach of using creative activities could be used in science to inform creative technological activities (Barlex, 2011). Zubrowski (2002) developed projects where students were provided with standard models and were challenged to analyse their weaknesses and improve them. "Design projects are presented to students in their science class. Teams of students assemble models with slight variation in their designs... (p. 49). Hence, creativity as a technological (designing) topic can be taught through Science, Technology, Engineering, and Mathematics (STEM) subjects.

Starting points tools, techniques and materials

The literature also discusses the nature of topics (or techniques) for teaching technological creativity. For example, Good (2002) provided an example of using a 'starting points' technique for teaching primary students creative practical tasks. This proved to be a valuable technique for enriching students' knowledge and giving a stimulus to form the basis for designing. The Design and Technology Association (2012) website (can be reached at https://www.data.org.uk/) describes rich contexts in which students can learn to be creative through designing starting points with relevance to tasks, products, progression and evaluation.

Rutland and Spendlove (2006) discussed the effectiveness of using the SCAMPER technique which encourages divergent thinking, where students can think of objects from different perspectives. The successful integration of technological creativity into elementary science will also depend on the textbooks and materials selected for teaching creative knowledge and skills through practical activities. Lewis (2008) claimed that creativity can be taught through design topics such as bridges, structures and materials. I selected the following technology education textbooks from the available literature as a means to provide alternatives for curriculum developers and teachers:

1. *Creativity Box* is a collection of resources designed particularly for pupils in years 7-11, although a number of the activities can be adapted for younger children. They are meant to be fun and challenging but some also embrace serious topics and practical considerations. Pupils of all abilities will enjoy many of the sections included, and high achievers in particular will find plenty of opportunities to stimulate them and extend their imaginations. Most of the activities provided opportunities for pupils to work individually at their own levels. Others are specifically designed for group work and to encourage teamwork, discussion, and presentation techniques. One of the features of the exercises in this activity book is that there are no 'correct' answers. Pupils have the opportunity to work on activities where the emphasis is on enjoyment, and at the same time to develop their logical, creative, imaginative, artistic, and personal skills. Saudi teachers will need to select appropriate units for teaching because the activity book consists of religiously inappropriate activities such as music but they can still benefit from the rest of the sections. Each section can be used in a variety of ways by teachers. For example, pupils could be set the same exercise to work on for a set time, followed by a class or group discussion, or pupils could be assigned different activities and then asked to discuss or compare notes with a fellow pupil. At times it might be appropriate to allow pupils to choose their own section to complete. Some of the discussion topics could also be used as starters for family discussions. In fact, teachers will find numerous ways in which this resource can be used effectively, according to the needs of their own students (Gifford, 2009).
2. *Steven Caney's Ultimate Building Book* is one of the recent books that focuses on providing design and technology ideas with various forms of lessons and activities which can be used not only in a technology classroom but also in science. The book illustrates creative knowledge and a comprehensive exploration of design, construction, and invention (Caney, 2006).
3. *Creativity, Design and Technology* is a hands-on guide to fostering creative thinking in students. This practical book offers teachers useful infor-

mation on the creative process (DeVore. et al., 1989). While this work was produced a long time ago, it is still a good source for teachers to find ideas for using the hand and the mind to design new technical means for the benefit of society. Flexibility is its main feature in that teachers can use it for their particular needs and situations. This source is suitable to all students at different levels of education.

4. *Applied Literacy Design and Technology Writing Skills* is an activity-based booklet. The activities in it are designed for application to a variety of subjects in the technology and applied studies key learning area. This source can also be useful for Saudi teachers to introduce writing skills in design and technology especially in the 5th and 6th grades in elementary education (the pre-intermediate) (Dove, 2009).
5. *Focus on Design in Technology:* Books *A* and *B*, a series of books providing teachers with contents that can be taught in a classroom (Williams, 2011a; Williams, 2011b).
6. A useful resource for teachers that can deepen their understanding of technology education is *100 Ideas for Teaching Design and Technology*. It is very much about 'how' rather than 'what' to teach in design and technology (D & T), it draws upon best practice in teaching and locates this within a D &T context. The book provides eight sections: the big picture, designing, using technology, extended curriculum, structuring the learning, including all, assessment, and the wider classroom (Spendlove, 2008).
7. *Teaching Technology in the Junior School*, books *A* and *B,* provide fun and hands-on activities for teaching technology. The two books in the resource series focus on units that integrate easily into many junior programmes. **Figure 12** shows the focus of Book A and B (Green, 2001a, 2001b).

BOOK A

Unit	Technology Focus	Context
• Rain Hats	Materials Technology	Personal
• That's Rubbish!	Biotechnology	School, Environmental
• Treasure Boat	Materials Technology	Recreational, Business
• Papermaking	Production and Process	Industrial, Home

BOOK B

Unit	Technology Focus	Context
• You've Got Mail!	ICT	Personal, School
• The Picnic Party	Food Technology	Home,Recreational
• Let's Go Fly a Kite!	Materials Technology	Recreational
• Teddy Chairs	Structures and Mechanisms	Home, School

Figure 12. Teaching Technology in the Junior School, books A and B.

Each unit of these activity books begins with an overview page that details the major technology focus. They contain design briefs for children to work towards. The work is structured so that children gain some background understanding of the topics in the first half of the units. This is important because once children have some understanding of the topic, lessons covering the design process are introduced. Pages for evaluating lessons are also included. The use of the units in these book activities can be adapted by enlarging worksheets to A3 size and completing them as a whole class or as a group activity. Parents could also be trained to take individual children aside throughout the day and work one-on-one on their children's projects. The making and evaluating could be done individually, in groups or as a whole class, depending on the needs of the children. These selected sources can assist teachers and curriculum developers to locate related technological themes that can enhance the creativity of students and be used in science lessons or when teaching practical activities (e.g., there are lessons where such subjects may be taught in conjunction with art education in drawing when using forms, objects and structures in the classrooms).

Technological creativity should involve a range of creative thinking skills that should be fostered. In the review of the relationships between technology education and creativity, three aspects were identified: using ICT as a learning tool, a communication tool, and an assessment tool. For learning, ICT tools can be helpful in teaching technological creativity at the classroom level. The discussion brings out some of the many ways in which ICT can support technological creativity. The opportunity that ICTs afford for teaching technological creativity is to help teachers create a sociable atmosphere within the classroom where pupils can feel secure in playing with ideas and risk-taking. ICTs can also be used as a medium for setting up a creative environment at a distance with collaboration between pupils and teachers and non-resident people like designers and engineers. Creative thinking can be developed through emails or video conference.

Assessing technological creativity

It has been shown how to evaluate technological creativity in terms of the three concepts generated in most of the research papers: imagination, originality, value and appropriateness. These are the three related criteria for evaluating technological creative products. Here I will critique how to assess previously identified teaching applications. In this section, I discuss Saudi educational assessment, various ways of evaluating creativity in technology education, the role assessment plays in pupils' creative development, and how evaluative thinking can be taught.

Assessment in the Saudi Arabian educational system

There are few research studies that provide a clear indication of the methods used for assessing student learning in the Saudi Arabian educational system. One article was included for critique, that of Al-Sadan (2000), who signals no major changes in the development of the assessment system in Saudi general education. Currently, for the lower primary Grades 1 to 3, a formative assessment is in use whereas both formative and summative assessments are used for the upper grade levels, Grades 3 to 6. Assessment methods are centralised and academically oriented, with electives for flexibility for teachers to develop the curriculum as in many other developed countries which can develop their own materials. Furthermore, like pupils elementary teachers cannot propose or change the method of assessing student learning or reflect upon content or materials of the subjects. Al-Sadan (2000) described assessment in primary schools based on the educational policy of the kingdom defined in 1970. The main objectives for elementary schools were:

- To implant the true Muslim faith in the heart of the child, and to raise him to behave in accordance with Islamic behaviour with a complete manifestation of its rules in his character, mind and language, and to identify with the Muslim nation.
- To train students to perform their prayers and to observe the rules of conduct and good manners;
- To develop basic skills in the student, particularly those of language, arithmetic and physical fitness;
- To provide the student with a suitable amount of information in all the various subjects;
- To acquaint him with the blessings bestowed by God on him and on his social and geographical environment, so that he may make good use of his gifts, allowing them to be beneficial to him and to his environment;
- To cultivate aesthetic tastes, nurturing creative activities and building a sense of appreciation for his handiwork;
- To develop his talents so that he is aware of the duties and rights appropriate to his age and the special particularities of the stage he is at, and to inculcate love for his fatherland and loyalty to his superiors, who are charged with authority;
- To generate in the student the desire to seek useful knowledge, to learn serviceable work and to benefit from leisure time;
- To prepare the pupil for that phase of life which is to follow his present one.

Assessment at this level of schooling is explained by the educational policy (1970) of Saudi Arabia, as follows:

(1) The year is divided into two terms.
(2) The total mark is divided between the two terms, 50% for each term.
(3) Thirty percent of the total mark is given to continuous assessment during the term (usually by periodic test).
(4) Seventy percent of the total mark is given for a written examination at the end of each term.
(5) The minimum pass mark is 40% of the total mark in social and science subjects, and 50% for other subjects.
(6) In the 1st and 2nd grade of this stage, the final examination for all subjects is oral, except maths and science, in which there are written examinations.
(7) In the 4th grade, all the examinations are written except reading, Islamic songs, Holy Quran, Quran intonation, Islamic law and *Tauhid* (the oneness of Allah).
(8) In the 5th grade, all subjects have written examinations except reading, Holy Quran, Islamic songs and *Tajweed* (Quran intonation), which have oral examinations.
(9) In the 6th grade, all examinations are written except for the Holy Quran, which is assessed by oral examination (pp. 150-151).

The purpose of this initial outline of educational objectives in Saudi Arabia is to show that no major changes are being made towards the development of education as a whole. Assessments remain the same with the only difference being in the method of assessment. Currently, formative and summative assessments are in use by the Ministry of Education; however, the role of teachers in developing any part of the curriculum is still neglected. The call here is for curriculum developers and policy makers to admit the voice of teachers and pupils. For practical subjects like technology, this kind of assessment may not be suitable.

Assessment should follow a different approach, such as assessing pupils' activity over a semester so that assessments would be made by teachers and aligned with the nature of the subject. For example, oral or written examinations are inadequate for assessing the technological outcomes of pupils. An adequate evaluation must embrace both making and doing because technological topics involve interaction between the mind and hand. Pupils should be introduced to a problem and given the task of finding a solution for it. The solution could be designing or making something to help solve the problem. Social, environmental, or economic problems can be set by the teachers.

There are many examples of designing and making activities online available for children all over the world (e.g., books, websites, and activity books) that can assess pupils' technological creativity. For example, pupils can be given the task of evaluating a product online or having them design something using software. This will enhance their imagination, knowledge and skills (Barlex, 2011; Howe et al., 2001). The advantages of using strategies of making and doing as pupils design something as a form of assessment include use of oral language for communication with peers and teachers, imagination, writing skills, drawing and use of materials.

Teachers can evaluate creative thinking, such as identifying ideas, producing appropriate solutions, and changing strategies while pupils process the task. This method of assessment can bring benefit to pupils using their knowledge gained from other subjects such as language, art or science. This type of assessment can also be applied to teaching technological creativity applications in which teachers can identify pupils' learning process. This thesis proposes terming this approach *evaluating technological creativity through making simple products*.

The use of websites is another good way for Saudi teachers because currently schools may lack sufficient space (the physical environment is too small). Thus, pupils can instead design and make things using computers and ICT devices as a starting point for assessment purposes. Using IT and ICTs can overcome the difficulty discussed in the literature that assessing and evaluating may kill a pupil's creativity. Here, the use of different electronic portfolios and questionnaires is recommended.

3.5. Section four: Creativity and culture

Culture plays a critical role in technological creativity in providing the context for creative activities. Whether a culture is and remains creative has much to do with that culture's attitude towards creativity and technology. Societies that have contributed the most to technological creativity have encouraged freedom and have had positive attitudes toward invention and change. In technology education, the meaning of culture is "the shared values and patterns of behaviour that characterise different social groups and communities (NACCCE, 1999, p. 42).

The purpose of discussing cultural values and spiritual awareness in Islam is to show some of the many ways researchers have tried to locate creativity in a culture. Why culture and the people in that culture are so important is that cultures place value on appropriateness and creativity, which is more than just imagination and original ideas. This is what makes culture so influential in the creative process. Culture is understood as a set of rules and symbols rather than something embedded in the mind of the creative person. This view conflicts with what was said previously, that the creative process is a process of mind (DeVore, 1987a; DeVore. et al., 1989; Gow, 2000; Heilman, 2011; Williams et al., 2010) but again this is due to the different ways of defining creativity and accounting for the relationships between creativity, culture, the creative process and the creative person and how they are all interconnected.

When teaching technological creativity, the need is to help students become aware of the use of creativity as it “can be used for good or evil. Not only artists but also criminals can be extremely creative people. This makes it necessary to include an ethical aspect when discussing creativity” (Saebø et al., 2007, p. 207).

3.5.1. Islamic culture: A religious context of creativity

The view of culture here is probably similar to that developed by Hennessey (2003) and Hennessey and Amabile (2010) in the social psychology of creativity. Their findings were based on both empirical research and literature linked to viewing creativity from a cross-cultural perspective. In fact, Hennessey’s (2003) study was a good example to include and was conducted to investigate the motivational orientation of a group of elementary school students and teachers working on creative tasks. The subjects came from two countries: the United States of America and the Kingdom of Saudi Arabia. Before developing the argument based on the relationship between creativity and culture, an illustration of what culture really means to creativity and creativity to culture is significant. In Hennessey’s words, culture:

> …refers to a shared system of cognitions, behaviors, customs, values, rules, and symbols that are learned and socially transmitted … it [culture] concerns the manner in which a set of people interact with their social and physical environment. In 1970, Dawkins coined the term “meme” to refer to units of imitation, pieces of structured information or instructions for action that are worth remembering and that are passed from one generation to the next… a second construct also be added to the cultural lexicon. He [Dawkins] operationalized a “domain” as a system of related memes that change through time. In essence, memes are seen as the building blocks of culture. What changes these memes is creativity. Cultures differ in the way memes are stored. If they are recorded orally and can be transmitted only from the mind of one person to that of another, theorists argue that traditions must be strictly observed so as not to lose information, and creativity is not likely to be prized (p. 192).

Based on the findings from social psychologists and theorists and the Qur’anic context, I developed a religious context of creativity that is based on the philosophy and roots of Islamic culture. As noted previously, close investigation of creativity appears only in the middle of the 20th century – after the 1950s. A large number of the papers included did not discuss the relationship between creativity and religion. Only three of them discussed creativity in its religious sense and seemed to provide some understanding of what creativity is in Islam. From the early stages of the research development:

> …creativity was understood mostly in religious terms – "God the Creator", who created things from nothing (*ex nihilo*). Hence, up to the 20th century, it became a dominant orthodoxy that creativity had a divine origin and creative results appeared from nowhere (e.g. creationism as the religious belief that humanity, life, the Earth, and the universe are the creation of a supernatural being, rejecting evolution as an explanation accounting for the history, diversity, and complexity of life on earth) (Surkova, 2012, p. 116).

This statement captures the similar view in Islam. The word creation is mentioned in the Qur'an in various places. It always refers to Allah's supreme power in creating from nothing. He challenges human beings, declaring that if He willed, He could destroy you and bring about a new creation (Quran 35:16).

> He created the heavens without any pillars that ye can see: He set on the earth mountains standing firm, lest it should shake with you: and He scattered through it beasts of all kinds. We send down rain from the sky, and produce on the earth every kind of noble creature, in pairs. Such is the Creation of Allah: now show Me what is there that others besides Him have created: nay, but the Transgressors are in manifest error (Qur'an 31:10-11).

This phrase quoted from the Qur'an clarifies the term creation which applies only to Allah's creation and cannot be applied to human creativity. Mesquita (2011) confirmed this meaning in Christianity when he states that "during the Christian period, *creatio* designated God's act *ex nihilo*, creation from nothing. *Creatio* thus meant something different than *facere* – to make – and did not apply to human activity" (p. xvii). However, an understanding of the concept of creativity in Islam can refer to two types: Allah's creation – not teachable and human creation – teachable.

The first is Allah's creation – the creation from nothing. By analysing the Qur'anic context, two sub-types can be identified. Humankind, earth, heaven, trees, animals, the moon, the sun, everything surrounding us is created by Allah (Subhanahu Wa Ta'ala) for a purpose, which is to worship Him. Allah in Islam defined as:

(1) Allah!! There is no god but He, – the Living, the Self-Subsisting, Eternal. No slumber can seize Him nor sleep. His are all things in the heavens and on the earth. Who is there can intercede in His presence except as He permitteth? He knoweth what (appeareth to His creatures as) before or after or behind them. Nor shall they compass aught of His knowledge except as He willeth. His throne doth extend over the heavens and the earth, and He feeleth no fatigue in guarding and preserving them for He is the most High, the Supreme (in glory) (Qur'an 2: 255).
(2) Allah is the Light of the heavens and the earth. The parable of His Light is as if there were a Niche and within it a Lamp: the Lamp enclosed in Glass: the glass as it were a brilliant star: lit from a blessed Tree, an Olive, neither of the East nor of the West, whose Oil is well-nigh luminous, though fire scarce touched it: Light upon Light! Allah doth guide whom He will to His Light: Allah doth set forth parables for men: and Allah doth know all things (Qur'an 24: 35).
(3) Allah is He, than whom there is no other god; who knows all things both secret and open; He, Most Gracious, Most Merciful. Allah is He, than Whom there is no other god; – the Sovereign, the Holy One, the Source of Peace (and Perfection), the Guardian of Faith, the Preserver of Safety, the Exalted in Might, the Irresistible, the Supreme: Glory to Allah! (High is He) above the partners they attribute to Him. He is Allah, the Creator, the Evolver, the Bestower of Forms (or Colours). To Him belong the Most Beautiful Names: whatever is in the heavens and on earth doth declare His Praise and Glory: and He is the Exalted in Might, the Wise (Qur'an 59: 22-24).

The concept of worship is clearly demonstrated in the Qur'an with a strong emphasis on the teaching that the main purpose for which all human beings and jinn are created is to worship Allah – "And I (Allah) created not the Jinn and humankind except that they should worship Me (Alone)" (Qur'an 51:56). Not only humans must worship Him but also everything He has created: "The seven heavens and the earth and all that is therein, glorify Him and there is not a thing but glorifies His Praise. But you understand not their glorification. Truly, He is Ever Forbearing, Oft-Forgiving" (Qur'an 17:44). Worship is a wide-ranging concept. It is not just a matter of the prayers people offer every day. Rather it is a holistic concept that embraces every aspect of daily life. In people's daily lives, everything provides an element of worship.

I do not mean to develop a religious argument but rather to clarify and link creativity to a religious context. In doing so, it is necessary to discuss the stories behind these verses in order to understand creativity in Islam and what it means for

Muslims. A good example of this is what the Qur'an has told us about stages of human development.

> And indeed We created man (Adam) out of an extract of clay (water and earth). Thereafter We made him (the offspring of Adam) as a *Nutfah* (mixed drops of the male and female sexual discharge and lodged it) in a safe lodging (womb of the woman). Then We made the Nutfah into a clot (a piece of thick coagulated blood), then We made the clot into a little lump of flesh, then We made out of that little lump of flesh bones, then We clothed the bones with flesh, and then We brought it forth as another creation. So Blessed is Allah, the best of creators (Qur'an 23: 12-14).

From the example above, teachers can develop case studies to teach pupils how human beings were created in a way that links science, technology (in terms of progress) and most importantly creativity which will not only enhance their understanding of creativity but can strengthen in them other aspects of religion such as faith. Another sub-type of the first type is illustrated through directions which Allah gave to His Prophets to deliver his messages to humankind. An example of this type is illustrated many times in the Qur'an. The most relevant to the idea of *creation from nothing* is what Allah has given Jesus Christ (SAW):

> And (appoint him) an apostle to the Children of Israel, (with this message): "I have come to you, with a Sign from your Lord, in that I make for you out of clay, as it were, the figure of a bird, and breathe into it, and it becomes a bird by Allah's leave: and I heal those born blind, and the lepers, and I quicken the dead, by Allah's leave: and I declare to you what ye eat, and what ye store in your houses. Surely therein is a Sign for you if ye did believe (Quran 3:49).

It is also argued by Surkova (2012) that this type of creativity is not accessible to everyone and is not teachable. "…only some elite people, e.g., genius writers, can get creative inspiration from God. These views did not allow regarding creativity as teachable" (p. 116). A second example is the story of Moses (SAW). Allah said to Mohammed (SAW):

> Has the story of Moses reached thee? Behold, he saw a fire: so he said to his family, "Tarry ye: I perceive a fire: perhaps I can bring you some burning brand therefrom, or find some guidance at the fire." But when he came to the fire, a voice was heard: "O Moses! "Verily I am thy Lord! Therefore (in My presence) put off thy shoes: thou art in the sacred valley Tuwa. "I have chosen thee: listen, then, to the inspiration (sent to thee). "Verily, I am Allah: there is no god but I: so serve thou Me (only), and establish regular prayer for celebrating My praise. "Verily the Hour is coming – My design is to keep it hidden – for every soul to receive its reward by the

> measure of its Endeavour. “Therefore let not such as believe not therein but follow their own lusts, divert thee therefrom, lest thou perish!”… “And what is that in thy right hand, O Moses?” He said, “It is my rod: on it I lean; with it I beat down fodder for my flocks; and in it I find other uses.” Allah said, “Throw it, O Moses!” He threw it, and behold! It was a snake, active in motion. (Allah) said, “Seize it, and fear not: We shall return it at once to its former condition”… “Now draw thy hand close to thy side: it shall come forth white (and shining), without harm (or stain), - as another Sign, - “In order that We may show thee (two) of our Greater Signs. (Quran 20:9-23).

The second type refers to the human creation of things (materials) and people - teachable. This type has its value in solving real issues. In Surah (Chapter) Al KAHF (Cave), the story of Zul-qarnain is one example:

> Until, when he reached (a tract) between two mountains, he found beneath them, a people who scarcely understood a word. They said: ‘O Zul-qarnain! The Gog and Magog (people) do great mischief on earth, shall we then render thee tribute in order that thou mightiest erect a barrier between us and them? He said: (The power) in which my Lord has established me is better (than tribute): help me therefore with strength (and labour): I will erect a strong barrier between you and them. Bring me blocks of iron. At length, when he had filled up the space between the two steep mountain-sides, he said. ‘Blow (with your bellows)” then, when he had made it (red) as fire, he said: “Bring me, that I may pour over it, molten lead. Thus were they made powerless to scale it or to dig through it. He said: this is a mercy from my Lord: but when the promise of my Lord comes to pass, He will make it into dust; and the promise of my Lord is true (Quran 18:93-98).

From this story, pupils can learn useful aspects related primarily to doing and making activities and how materials can be used for doing good deeds. The story began with identifying a real social problem (Gog and Magog do great mischief on earth) and then the people who sought help from Zul-qarnain had the idea to build a barrier between them and other people to protect them. This example can provide students with a task in the form of an activity linked to their culture; in it they can learn a form of the creative process.

Islam is the main religion in Saudi Arabia and the Qur’an is the first source for every aspect of life. In Saudi science textbooks (all textbooks can be found at www.nooor.com and all are written in Arabic), there are verses and direct quotations from the Qur’an used at the beginning of each lesson to express the importance of learning science and in assisting pupils to explore scientific concepts and truths related to religion as well as in having them understand the importance of observation (as a scientific technique) and thinking – two terms that are widely used in the Qur'anic context. Thus, it is also of major relevance that students should be introduced to the technical components (technology) and encouraged to stimulate their inventive thinking and employ their interests in making and doing activities. Technology (as an area of study) could be introduced to students through their study of science. The Qur'an provides instances of technological concepts and activities. The story of Zul-qarnain is a good example of creativity in designing and creating. It might bring the question to mind regarding how he thought of using these specific materials, blocks of iron and pouring lead, to fill the gap between the two mountains. This is only one example of the creative ideas illustrated in the Qur'an. Indeed, there are many names of materials that can be used to benefit people and help them. For example, Surah Al-HADEED (iron):

> …We sent down Iron, in which is (material for) mighty war, as well as many benefits for mankind, that Allah may test who it is that will help, Unseen, Him and His apostles: for Allah is Full of strength, Exalted in Might (and able to enforce His will)" (Quran 57:25).

In short, the point is that the view of the relationship of creativity to culture differs from one country to another based on the beliefs and attitudes people hold. Therefore, culture can also be added to the features that define creativity. As illustrated in the examples used from the Qur'an, religious creativity includes reference to technical strategies and actions. Technological creativity, then, is the process to produce original, imaginative, valuable and appropriate, and most importantly ethical and culturally-appropriate ideas.

CHAPTER FOUR: CONCLUSION

4.1. Summary

The findings of this CIS and the papers studied produced a large amount of data that informs the educational context in Saudi Arabia. In this chapter, a reflection on the thesis process along with a concise answer to the research question are developed with recommendations for further research.

The previous chapter presented four sections on the topic of creativity in technology education. Section one illustrated and discussed research and definitions from psychology, education and technology education. Section two reviewed key dimensions of creativity and their role in constructing technological creativity. Section three concluded by first presenting the place of technological creativity in the form of practice and secondly by a brief description of the pedagogy of technological creativity. It also focused on developing an understanding and awareness of the relationship between science and technology and how technological creativity can be taught through existing elementary school subjects. Section four explored the mutual relationship between culture and creativity and developed an Islamic context for creativity with some examples from the Qur'an and how it plays important role in guiding pupils in linking the creative process to what is religiously, culturally and ethically appropriate and inappropriate, based on the beliefs and attitudes held by Saudi Arabian culture and people.

What was found particularly useful about CIS, the research methodology selected, was the exploration of concepts, themes and categories across the papers. This CIS study affords an opportunity not only to identify themes by the authors but to construct an interpretation argument about the topic proposed, teaching technological creativity in the Saudi Arabian elementary school context. I began this review trying to find key themes in the literature on how technological creativity can be taught in elementary education in Saudi Arabia by making connections between relevant studies from different countries and various educational contexts. What I have in fact found is that there is no single study that can help in providing an in-depth view of the topic, especially with respect to Saudi Arabia. Thus, I decided to aggregate relevant literature about teaching technological creativity in the technology education context in developed countries and how technological topics can be taught in order to appropriately answer the thesis question. After gathering a diverse body of literature, synthetic constructs were developed to create the synthesising argument which is the core element of the whole process and to provide insights first of all into how technological creativity as a technology topic could be taught in the Saudi context and secondly, to call for the integration of technology education into Saudi general education. As a technology educator, I advocate the demonstration of the kind of research and possibilities that are available through an examination of the literature utilised. As I have produced a new comprehensible model about how the topic can be taught, I realise that I have done something *new* for Saudi Arabian education and *different* for developed countries that have the topic defined in their curriculum.

In the review process, I started by identifying concepts and themes that could assist in developing a critical view of the studies. Categories such as the development of the concept of creativity, its process in technology education, and implications for curriculum and teaching practices were utilised in the review (Chapter Three) but were not directly developed in all of the included studies. In each of these categories, there were concepts forming sub-categories related to each of them. For example, when defining creativity in technology education, I also presented researchers' perceptions of invention and innovation. Then, for the pedagogy of technological creativity, I critiqued studies which can inform the Saudi context by identifying studies on how technological concepts can be taught through other subjects, using the idea of technology across curriculum. I decided to focus on themes that have direct responses to the research question because the findings would have a wider applicability to the topic of teaching technological creativity. Under the headings, key elements emerged from a CIS review of the literature. Those headings were utilised as a framework for synthesizing the data. Each of these themes presented a construct of its own because each focused on a separate theme but still plays its role in the construction of the process.

4.2. Teaching technological creativity in the Saudi Arabian elementary school context

It is apparent that teaching technological creativity in the Saudi Arabian elementary school context is possible. This possibility is accompanied by considerable constraints at various levels. Based on the findings, the answer to the question can be found at four connected levels: the societal level, Ministry of Education level, school/classroom level, and teacher level.

Foremost at the social level, if there is no religious awareness for developing and understanding technological creativity as a good deed activity, teaching technological creativity can be difficult. People at all levels of schooling, including adults and extra-mural students, are guided and influenced by their Islamic roots and religion. A successful implementation of technological creativity and hence technology education is dependent on the religious view of the subject, technology education – how Islam sees technology education. If people understand technology as a good deed activity, that good deeds can take many forms, then it will be much easier for the Ministry of Education to develop an independent learning area called technology education which will then support teaching technological creativity. This is not to say that pupils should wait until a technology subject is introduced. I argued that technological creativity should be taught through existing subjects and that each of the learning areas presented in **Table 13** can contribute to teaching pupils technological creativity.

For instance, through the Islamic studies subject teachers can develop an awareness in pupils that technological creativity is a good deed activity in which it can serve people in solving social, environmental, and economic problems by considering the “doing” aspect of technology. All that pupils currently learn are theories and facts as is the case in science education, as argued previously in this research. Pupils do not practice what they learn in science but this problem can be solved by teaching technological creativity as pupils will need to have a general understanding of the nature of scientific knowledge, for example knowledge of materials, forces and tensions. In addition, they will need to have an understanding of specific domain knowledge which includes technological, practical knowledge.

Creative knowledge is indeed a combination of general and specific knowledge needed for both teachers and pupils. This knowledge of science and technology can be identified in the Qur'an; a few examples were illustrated in Sections Three. Thus, developing an awareness in pupils through the Islamic studies subject can shorten the way and save time in getting technology education into pupils' lives. While this seems a very general method for teaching/studying practical subjects such as technology education, no one can dismiss the fact that a large percentage of people in Saudi Arabia (90% and above) would agree about the necessity of good deed activities of every kind. Thus, technology education is the only subject pupils need to learn when it comes to teach them manufacturing, designing, technological problem-solving, thinking and creative thinking skills.

In the area of Arabic studies, I noted that the language includes an element of creativity and was the focus of a number of papers on technology education (Campbell & Jane, 2012). Pupils need to have a language of communication in order for them to know the names of materials or processes and also in order for them to communicate with their colleagues and other teachers. From Grade 4 when pupils are 9 or 10 years old, they can learn technological language as they take the English language subject. The use of the English language from Grade 4 brings other learning benefits, e.g., practicing what they learn in the English classroom. Thus, this makes English language teachers involved in teaching technological vocabulary to pupils at Grades 4, 5, and 6. Teachers can use the history of technological innovations available online to create and develop lesson plans and activities on the subject. Teaching technological English words to pupils will not require any changes in the current curriculum as it relates more to the teacher's responsibility to include appropriate use of technological language in their classroom tasks.

Above all, social studies such as geography, history and national education, as it is called in the Saudi Arabian education system, or citizenship education as it is known in Western countries (Howe et al., 2001) are a good place to develop an awareness in pupils of the social and environmental values of teaching technological creativity and technology education. Science and mathematics are essential to technology education. This links to cognition and acquiring knowledge in these subjects.

Art education also proceeds in a similar way in terms of the learning process. Pupils usually are introduced to an artistic work and asked to produce something that is of interest to them. Learning involves the use of materials and special tools for accomplishing the activity or task. So there is an identified topic, use of materials, and procedures. This can function as a technological creativity activity or lesson but is still different in that lessons in art education usually are not introduced as problem-solving which is the core of technological creativity. Some examples were identified in Section Three. With the exception of physical education, all existing subjects can provide opportunities for teaching technological creativity. Thus, technological creativity can easily be taught and learned independently until a technology curriculum gets established in the general education system.

One more aspect to highlight is the use of computers. Computers and the internet can be a useful tool of technological creativity at the beginning stages of the teaching and learning process. Barlex (2011) and Howe et al. (2001) introduced what they termed visual literacy where pupils can use ICT tools, for example to evaluate other products online or exercise their skills through the use of online activities.

At the Ministry of Education level, curriculum developers should take curriculum design theories into account. In all existing subjects, there should be a clear definition of what technology education is and why pupils need to learn it. Not all curriculum design theories will be used in the development of a technology curriculum. For example, the religious relevance curriculum design theory can be developed in Islamic studies subjects which will then inform pupils and make them aware of the importance of learning technology education. The religious relevance developed in Section Three supports both technology education (the subject) and technological creativity (the topic of the thesis). The topic should be considered a compulsory skill and every pupil should have at least a general understanding of it. This can be aligned with science with clear definitions of both science and technology education. There is the possibility of integrating lessons into the current science curriculum. The use of materials is a sub-field in technology education and shares with it common knowledge, scientific and technological.

A second task for the Ministry to consider is to allow teachers to be more independent in choosing appropriate methods and allow for creative teaching approaches to be adopted at the classroom level. Students also should have greater freedom in choosing activities that inform their own interests and are relevant to their lives. This will then reflect on teachers' decision-making strategies and their relevance in constructing pupils' learning.

At the school/classroom level, the Ministry has the responsibility to provide a comfortable physical and psychological environment for teachers and pupils to enable them to act effectively. The physical environment concerns classroom equipment from lighting to furniture, resources, class size, and the use of computers, decoration, and space configurations in allowing risk-taking to take place. Saudi Arabia is currently witnessing a development, the first of its kind across the country, in the construction of schools so for schools that lack necessary equipment, science laboratories – if necessary – can be used instead.

At the teacher level, there is the need to educate in-service teachers about cognition and learning in technology education and aspects of technology and technology education such as knowledge and technological literacy. Teachers do not have to be specialists in order to teach technological creativity or technology education at the elementary level. At this level, technology can take a general form in technology education. Three major themes for teachers are: having good knowledge of the domain, encouraging pupils and this will depend on the use of creative approaches, and motivating pupils and having them enjoy learning.

4.3. Further research

This review presented theoretical and practical orientations for teaching technological creativity. It also emphasised the integration of technology education as a discrete subject in Saudi Arabian schools, which is an urgent area of need for close investigation.

For future attempts at CIS, technology scholars could draw on this thesis. Different criteria for the formulation of the research question and inclusion of related literature from various philosophical and methodological assumptions can add to the existing body of literature, developing new alternatives for understanding and critique. This would benefit future researchers of technology education. There are many more areas where CIS can offer a rich context to inform Saudi Arabian general education, for example using CIS for conducting similar studies on different topics that can help learning and teaching situations. Some areas of needs are: the nature of technology and technology education, the nature of technological knowledge and practice, technological literacy, assessment and curriculum development.

For future research, this thesis considers the inclusion of technology education in elementary schools a necessary foundational subject if Saudi Arabia is to maintain and increase its economic competitiveness on the global stage. The need is to develop a form of technology education defined in the curriculum as well as clear strategies and goals for achieving this. It is important for Saudi Arabian educational policy makers to acknowledge that:

- Technology education should be taught in elementary schools;
- The technology curriculum should aim at providing citizens with technological literacy; and
- Given the fact that little research in technology education has ever been done in Saudi Arabia with respect particularly to elementary education, it is urgent that planning of research in technology education be considered so that current curriculum and innovations in teaching, learning, assessment, and teacher education and teacher development in technology are research-based.

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APPENDIX

An integrative grid table of papers, researchers, and countries represented

Paper no., author, date & country	Title	Focus (themes, concepts, main constructs)	Research approach & methodological characteristics	Publication/data source
1. AbuJarad, I. Y., & Yusof, N. (2010) Malaysia	Innovation creation and innovation adoption: A proposed matrix towards a better understanding	- To distinguish between innovation adoption and innovation creation as two different concepts. - To differentiate between innovativeness, invention, and creativity. The paper introduced a matrix which explains the two concepts of innovation creation and innovation adoption as two separate concepts. The matrix differentiated between those firms which are innovative from those which are adopters of innovation.	**An analysis of previous research	*International Journal of Organizational Innovation*, *3*(1), 303-325. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/746769259?accountid=

				17287
2. Almutairi, A., Everatt, J., Davis, N., & Snape, P. (2010) Saudi Arabia and New Zealand	Technology education in primary schools of New Zealand and Saudi Arabia: A comparative study	To explore whether technology education should be taught as a separate subject in Saudi Arabia. The overall aim of the paper was to inform a reconceptualization of technology education in the Saudi curriculum. This short paper is a part of ongoing research (as part of the researcher's doctoral dissertation) and presented early findings from the documentary analysis and classroom observations. The findings suggested that technology education may be a worthwhile addition to the Saudi national curriculum and that more research is required.	*Qualitative approach. Document analysis, classroom observation, and interviews with participants were used as major instruments to obtain the data for the investigation	*The Biennial Conference of Technology Education New Zealand (TENZ 2011)* 1-10. Retrieved from http://www.tenz.org.nz/2011/proceedings.cfm
3. Al-Sadan, I. (2000) Saudi Arabia	Educational assessment in Saudi Arabian schools	The paper described the methods of assessing pupils' learning which are currently in use in the Saudi system. It started with an overview of Saudi Arabia and then described main features of the Saudi educational system, with special reference to the structure of the curriculum, its design and its development process. It then explained the assessment, guidance and regulation from the Minis-	**Review of literature	*Assessment in Education*, *7*(1), 142-155. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://searc

		try of Education.		h.proquest.com/ docview/204096 784?accountid= 17287
4. Amabile, T. M. (1997) USA	Motivating creativity in organization: On doing what you love and loving what you do	To discuss the role that intrinsic motivation, expertise, creative thinking skills and environment play in creativity, particularly in management.	*Review of previous research & a research study on creativity using an instrument called KEYS for data collection (using a standard questionnaire). Assessing the Climate for Creativity consisting of 78 items that constitute eight scales addressing different aspects of the work environment, plus two scales assessing the	*California Management Review 40*(1), 39-58. Retrieved from http://ezproxy.wai-kato.ac.nz/login ?url=http://search.proquest.com/ docview/216129 307?accountid= 17287

			work outcomes of creativity and productivity.	
5. Balchin, T. (2008) UK	A creativity feed-back package for teachers and stu-dents of design and technology (in the UK)	A brief synopsis of some of the major findings from a 3-year research project, carried out with the aim of developing materials which recognize and support creativity for learners at Key Stage 3 (age 12-14).	*Doctoral thesis	*Design and Technology Ed-ucation: An In-ternational Journal*, *10*(2), 31-43. Retrieved from http://ojs.lboro.ac.uk/ojs/index.php/DATE/article/view/124
6. Banaji, S., & Burn, A. (2007) UK	Creativity through a rhetorical lens: Im-plications for schooling	(1) To develop a form of creativity that constructs it as a series of rhetorical claims. These claims emerged from the different contexts of re-search, theory, policy and practice. (2) To explain how different rhetorical construc-tions of creativity might have differing impacts on pedagogic strategies in relation to literacy.	**Review of litera-ture	*Literacy*, *41*(2), 62-70. doi: 10.1111/j.1467-9345.2007.00459.x

7. Baqutayan, S. M. S. (2011) Saudi Arabia	Issues in the implementation of science and technology education in Saudi Arabia	To discuss the barriers towards the implementation of science and technology in the Arab world with an overview focus on Saudi Arabian education. The article discussed language, curriculum, and the method of teaching.	**Review of literature	*International Journal of Applied Science and Technology, 1*(5), 165-170. Retrieved from http://www.ijastnet.com/journals/Vol_1_No_5_September_2011/21.pdf

8. Barlex, D. (2007) UK	Creativity as a feature of technological literacy	To present considerations of the place of designing creativity within technology education and features of creativity as outlined in the report *All Our Future: Creativity, Culture and Education* (Robinson, 1999), conditions needed for creativity.	**Review of literature	Paper presented at the PATT 18, Pupils Attitudes Towards Technology. International Conference on Design and Technology Educational Research, Teaching and Learning Technological Literacy in the Classroom, Glasgow, Scotland. Retrieved from http://www.iteea.org/Conference/PATT/PATT18/fullprog-21a[1].pdf

9. Barlex, D. (2011) UK	Achieving creativity in the technology classroom	To discuss the implications for creativity in the technology classroom. The study discussed and presented eight considerations relating to achieving creativity in a technology classroom: - Relating creativity to designing - Achieving creativity through designing and making - Achieving creativity through designing without making - Developing a curriculum framework that supports creativity - Using the digital Design and Technology programme to support creativity - Creativity through design and technology in the STEM context - The relationship between assessment and creativity - The role of collaboration in achieving creativity through design and technology.	**Review of research	In M. Barak. & M. Hacker (Eds.), *Fostering human development through engineering and technology education*, (pp. 103-129). Rotterdam, Netherlands: Sense Publishers.

10. Benson, C. (2011) UK	"I'm choosing purple not pink": Investigating children's perceptions of their experience of design & technology in relation to creativity	To investigate children's perceptions of their experience of design and technology in relation to creativity. The research study developed a framework for teaching creativity in design and technology in the classroom. The study considered four key elements: ownership and control, relevance and motivation, space and time, and interaction with others.	*Questionnaire data were collected from five primary schools in the West Midlands to draw on children's perceptions in years 5 and 6 (aged 9-11)	Paper presented at the PATT 25:CRIPT8, *Perspectives on Learning in Design & Technology Education*, London.
11. Biddulph, F., & Carr, C. K. (1999) Hamilton, New Zealand	Learning theories and curriculum	Like those of Zuga (1989) and Williams (1996a), this article focused on learning theories and their role in curriculum design.	**Review of literature	*Teachers and Curriculum, 3*, 31-35.

12. Bitter-Rijpkema, M., Pannekeet, K., Rutjens, M., Sloep, P., Georgiakakis, P., Retalis, S., & Dolog, P. (2008) The Netherlands	Creativity: A unique quality	(1) To develop a set of web-based, context sensitive tools and techniques that may enhance a team's creativity in the creative phases of New Product Development (NPD). (2) To explore the concepts of creativity, invention and innovation as important concepts in the context of NPD. Innovation can be defined as the process of putting new ideas into practice; it refers to the implementation of new or significantly improved products (goods or services) and processes. The IdSpace project focused on the support of the creative phases of idea generation, idea selection and construction.	**Project deliverable report (IdSpace)	Creativity: A unique quality (idSpace D1.1 State of the Art on Pedagogical Strategies, pp. 16-29). Heerlen, Netherlands: Open University of the Netherlands.

13. BouJaoude, S. (2003) Lebanon	Science and technology in the Arab world in the 21st century	This article discussed concerns about science and technology education in the Arab world with respect to the issues facing student learning in many Arab countries.	** A general review of the literature	*UNESCO International Science, Technology & Environmental Education Newsletter*, pp. 1-6. Retrieved from http://unesdoc.unesco.org/images/0013/001335/133581e.pdf
14. Burton, P. (2010) Hong Kong	Creativity in Hong Kong schools	The researcher examined discourses of creativity in English-language education in post-colonial Hong Kong, where educational reform has mandated a change from transmissive to interactive modes of teaching and learning and a shift towards more creative methods of teaching English. The literature was reviewed with respect to discourses of creativity both internationally and in the Hong Kong context. An ethnographic study of an inno-	**Review of research literature	*World Englishes, 29*(4), 493-507. doi:10.1111/j.1467-971X.2010.01677.x

		vative project in a Hong Kong secondary school, using poetry and creative writing in the language classroom, was presented. Findings from this study, carried out between 1999 and 2001, illustrate how pedagogical discourses of creativity – such as creative tasks, the creative process and communities of practice – are more significant at classroom level than simple East-West dichotomies, and how such discourses can be productive both for teachers and students despite institutional and social constraints.		
15. Campbell, C., & Jane, B. (2012) Australia	Motivating children to learn: The role of technology education	The study was conducted to report on research that focused on the language that children used when they were involved in a design and technology activity. The findings suggested that the children's motivation was high and played a significant role in children's task engagement and persistence. The analysis of this study's findings illustrated that there were key concepts that the children focused on, namely: the fun experienced by participating in the activity, the difficulty of doing the task, the satisfaction of completing the task, the importance	*Content analysis was used as a research approach in a traditional and descriptive manner. The researchers used a written recorded booklet – a journal of thoughts for seeking the children's perspec-	*International Journal of Technology and Design Education*, *22*(1), 1-11. doi:10.1007/s10798-010-9134-4

		of social interaction and the frustrations surrounding aspects of the task.	tive on aspects of the technology task. The total number of booklets was 80 and each booklet consisted of five pages for writing and five pages for annotated drawings. Two case study schools involved four separate classrooms of Grade 4 (9-10 years of age) who were the participants in this research study.	
16. Caney (2006) USA	*Steven Caney's ultimate building book*	One of the recent books that focuses on providing design and technology ideas with various forms of lessons and activities which can be used not only in a technology	***Activity book	China: Running Press Book Publishers.

		classroom but also in science. The book illustrates creative knowledge and a comprehensive exploration of design, construction, and invention.		
17. Chiu, C., & Kwan, L. Y. (2010) Singapore	Culture and creativity: A process model	(1) To discuss the role of culture in creativity; providing a process model of creativity that explains the role of culture at each stage of knowledge creation. (2) To develop an argument that a successful innovation involves one or more iterations of the following three stages: (1) authoring new ideas, (2) selecting, editing, and marketing new ideas, and (3) acceptance of the new ideas in the market. (3) To discuss different social and psychological processes which impact the stages of the creative process.	**Review of literature and research	*Management and Organization Review, 6*(3), 447-461. doi:10.1111/j.1740-8784.2010.00194.x
18. Christiaans, H., & Venselaar, K. (2005) The Netherlands	Creativity in design engineering and the role of knowledge: Modeling the expert	To focus on the relationship between the acquisitions of design knowledge by novice design students and the quality of their designs. Also, knowledge of solution processes and knowledge of	*Research based on projects designed during a design course in the	*International Journal of Technology and Design Educa-*

		managing and monitoring the solution finding process.	School of Industrial Design Engineering (Shneiderman) at Delft University, the Netherlands. 20 first-year students were asked to write a 'learner report' at the end of a design project. The learners' reports were used as data input for the study.	*tion, 15*(3), 217-236. doi: 10.1007/s10798-004-1904-4
19. Clinton, G., & Hokanson, B. (2012) USA	Creativity in the training and practice of instructional designers: The design/creativity loops model	To offer a conceptual model of the connection between creativity and instructional design. To explore ways that design and the development of the creative process can benefit from an emphasis on creativity.	**Review of research	*Educational Technology Research and Development, 60*(1), 111-130. doi:10.1007/s11423-011-9216-3

20. Craft, A (1999) UK	Creative development in the early years: Some implications of policy for practice	To identify creative development as a desirable early years learning outcome by the School Curriculum and Assessment Authority (SCAA) with the aim to provide a rationale for the inclusion of creativity in the curriculum of young children in a post-modern world at the turn of the century. The study concluded by proposing a framework for interpreting the creative development characterized by SCAA and the way it should be translated into practice. The main focus of this study was on creativity in education.	**Review of literature	*Curriculum Journal*, *10*(1), 135-150. doi: 10.1080/0958517990100110
21. Craft, A. (2001) UK	An analysis of research and literature on creativity in education	The paper was an analysis of research literature on creativity in education. It provided a comprehensive view of the research development of creativity prior and post the 1950s – the recognition in research of Guilford's work in psychology. In the review, Craft focused on analyzing texts related to education and developed in the foundation disciplines of psychology, philosophy, sociology and neurophysiology, as well as applied areas such as business and education policy and practice. The texts are mainly from North America and Great	**Analysis of research literature	Qualifications and Curriculum Authority, 1-37. Retrieved from http://www.euvonal.hu/images/creativity_report.pdf

		Britain but also include texts from Australia, Austria, Germany, Japan, the Macedonian region of former Yugoslavia, Italy, Bulgaria, Norway, Sweden and the Sudan. The paper investigated previous studies on creativity in its generic form rather than within subject domains. Briefly, the paper examined themes such as the nature of creativity, the development of creativity in education, and assessing creativity. Each of these themes has related sub-themes which all provided a generic view of the topic of creativity for both classroom and school curriculum – especially in the early years.		
22. Craft, A. (2003) UK	The limits to creativity in education: Dilemmas for the educators	To examine possible social, environmental, cultural and ethical limits to creativity, in the context of educating for creativity. To argue against the context of a political, social and economic discourse of creativity in education. Presenting the issues that stifle creativity, the author suggested that there were a number of potential limitations to the fostering of creativity in education, i.e. difficulties of terminology, conflicts	**Review of literature	*British Journal of Educational Studies*, *51*(2), 113-127. Retrieved from http://www.jstor.org.ezproxy.waikato.ac.nz/stable/3122416

		between policy and practice, limitations in curriculum organization, and limitations stemming from a centrally controlled pedagogy. The author also suggested that there were issues related to the social, environmental and ethical limits to creativity, noting that creativity may not necessarily be seen as having universal relevance and value.		
23. Cropley, A. (2006) Australia	Creativity: A social approach	The author developed a social approach to creativity. A social approach can offer the opportunity of distinguishing between large and small amounts of novelty, as well as between "orthodox" and "radical" novelty. The approach is also a way to explain some differences among teachers in the way they see creativity and creative students. The social approach also emphasizes the importance of groups, role models and mentors, and classroom climate, all of which teachers can influence.	**Review of research	*Roeper Review*, 28(3), 125-130. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/206711801?accountid=17287

24. Cropley, D. & Cropley, A. (2010) Australia and Germany	Recognizing and fostering creativity in technological design education	To provide a functional model of creativity that offers guidelines for making plain to students what they are expected to achieve with their designs and for diagnosing the creativity of the designs they offer (guidelines for design pedagogy).	**Review of previous research and literature	*International Journal of Technology and Design Education, 20*(3), 345-358. doi: 10.1007/s10798-009-9089-5
25. Custer, R. L. (1999) USA	Design and problem-solving in technology education	(1) To examine problem-solving and design from the perspective of technology education. (2) To suggest ways in which the technology education field can contribute positively across the entire school system.	**Review of Literature	*National Association of Secondary School Principals. NASSP Bulletin, 83*(608), 24-33. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/216046803?accountid=

				17287
26. Custer, R. L., & Wright, R. T. (2002) USA	Restructuring the technology teacher education curriculum	The paper provided insights into training pre-service educators how to teach the content contained in Standards for Technological Literacy in their K-12 classrooms. It is important that the field think more broadly about curricular reform, including such thorny challenges as integrating technology content across disciplines, stimulating students to engage in meaningful reflection on technological activities, and equipping students to cope with the inherently dynamic and expansive nature of technology. The paper raised, framed and clarified curricular issues that, in the authors' judgment, must be addressed as a function of what Standards for Technological Literacy contains.	**Review of literature	In CTTE yearbook planning committee (Ed.), *Essential Topics for Technology Educators* (pp. 150-173). New York: McGraw-Hill. Retrieved from http://www.glencoe.com/sites/common_assets/trade_ind_ed/pdfs/ctte_yearbook_2009.pdf

27. Davis, M. (2011) USA	Creativity, innovation, and design thinking	To establish operational understandings of the terms curriculum, pedagogy, and assessment that foster students' creative thinking specifically in relation to design problem-solving.	**Review of research and literature	In S. A. Warner. & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education*, (pp. 149-181). Reston, VA: Council on Technology Teacher Education (CTTE USA). Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011

28. Day, G. F. (2011) USA	Developmental stages of humans and creativity	The paper dealt mainly with the developmental stages of humans and creativity. It argued that educational reforms should come through the building of curricular activities around developmental insights from, for example, Piaget, Bruner, Erikson, Bloom, and Maslow. They developed their insights based on the concept that human beings go through fairly discrete stages of development that have specific developmental needs or tasks, and that each stage calls for a rather special educational treatment. The paper concluded with a stress on the necessity of taking into consideration the physical, intellectual, emotional, and social developmental needs of students in order to promote the concept of creativity in technology education.	**Review of research literature	In S. A. Warner. & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education*, (pp. 88-119). Reston, VA: Council on Technology Teacher Education (CTTE). Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011
29. Demirkan, H., & Hasirci, D. (2009) Turkey	Hidden dimensions of creativity elements in design process	To determine the items that can be evaluated as the components of creativity in design process. The researchers' findings emphasized the product as the strongest factor (a hypothetical construct) in	Factor analysis technique was used to determine the components of cre-	*Creativity Research Journal, 21*(2-3), 294-301. doi:

		determining creativity in the design process. From their components analysis, they found that the primary dimension responsible for 46% of the total variance is only composed of the product components. The second dimension, responsible for 19.54%, and the third dimension, responsible for 14.46% of the total variance, are both composed of the interaction of person and process components.	ativity dimensions that comply with the design process. There were 15 participants from 3rd-year design students. The data were collected while designing a task in the design studio using observational sheets. Then from these data new dimensions were developed.	10.1080/10400410902861711

30. DeVore,P. W., Horton, A., & Lawson, A. (1989) USA	Creativity, design and technology	(1) To provide a hands-on guide source to fostering creative thinking in students. (2) To offer teachers useful information on the creative process for extracting ideas to use the hand and the mind for teaching creativity and its processes in the design and technology context.	***Activity book	New York: Delmar Publishers, Inc.
31. DeVore, P. W. (1987) USA	Creativity in the technologies: A search for insight-inventors and inventions	To investigate the technical research process from three perspectives: (1) the individual inventor or researcher, (2) the manager of the research process and (3) selected inventions in several fields of technology.	**Review of research	In CTTE yearbook planning committee (Ed.), *Essential Topics for Technology Educators* (pp. 75-101). New York: McGraw-Hill. Retrieved from http://www.glencoe.com/sites/common_assets/trade_ind_ed/pdfs/

				ctte_yearbook_2009.pdf
32. DeVore, P. W. (1987) USA	Technology and science	An investigation of technical related research on the different forms of technology and science. The paper argued that the distinction between technology and science as different forms of human behavior, where the concepts of technology and science are found at different ends of the continuum, is probably false. The paper suggested that the truth of the matter is that (1) technology is one of the sciences, as are biology, psychology, sociology and other disciplines concerned with human behavior, and (2) the source of the problem is the	** Technical research and literature	In CTTE yearbook planning committee (Ed.), *Essential Topics for Technology Educators* (pp. 2-20). New York: McGraw-Hill. Retrieved from Retrieved from

		term science as it is commonly used. Even if the problem is explored using the commonly accepted definitions of science and technology, we find two distinctly different forms of activity with different goals, questions and means. Each field is mutually exclusive and not mutually dependent, although as with all sciences, each has been enhanced by the other. The paper's findings differed from what was found in research about technology and science and concluded that perceptions on the relationship between the nature of science and technology depend on a person's background. Those perceptions varied all the way from seeing technology as a tool, to regarding technology as a major component of the adaptive systems of civilization. Other views defined technology as a skill, craftsmanship, artifacts, technique, work or a system of work, engineering, a body of knowledge, a discipline, a system of means, an effect and other similar constructs. The same was the case with perceptions about science. Each perception differed, depending		http://www.glencoe.com/sites/common_assets/trade_ind_ed/pdfs/ctte_yearbook_2009.pdf.

		on the viewpoint of the individual espousing the view or perception.		
33. Dove, J. (2009) Australia and New Zealand	Applied literacy design and technology writing skills	(1) To supply teachers and students with writing activities which can be applied to design and technology, graphics technology, tehnics, industrial technology, information processes and technology. The activities presented in this book are designed for application within a variety of subjects. The writing tools presented in this activity book are necessary for students to acquire sound writing skills and to be successful communicators, which is a vital component of all academic courses. (2) To provide students with vocabulary, scaffolds and a model demonstrating the outcome of their writing. These necessary writing tools are included for each text type presented in the book. These text types include procedures (writing directions), factual reports (pamphlets, newspaper reports), expositions (letters of opinion, formal speeches), recounting (diary entry), explanations (web pages, formal es-	***Activity book	Christchurch, New Zealand: User Friendly Resources.

		says-generic structures, feature articles, design journal entries), and discussions (extended responses for senior courses).		
34. Dow, W. (2006) UK	Implicit theories: The impact on technology education	To explain the potential of implicit theories for teachers and students in relation to everyday learning and with a particular focus on the consideration of how these theories may enhance the learning situation in a technology classroom. The author's view of implicit theories made a strong link to the aspects that are particularly relevant to the teaching of design and technology where creativity was one of the core elements.	**Critical review	In J. R. Dakers (Ed.), *Defining Technological Literacy towards an Epistemological Framework* (pp. 239-250). New York: Palgrave Macmillan.
35. Fleer, M. (1999) Australia	The science of technology: Young children working technologically	To examine the feelings, experiences and design ideas expressed by children in a technological activity.	*Content analysis of video materials, field notes, photographic material and children's workbooks of 5-11 year old students.	*International Journal of Technology and Design Education, 9*(3), 269-291. doi:10.1023/A:1008929926002

36. Forret, M., Jones, A., & Moreland, J. (2002) New Zealand	Technology education in New Zealand	The papers reviewed technology education in New Zealand. Technology education is one of seven learning areas that all New Zealanders need to acquire. The paper discussed aspects of the technology curriculum. Its use in the thesis was only to illustrate a form of technology education. Specifically, the paper was one of those selected to develop Table 12.	**Review of literature	*Journal of Technology Studies*, *28*(1/2), 38-44. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/217772333?accountid=17287
37. Friedman, K. (2010) Australia	Heuristic reflections on assessing creativity in the design disciplines	To provide a contribution to the topic of creativity in design: providing the meaning of creativity as a general term and specifically in design.	** ("an essay" – to use the author's term)	In Williams, A., Ostwald, M. J., & Askland, H. H. (Eds.), *Creativity, Design and Education: Theories, Positions and Chal-*

				lenges (pp. 171-180). Canberra, Australia: Australian Learning & Teaching Council.
38. Garmire, E., & Pearson, G. (2006) USA	Tech tally: Approaches to assessing technological literacy	The authors explored methods and opportunities for assessing technological literacy in K-12 students, K-12 teachers, and extra-mural adults. The authors suggested how scientifically valid and broadly applicable assessments might be developed for the three target populations. Findings and related recommendations were provided in five critical areas: instrument development, research on learning, computer-based assessment methods, framework development, and public perceptions of technology. While this book is more suitable for American students, its content can be aligned with any given technology curriculum in a school level context.	**Book	Washington, DC: The National Academies Press.

39. Ghosh, S. (2003) USA	Triggering creativity in science and engineering: Reflection as a catalyst	To present insights into the nature of creativity by observing (i) documented manifestations of creative discoveries and inventions by leading scientists and inventors, (ii) records of creative flashes in many day-to-day ordinary activities, and (iii) instances of creativity in nature. To analyze and critique these observations and to uncover what mechanisms trigger the processes that eventually lead to creative solutions to problems. The paper submitted three hypotheses for cases (i) through (iii) and claimed that reflection constitutes the underlying mechanism in each of them, serving as a catalyst for creativity. The first hypothesis is that in many of the highly creative scientific and engineering discoveries, reflection has played an explicit role in catalyzing the onset of creativity in the scientists and inventors, leading to spontaneous solutions. The second hypothesis is that creativity may be triggered by resorting to implicit reflection. The third hypothesis is that nature is guided by reflection, while using enormous resources and	**Critical analytical review	*Journal of Intelligent and Robotic Systems, 38*(3-4), 255-275. doi:10.1023/B:JINT.0000004971.25256.f0

		knowledge. The key contribution of the paper was that although the exact definition of creativity continues to elude people, two mechanisms have been uncovered that are potentially useful in triggering creativity in ordinary scientific and engineering personnel to achieve quantum leaps in people’s knowledge and achievement.		
40. Gibbs, C. (2006) New Zealand	The Montessori teacher	A useful source for elementary teachers especially for those who work with students from multiple cultures. It is a psychological-educational source and comprises various themes from psychology, social psychology, culture, religion, and education. Some of the themes concern the development of student learning and the common psychological, social, cultural, and educational factors that influence the way students learn. The book originated in New Zealand.	**Review of literature	In C. Gibbs (Ed.), *To Be a Teacher Journeys Towards Authenticity* (pp. 122-149). New Zealand: Pearson Prentice Hall.
41. Gifford, M. (2009) New Zealand, Australia and	*Creativity box*	Creativity box is a collection of resources designed particularly for students in years 7-11, although a number of activities can be adapted for younger children. One of the features of this activity book	***Activity book	Christchurch, New Zealand: User Friendly Resources.

United Kingdom		is that there are no correct answers. Students have the opportunity to work on activities where the emphasis is on enjoyment, and at the same time to develop their logical, creative, imaginative, artistic, and personal skills. Forty-eight activities and exercises are provided.		
42. Good, K. (2002) UK	An approach to primary design in technology education and some innovative techniques	To explain an approach and new techniques trialed with children and student primary teachers at the university of Greenwich. To develop and trial a particular approach to Design and Technology (D&T) project work with trainee teachers and pupils. The research study was intended to elicit maximum creativity while ensuring success, confidence, coverage of programs of study and manageability for the teacher.	*Questionnaire, interview, observation Target age: 7-13 year-old students	*Journal of Science Education*, *3*(2), 90-92. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/196912628?accountid=17287
43. Gow, G. (2000) USA	Understanding and teaching creativity	The author provided a broad definition of creativity, its elements and dimensions. Creativity was divided into two types: type A creativity (extraordinary), and type B creativity (ordinary). For both	**Review of literature	*Tech Directions*, *59*(6), 32-32. Retrieved from http://ezproxy.w

		types, the researcher examined how creative thinking skills always play an essential role. This paper reviewed creativity as a process of mind where imagination, dispositions and creative thinking were the major focus.		ai-kato.ac.nz/login?url=http://search.proquest.com/docview/218510203?accountid=17287
44. Green, R. (2001a) New Zealand	*Teaching technology in the Junior school Book A*	The activity book is a useful source which can be used by teachers in elementary school to teach technology though a hands-on approach. Book A contains four technology areas: materials, biotechnology, production and processes. There are activity units aligned with the major technology focus and personal, school, environmental, recreational, business, industrial, and home contexts.	***Activity book	Christchurch, New Zealand: User Friendly Resource Enterprises Ltd.
45. Green, R. (2001b) New Zealand	*Teaching technology in the Junior school Book B*	The activity book is a useful source which can be used by teachers in elementary school to teach technology though a hands-on approach. *Book B* covers technology ICT, food technology, structures and mechanisms. There are activity units aligned with a major technology focus and personal, school, recreational, and home contexts.	***Activity book	Christchurch, New Zealand: User Friendly Resource Enterprises Ltd.

46. Hall, C. (2010) UK	Creativity in recent educational discourse in England	The paper offered an analysis of creativity in educational discourse in England over the Labour government's three terms in office. It traces the changing definition and uses of the term in relation to the agenda about raising standards in schools, promoting the arts and cultural education, and developing entrepreneurialism. In particular, it offered an analysis of the ways that these changing definitions influenced the Creative Partnerships programme, a national initiative to encourage schools in England to work in partnership with the creative sector.	** Review of literature	*World Englishes, 29*(4), 481-492. doi:10.1111/j.1467-971X.2010.01676.x

47. Hall, G. (2011) USA	Curriculum, instruction, and assessment for creativity and design	To explore contemporary research on: (1) Curriculum, instruction, and assessment. (2) Creativity and design in technology and engineering education curricula (3) Standards for creativity and design in curricula (4) Pedagogy for creativity and design in technology and engineering education (5) Curriculum for creativity and design in technology engineering education (6) Assessing creativity and design in technology and engineering education (7) Educating students for the conceptual age (8) Creativity and design thinking for employment.	**Review of literature	In S. A. Warner & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education, 60th Yearbook, 2011*, Council on Technology Teacher Education (CTTE), (pp. 262-289). New York: McGraw-Hill.

48. Harlen, W., & Crick, R. D. (2003) UK	A systematic review of the impact on students and teachers of the use of ICT for assessment of creative and critical thinking skills	The researchers conducted a systematic review of the impact on students and teachers of the use of ICT for assessment of creative and critical thinking skills. Twelve studies were analyzed in the review and there were three types of evidence findings: high evidence, medium evidence, and low evidence. The focus was on school aged students, ranging from 4-18 years. The findings were further reviewed by 20 participants who were from staff and higher degree students involved in research, practice or the study of information technology in education. They were asked initially to respond to a summary of the findings from the perspective of their experience and then, in groups, to consider the implications of the review.	** Systematic review	(pp. 1-93). EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

49. Heilman, K. M. (2011) USA	The creative brain	A brief overview of how the human brain mediates acts of creativity. It also discusses the brain mechanisms that are involved with creativity.	**Review of literature	In S. A. Warner & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education, 60th Yearbook, 2011*, Council on Technology Teacher Education (CTTE), (pp. 120-148). New York: McGraw-Hill. Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011
50. Hennessey, B. A	Is the social psychology of creativi-	The paper discussed previous empirical research undertaken by the researcher on the social psy-	An analysis of previous empirical	In P. B. Paulus. & B. A. Nijstad

(2003) USA	ty really social?	chology of creativity. In particular, the paper investigated the importance of intrinsic motivation in group creativity. The purpose in using this specific psychology related study was its presentation of the relationship between culture and creativity. It highlighted cross-cultural research work and how creativity can be viewed differently between West and East. Western culture views creativity as involving cognition and problem-solving elements while Eastern culture is influenced by religion which sees creativity as a religious concept.	research and literature on motivation and group creativity.	(Eds.), *Group Creativity Innovation Through Collaboration* (pp. 181-201). Cary, NC, USA: Oxford University Press. Retrieved from http://site.ebrary.com.ezproxy.waikato.ac.nz/lib/waikato/docDetail.action?docID=10085239
51. Hennessey, B. A (2004) USA	Developing creativity in gifted children: The central importance of motivation and class-	The paper was a good example of much other research on the topic of motivation and how social and environmental factors affect the creative process. The views expressed in this paper's findings were similar to those of Amabile who considerable	*Research and review of related literature	Research Monograph Series, RM04202. National Research Center on the

	room climate	effort on exploring two elements of creativity: (1) motivation, intrinsic and extrinsic, and (2) the social, physical and environmental factors.		Gifted and Talented. Storrs, CT: University of Connecticut. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/61875633?accountid=17287
52. Hennessey, B. A., & Amabile, T. M. (2010). USA	Creativity	The authors seemed to have similar perceptions about creativity from psychological and social-psychological points of view. The paper explored psychological aspects of creativity. The literature review revealed both a growing interest in creativity among psychologists and a growing fragmentation in the field. The paper highlighted theoretical and methodological changes into the research on creativity in which researchers have made im-	**Review of literature	*Annual Review of Psychology*, *61*, 569-598. doi: 10.1146/annurev.psych.093008.100416

		portant contributions from an ever-expanding variety of disciplines.		
53. Herbert, A. (2010) Sweden	The pedagogy of creativity	An investigation about the pedagogy of creativity (poststructuralist pedagogy) and elements of the creative processes, knowledge, and skills, from a psychological point of view. It also investigated the human problem-solving theories such as those of Freud and Lacan.	**Book	London: Routledge.
54. Herschbach, D. R. (1992) USA	Curriculum change in technology education: Differing theoretical perspectives	To discuss curriculum design theories: academic rationalist, technical, intellectual processes, personal relevance, and social reconstruction, and their importance in constructing a technology curriculum.	**Review of literature	*Journal of Technology Education, 3*(2), 4-5. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v3n2/html/intro.html

55. Herschbach, D. R. (1995) USA	Technology as knowledge: Implications for instruction	The paper suggested technological knowledge is not a type of formal knowledge similar to that associated with the recognized academic disciplines. It has distinct epistemological characteristics that set it off from formal knowledge. A deeper understanding of technological knowledge opens the curriculum to possibilities that are obscured by a more restricted view. Greater direction was also given to the task of curriculum development.	**Review of literature	*Journal of Technology Education, 7*(1), 31-42. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournals/JTE/v7n1/herschbach.jte-v7n1.html
56. Hill, A. M. (1997) USA	Reconstructivism in technology education	The researcher discussed some of the philosophies that inform educational practice in North America, providing a background for an analysis of the different philosophies in relation to technology education, and providing insights into the importance of reconstructionism, an outgrowth of pragmatism, as a philosophy in which to frame and describe technology education. The paper illustrated several examples of a reconstructionist approach to technology education.	**Review of literature	*International Journal of Technology and Design Education 7*(1), 121-139. Retrieved from http://course.zjnu.cn/kcjx/uploadfile/2008112719

				4136929.pdf
57. Hill, A. M. (1998) Canada	Problem-solving in the real-life context: An alternative for design in technology education	To focus on one way to study technology which is through technological problem-solving situated in real-life contexts. In problem-solving for real-life contexts, design processes are seen as creative, dynamic and iterative processes that engage exploration; join conceptual and procedural knowledge, both thought and action; and can encourage considerations of technology, and human and environmental interactions. To define technology as the use of materials, energy, skills and knowledge to create artifacts, systems, processes, or even new knowledge to meet human needs in a context of human and environmental considerations through open-ended problem-solving. The study provided two exemplars reporting on technology education in Canadian schools (primary and secondary) in the province of Ontario.	**A theoretical framework based on the development of two case studies adapted from research which were used to document and describe an interpretation of technology education as open-end problem-solving using design processes for real-life contexts.	*International Journal of Technology and Design Education, 8*(3), 203-220. doi:10.1023/A:1008854926028

58. Hodges, G. C. (2005) USA	Creativity in education	To provoke discussion about how creativity in education is defined and the impact of more explicit understandings of creativity in classrooms.	**Review of literature	*English in Education, 39*(3), 47-61. doi:10.1111/j.1754-8845.2005.tb00624.x
59. Hope, S. (2010) USA	Creativity, content, and policy	To make connections between creativity, content, and policy in a way that helps to address a number of important questions (e.g., where does creativity come from? Why does innate creative ability show up in different ways in different individuals?) and issues in mind when dealing with creativity in various areas of responsibility.	**Review of literature	*Arts Education Policy Review, 111*(2), 39-47. doi: 10.1080/10632910903455736
60. Howe, A., Davies, D., & Ritchie, R. (2001) UK	*Primary design and technology for the future: Creativity, culture and citizenship*	- Focused on views of creativity in design and technology. - Concerned with the education of children 4-11 years old. The book was a helpful source for understanding creativity in design and technology in the English context, providing several themes on creativity,	**Book	London: David Fulton Publishers.

		design and technology. The book provided case studies for teaching and learning practices for pupils aged 4-11 years. The book can be useful for in-service and pre-service training and for the scholar of technology education, given the fact that research on creativity in technology education is still in its early years.		
61. Ihde, D. (1997) Germany	The structure of technology knowledge	This philosophical paper is characterised by a different and unique perceptive concerning the nature of technological knowledge and sees it as having several dimensions: (1) Knowledge about technologies. This is the engineer's or technician's knowledge, the knowledge of how a machine is made and how it functions. (2) What could be called theoretical technology knowledge, i.e., the knowledge of the physical, chemical or electrical laws and principles which allow any given technology the capacity to do what it does. This is the scientist's or scientific engineer's knowledge. (3) But there is also a different kind of technological knowledge – knowledge through technologies. This is a special kind of practical or use	** A philosophical perspective	*International Journal of Technology and Design Education, 7*(1), 73-79. doi: 10.1023/A:1008809019482

		knowledge which runs through a wide range of human actions.		
62. Jeffrey*, B., & Craft, A. (2004) UK	Teaching creatively and teaching for creativity: Distinctions and relationships	To examine the two teaching applications: teaching creatively and teaching for creativity identified in the report from the National Advisory Committee on Creative and Culture Education (NACCCE, 1999). To examine the use of four characteristics of creativity and pedagogy identified by Peter Woods (1990) – relevance, ownership, control and innovation – to show the interdependence of the NACCCE distinctions.	**Review of research	*Educational Studies*, *30*(1), 77-87. doi: 10.1080/0305569032000159750
63. Johnmann, C. A., & Rieth, E. J. (1999) USA	*Bridges! Amazing structures to design, build and test*	The book provides useful bridges and structures activities for children suitable for pre-school and primary school students that are of benefit to both students learning in their own time (e.g., at home) or in the classroom. It is also beneficial for teachers to design lesson plans, worksheets, and activities to teach students how to create and enhance their creative thinking.	*** Activity book	Nashville, TN: Williamson Books.
64. Johnson, S. D.	A framework for technology educa-	To explore intellectual processes, theory and elements with respect to technology education.	**Review of research	*Journal of Technology Ed-*

(1992) USA	tion curricula which emphasizes intellectual processes.			*ucation, 3*(2), 26-36.
65. Jones, A. (2001) New Zealand	Theme issue: Developing research in technology education	To investigate past research and literature on key issues in the research of technology education concerning the nature of technology, learning and teaching technology, the impact of the classroom culture on learning, teacher professional development and assessment.	**Review of literature	*Research in Science Education, 31*(1), 3-14. doi:10.1023/A:1012658211512
66. Kelly, T., & Rayala, M. (2011) USA	The knowledge and skills of creativity and design	To identify the vital knowledge and skills which are necessary to effectively teach creativity and design.	**Review of literature and research	In S. A. Warner & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education, 60th Yearbook, 2011*, Council on Technology Teacher Education (CTTE),

				(pp. 182-211). New York: McGraw-Hill. Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011
67. Kerem, E. A., Kamaraj, I., & Yelland, N. (2001) Turkey	An analysis of Turkish pre-school teachers' ideas about the concept of creativity and the activities that can foster creativity in young children	(1) To seek pre-school teachers' opinions about aspects of creativity in early childhood centers in Istanbul. (2) To determine what characteristics pre-school teachers deemed as being creative. (3) To find out the activities pre-school teachers use to develop creative thinking skills in young children.	*Interview of 310 pre-school teachers who were employed in Istanbul	*Contemporary Issues in Early Childhood 2*(2), 243-252. doi:http://dx.doi.org/10.2304/ciec.2001.2.2.10
68. Kind, P. M., & Kind, V. (2007) UK	Creativity in science education: Perspectives and challenges for developing school science	The papers explored creativity in the science context in England and provided useful data about good creative teaching methods and how creativity should be taught in science education. The paper consisted of three sections. The first reviewed common approaches to creativity in sci-	**Review of literature	*Studies in Science Education, 43*, 1-37. Retrieved from http://ezproxy.wai-

		ence education. The second served to illustrate the authors' point that, to be meaningful in the science context, current interpretations of creativity are far removed from those needed. Next, the authors highlighted psychological approaches that have received more systematic treatment. The paper also offered the underpinning theory necessary for taking creativity in school science beyond the initial stages, summarized perspectives from the review and looked for further routes towards making science education a contributor to developing students' creativity.		kato.ac.nz/login?url=http://search.proquest.com/docview/222845211?accountid=17287
69. Lewis, T. (1999) USA	Research in technology education – some areas of need	The paper demonstrated an analysis of the areas of need for further research in technology education. Creativity was one of them. The article identified promising lines along which research in technology education can proceed. The article, based on the research literature identified, included (a) a willingness to look at research in other subject matter areas of the school curriculum for inspiration for inquiry in technology education, and (b) a willingness to go beyond mere prescrip-	** Analysis of research literature	*Journal of Technology Education, 10*(2), 41-56. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournals/JTE/v10n2/le

		tion of what ought to be studied, by dwelling and reflecting upon examples of the kind of inquiry being envisaged.		wis.html
70. Lewis, T. (2000) USA	Technology education and developing countries	To consider the problem of introducing technology education as a school subject in developing countries using approaches such as technology across-curriculum.	**Review of research	*International Journal of Technology and Design Education, 10*, 163-179.
71. Lewis, T., & Zuga, K. F. (2005) USA	Creativity – the missing link in the American Standards for Technological Literacy	This study by well-known researchers in the USA examined creativity in technology education with special focus on the link to the American Standards for Technological Literacy. The paper sought to stimulate a conversation about the inculcation of creativity as an important goal of technology education, in direct response to its exclusion from the Standards for Technological Literacy: Content for the Study of Technology. The authors' purpose was to direct the attention of the field to creativity – a relatively unexplored aspect of technology education. The study in its overview presented creativity, creative cognitive	**Review of research literature	*A Conceptual Framework of Ideas and Issues in Technology Education* (pp. 66-77). National Science Foundation Grant No. ESI-0138671.

		processes, schooling and creativity, creativity and technology education, and implications for technology education.		
72. Lewis, T. (2009) USA	Creativity in technology education: Providing children with glimpses of their inventive potential	To examine technology education as a vehicle for inculcating creativity in the curriculum by introducing children to the world of problem-solving and innovation. This paper on the nature of creativity in technology education was based on previous research and literature. It concluded by offering problem-solving, analogical, metaphorical, combination, and divergent thinking as possible bases for the pedagogy in technology education.	**Review of literature and research	*International Journal of Technology and Design Education, 19*(3), 255-268.
73. Lin, Y. (2011) China	Fostering creativity through education – a conceptual framework of creative pedagogy	- To propose a three-element framework of creative pedagogy for offering a more holistic view of enhancing creativity through teaching. - To cover the aspect of creative learning which was overlooked in the past. - To provide a different explanation to some arguments about teaching creativity. - To provide implications for applying creative pedagogy in the classroom and in the Asian	**Review of literature and previous research	*Creative Education, 02*(03), 149-155. doi: 10.4236/ce.2011.23021

		context.		
74. Lubart, T. I., & Georgedottir, A. (2004). USA	Creativity: Developmental and cross-cultural issues	The study used a multivariate approach to study developmental and cross-cultural differences in creativity. The authors proposed that cultures shape the development of creativity differently through their influence on children's cognitive development, personality development, and the environment in which children grow up. They started with an overview of recent work on the development of creativity in children. Then they turned to how cultures shape creativity through different definitions of creativity, by differential emphasis on creative activity, and by channeling creativity into some sectors more than others. Finally, the	**Review of research	In S. Lau., A. N. N. Hui. & G. Y. C. Ng (Eds.), *Creativity: When East Meets West* (pp. 23-54). River Edge, NJ: World Scientific Publishing Co. Retrieved from http://site.ebrary.com.ezproxy.w

		authors examined how culture interacts with development to shape creativity differently in the west and in the east. They concluded that creativity training needs to take into account cultural differences that may foster or inhibit creativity, in order to build on the strengths and compensate for the limits of each culture to better foster children's creative development.		ai-kato.ac.nz/lib/wai-kato/docDetail.action?docID=10106583
75. Mawson, B. (2003) New Zealand	Beyond 'the design process': An alternative pedagogy for technology education	To examine the design process and the implementation of models of the design process and their influences on a teacher's classroom practice. To develop pedagogy for teaching technology education, focusing on design process approaches.	**A theoretical paper on a number of design process models	*International Journal of Technology and Design Education 13*, 117-128.
76. McCormick, R. (1997) USA	Conceptual and procedural knowledge	The article examined the nature of technological knowledge and its relation to learning. It further argued that acquiring procedural and conceptual knowledge associated with technological activity poses challenges for both technology educators and those concerned with research on learning.	**Review	*International Journal of Design and Technology Education, 7*(1), 141-159. doi: 10.1023/A:1008819912213

77. McCormick, R. (2004) USA	Issues of learning and knowledge in technology education	The article examined issues that arise from learning and knowledge in technology education. The issues examined were, first, the definition of technological knowledge and what the nature of that knowledge should be, where the concern is with how knowledge is defined, especially in the context of how students learn and use knowledge in technology education. The paper also focused on the relationship between learning and knowledge, in particular the interrelationship between learning and knowledge, focusing on a situated view of learning.	**Review	*International Journal of Technology and Design Education, 14*(1), 21-44. doi: 10.1023/B:ITDE.0000007359.81781.7c
78. Middleton, H. (2005) Australia	Creative thinking, values and design and technology education	To examine literature on: - Cognitive research into designing and problem-solving to support the argument that designing is a complex intellectual activity. - Mental imagery, engineering and invention. - Exploring creative thinking strategies, their applications in design. - Recent research on values and theirs importance for design and technology education.	**Review of research	*International Journal of Technology and Design Education 15*, 61-71.

79. Moreland, J., Cowie, B., Jones, A., & Otrel-Cass, K. (2008) New Zealand	Developing teaching knowledge in primary technology.	A 3-year project (SiTE) carried out by the researchers to investigate these questions: how might a teacher set about teaching five-year olds how to design successfully? What could a teacher do when their students are unable to resolve construction problems? How do teachers teach technological concepts in a subject that is very practical? The researchers explored teacher knowledge, its sources and development, and the ways it was used by primary teachers so that their students had worthwhile learning experiences in both technology and science education. However, the article used in the synthesis was a discussion of the implications for teaching of a subject-specific planning framework.	** A discussion about the SiTE project carried out by the researchers during three years of research	Set: Research Information for Teachers (Wellington), 3, 38-41. http://go.galegroup.com.ezproxy.waikato.ac.nz/ps/i.do?id=GALE%7CA192000743&v=2.1&u=waikato&it=r&p=AONE&sw=w
80. Myers, K. L., & Shinberg, M. (2011) USA	Physical environment for creativity and design	To explore the importance of the relationship of the physical environment to students' creative output and how the physical environment influences students. The paper also provided an explanation of the eight major physical environmental variables, which can affect the creative potential in all	**Review of literature and research	In S. A. Warner & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engi-*

		classrooms and especially in technology education. The environmental variables discussed are: lighting, color, decorations, furniture, resources, sensory variables, space configurations, class size.		*neering Education, 60th Yearbook, 2011*, Council on Technology Teacher Education (CTTE), (pp. 182-211). New York: McGraw-Hill. Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011.
81. Nelson, R. (2004) New Zealand	Technology for tiddlers: Technology challenges for the first years of school Technology for tiddlers – Book A	The source was written in response to requests made by teachers of Years 1, 2, and 3 in New Zealand and Grades Prep 1 and 2 in Australia for technology activities that were suitable for their children. Book A looks at materials and systems technology. The resource has two kinds of pages, one for	***Activity book	Christchurch, New Zealand: User Friendly Resource Enterprises Ltd.

		teachers and one for students.		
82. Nguyen, L., & Shanks, G. (2009) Australia	A framework for understanding creativity in requirements engineering	To explore elements, dimensions, processes of creativity in Requirements Engineering (RE) by synthesizing two bodies of knowledge: creativity research and RE creativity research.	**A theoretical framework	*Information and Software Technology 50*, 655-662.
83. Perkins, D. N., Jay, E., & Tishman, S. (1993) USA	Beyond abilities: A dispositional theory of thinking	The paper proposed a theory of good thinking based on the concept of dispositions (dispositions are often considered to be a matter of motivation). The paper defined an extended concept called "triadic dispositions" which emphasizes (1) inclinations which may reflect motivation, habit, policy, or other factors, (2) sensitivity to occasion, and (3) abilities. The paper argued that a dispositional perspective on good thinking is a generative way of approaching issues concerning theories of thinking, the generality of thinking abilities, conceptual development, culture, and education.	**Review of literature	*Merrill-Palmer Quarterly, 39*(1), 1-21.
84. Petrina, S. (1992) USA	Curriculum change in technology education: A theoretical	The article provided insight into personal relevance curriculum designs through a discussion of a theoretical perspective on their nature, underlying	**Review of literature	*Journal of Technology Education, 3*(2),

	perspective on personal relevance curriculum designs	rationale and application to a study of technology, source of content, organizational structure, and use in technology education. The discussion was on middle, junior, and senior high levels of schooling.		37-47. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v3n2/html/petrina.html
85. Petrina, S., Feng, F., & Kim, J. (2007) USA	Researching cognition and technology: How we learn across the lifespan	The paper addressed how technology can be learned across lifespan. It provided effective methods for researching cognition and technology. The intention was to sketch a lifespan learning context for undertaking studies of cognition and technology, and to provide a methodological and theoretical analysis for researchers venturing into this dynamic and volatile field. The paper summarized by providing a far-ranging agenda for researching cognition and technology. The meta-study is a useful source for knowing how people at different ages view technology – the reason for including it in the synthesis process.	**Review of research literature: 237 reports were reviewed. The review was limited to empirical research studies in 47 journals between 1998 and 2003 focusing on learning action (e.g. research methods such as experiments, ethnographies, interviews, observations, question-	*International Journal of Technology and Design Education, 18*(4), 375-396. doi: 10.1007/s10798-007-9033-5

			naires).	
86. Phillips, B. (2002) Canada	Can creativity be assessed?	The paper proposed an alternative model for creativity, a cultural one where creative ideas, actions or products are situated within a context of community and dialogue. This social theory rethinking of creativity is, by its very nature, more inclusive a model than the personality-focused, slightly mysterious, romantic model. In this conception of creativity as culturally-based and informed, the where and when of creativity become important as a defining context; in other words, nothing can be deemed creative unless it is shared among others and initiates a form of dialogue where ideas are exchanged about what is creative and why. The article was directed to the assessment element of creativity.	**Report	*Orbit, 32*(3), 10-14. Retrieved from http://ezproxy.wai-kato.ac.nz/login?url=http://search.proquest.com/docview/213735709?accountid=17287
87. Roeckelein, J. E. (2006). No author or country indicat-ed	Problem-solving and creativity stage theories (2006)	This short paper illustrates problem-solving and creativity stage theories as indicated in Table 9 in Section Two of Chapter Three.	**Review of literature	*In Elsevier's Dictionary of Psychological Theories*. Retrieved fromhttp://ezpro

				xy.waikato.ac.nz /login?qurl=http %3A%2F%2Fwww.credoreference.com/entry/estpsyctheory/problem_solving_and_cr
88. Rasinen, A. (2003) USA	An analysis of the technology education curriculum of six countries	The paper analyzed the technology education curriculum in six countries: Australia, England, France, the Netherlands, Sweden, and the United States of America. The paper aimed to synthesize the theory and practice of these countries' curriculum and did not mean to compare them. It also aimed to search for more detailed and concrete curriculum materials for provincial, district, municipal, and school purposes.	**Review of literature	*Journal of Technology Education, 15*(1), 31-47. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournals/JTE/v15n1/pdf/rasinen.pdf

89. Ronald, A. B. (2005)	Does assessment kill student creativity?	The study answered the question posed in the title and found assessment does not kill student creativity but can be used to motivate students. Effective assessment depends on considering the relationship between creativity motivation and assessment. Creativity and motivational researchers have found that certain assessment practices have a strong influence on motivational beliefs that can, in turn, undermine students' expression of creativity. To add to the main question whether assessment kills student creativity, the author answered two more questions: Which assessment practices diminish creativity? What can teachers do to help ensure that their use of assessment supports student creativity?	**Review of literature	*The Educational Forum, 69*(3), 254-263. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/220696685?accountid=17287
90. Ropohl, G. (1997). Germany	Knowledge types in technology	Ropohl discussed the difference between technological and technical knowledge, and the relationship between science and technology, arguing that technology is a genuine type of knowledge rather than "applied science." The paper used a classification of knowledge types for determining which	**Review	*International Journal of Technology and Design Education, 7*(1-2), 65-72. doi:

		kind of knowledge may seem appropriate for general technology education.		10.1023/A:1008865104461
91. Roseman, M. A., & Gero, J. S. (1993)	Creativity in design using a design prototype approach	In chapter 6, Roseman and Gero focused on the use of design prototypes, including problem statements and wider design knowledge at different levels. "The main problem in all classes of design is the configuration problem. None of the works to date satisfactorily provides solutions to this problem … it may well be that there needs to be special knowledge on junctions, treating junctions in the same way as other objects" (p. 134).	**Review of research	In J. S. Gero and M. L. Maher (Eds.), *Modeling Creativity and Knowledge-based Creative Design* (pp. 111-138). Hillsdale, New Jersey: Lawrence Erlbaum Associates.
92. Rugh, W. A. (2002) Saudi Arabia	Education in Saudi Arabia: Choices and constraints	The study focused on the history of the educational system in Saudi Arabia. It discussed changes made to Saudi education after 1950 as well as current trends and subjects such as science and technology.	**Review of literature	*Middle East Policy*, *9*(2), 40-55. doi:10.1111/1475-4967.00056

93. Runco, M. (2004b) USA	Personal creativity and culture	Runco offered an operational definition of culture. It is not a very broad definition, in part because it is based on one particular model of creativity. This model is in turn based on the theory of personal creativity. The chapter of the online book explored several topics which have not been presented elsewhere. These deal primarily with culture as an influence on personal creativity. It suggested that studies of implicit theories will help to understand personal creativity and the relevant cultural differences. Various specific expressions of culture such as tolerance, control, and conventionality were highlighted. In its overview, the paper was a comprehensive review of the literature on culture and creativity.	**Review of research	In S. Lau, A. N. N. Hui & G. Y. C. Ng (Eds.), *Creativity: When East Meets West* (pp. 9-21). River Edge, NJ: World Scientific Publishing Co. Retrieved from http://site.ebrary.com.ezproxy.waikato.ac.nz/lib/waikato/docDetail.action?docID=10106583

94. Runco, M. A. (2004a) USA	Creativity	To explore research on aspects of creativity: traits, capacities, influences, and products. To explore disciplinary perspectives on creativity (e.g. biological, cognitive, developmental, organizational)	**Review of research and literature	*Annual Review of Psychology*, *55*(1), 657-687. doi:10.1146/annurev.psych.55.090902.141502
95. Rutland, M., & Barlex, D. (2007) UK	Perspectives on pupil creativity in design and technology in the lower secondary curriculum in England	The paper is based on a research study exploring the professional practices of teachers in technology education in the lower secondary curriculum, with specific reference to fostering the creativity of students' aged 11-14 years. The research question that drove the study was, "to what extent can teachers influence the creativity of pupils aged 11-14 years in design and technology lessons?" The study generated a unique theoretical three-feature model or framework that can be used to explore creativity within an educational context. The first model feature relates to factors in a specific subject domain such as design and technology. The two other features of the theoretical model could be used to explore creativity within other domain areas of the school curriculum. The model	*Qualitative research methodology used in this research study which applied to a case study for data collection. The research study also included ethnographical methodology involving observational techniques.	I*nternational Journal of Technology and Design Education, 18*(2), 139-165.

		consists of three features termed: (1) Domain relevant features (a set of practices associated with an area of knowledge, for example design and technology or other subjects such as science, mathematics; (2) Process-relevant features – influencing, controlling the direction and progress of the creative process; (3) Social, environmental features – macro/micro environmental, social and cultural issues.		
96. Sade, D., & Coll, R. K. (2003) New Zealand Centre for Science and Technology Education Research	Technology and technology education: Views of some Solomon Island primary teachers and curriculum development officers	To gain an understanding of primary teachers' and curriculum development officers' perceptions of technology and technology education for a small island nation in the South Pacific.	*Qualitative approach. Semi-structured interviews (40-45 minutes)	*International Journal of Science and Mathematics Education, 1*, 87-114.

97. Saebo, A. B., McCammon, L. A., & O'Farrell, L. (2007) Country not stated	Creative teaching and teaching creativity	(1) To explore the concept of creativity in education. The concept is discussed and concretized with reference to education. (2) To consider how the literature on creativity describes the distinction between creative teaching and teaching creativity. The study presented the first step in what is planned to be a 3-year journey of exploration about creativity and teaching creatively in drama/theater classrooms internationally.	**Review of literature	*Caribbean Quarterly, 53*(1/2), 205-215. Retrieved from http://www.jstor.org.ezproxy.waikato.ac.nz/stable/40654985
98. Shaheen, R. (2010) UK	Creativity and education	The article provided a brief background of the link between creativity and education with a rationale for the inclusion of creativity in education. The paper discussed the dissatisfaction over current education and its changing role in the light of the increasing importance being accorded to creativity. An illustration showing evidence of educational policy documents from around the world was presented to show the steps being taken for the implementation of creativity in education.	**Review of literature	*Creative Education, 01*(03), 166-169.

99. Sharkawy, A., Barlex, D., Welch, M., McDuff J., & Craig, N (2009) UK	Adapting a curriculum unit to facilitate interaction between technology, mathematics and science in the elementary classroom: Identifying relevant criteria	The authors reflected on their research study that investigated the extent to which: (a) relevant mathematics and science can be made explicit in a technology curriculum unit, (b) pupils utilize this mathematics and science learning, and (c) pupils' ability to design is enhanced by making mathematics and science explicit and useful. To report the results of Phase 1 of the study, an examination of research literature was made in order to identify criteria to inform the rewriting of an existing technology curriculum (to be used as a research instrument) that previously did not make explicit embedded mathematics and science concepts. The authors' reading of literature had identified two essential criteria that must be met during the rewriting: (a) protecting the integrity of the subjects and (b) identifying the nature and purpose of the intended learning.	**Review of previous research studies and literature	*Design and Technology Education: An International Journal*, *41*(1), 7-20. Retrieved from http://ojs.lboro.ac.uk.ezproxy.waikato.ac.nz/ojs/index.php/DATE/article/view/197/173

100. Sidawi, M. M. (2007) USA	Teaching science through designing technology	To review the literature related to teaching science through designing technology as this subject can present the students with the context through which they can apply the science concepts they learned and thus enhancing their understanding of these concepts. To extract from the literature a better understanding of teaching science through designing technology and the elements that a teacher needs to satisfy in order to increase the chances of successfully implementing this method in the classroom.	**Review of research	*International Journal of Technology and Design Education, 19*(3), 269-287. doi: 10.1007/s10798-007-9045-1
101. Siddiqui, M. (1996) Saudi Arabia	Library and information science education in Saudi Arabia	This paper was useful as it provided insights into the educational system and illustrated school levels and the philosophy of Saudi Arabian education.	**Review of literature	*Education for Information, 14*(3), 195. Retrieved from http://search.ebscohost.com.ezproxy.waikato.ac.nz/login.aspx?direct=true&db=iih&AN

				=9612180539&site=ehost-live
102. Skolimowski, H. (1966) USA	The structure of thinking in technology	(1) To provide a proper philosophy of technology. (2) To analyze the relationship of technology to science. (3) To develop an argument based on three concepts: (1) it is erroneous to consider technology an applied science, (2) that technology is not science, (3) that the difference between science and technology can be best grasped by examining the idea of scientific progress and the idea of technological progress.	**A philosophical perspective	*Technology and Culture*, *7*(3), 371-383.
103. Spendlove, D. (2008) UK	100 ideas for teaching design and technology	The book is very much about ‘how’ rather than ‘what’ to teach in design and technology (D &T). It draws upon best practice in teaching and locates this within a D &T context. The book provides eight sections: the big picture, designing, using technology, extended curriculum, structuring the learning, including all, assessment, and the wider classroom.	***Activity book	London: Continuum.

104. Strzalecki, A. (2000) Poland	Creativity in design: General model and its verification	To demonstrate that creativity, seen as a higher order construct, could be better understood by three low order constructs: (1) flexibility, originality, and fluency of cognitive processes, (2) freedom and originality of personal expression, (3) autonomy of an axiological system.	*An empirical model Creativity as Style validated in three independent studies. A questionnaire, *The* Creative Behavior Questionnaire (the CBQ), involved a group of 117 outstanding applied scientists and designers.	*Technological Forecasting and Social Change, 64*(2-3), 241–260. Retrieved from http://dx.doi.org/10.1016/S0040-1625(00)00077-9
105. Surkova, I. (2012) Latvia	Towards a creativity framework	To elaborate a systemic model of creativity as a subject of exploration in any domain. The framework can serve as an instrument in an attempt to solve problems in many different fields.	**A theoretical framework (system model)	*Society and Economy, 34*(1), 115-138. doi: 10.1556/SocEc.2011.0013
106. Tatweer. (2010) USA	King Abdullah Bin Abdul-Aziz project for developing general education	The webpage used to support the main argument of the thesis, illustrating the main objectives of the King Abdullah Bin Abdul Aziz project for developing general education.	**Policy document	Retrieved from http://www.tatweer.edu.sa/content/aboutus

107. Tay, L. Y., Lim, S. K., & Lim, C. P. (2011) USA	Exploring alternative assessments to support digital storytelling for creative thinking in primary school classrooms	The research study documented the use of digital storytelling as a teaching approach to facilitate the learning of creative thinking among students (aged 7 and 8) in a primary school setting. A constructive teaching approach was adopted to allow students to create their own digital stories based on an authentic experience and expressing their thoughts. The aim was to show how a shift from traditional classroom assessment to a more flexible, alternative assessment format facilitates higher level thought processes (e.g. creative thinking) and range of skills. Several issues and challenges of using alternative assessment in digital storytelling are explored and discussed. The findings suggested that digital storytelling may be effectively used as an approach to foster creative thinking. They also suggested that refinements to the assessment process are needed to make it more formative in nature.	*Data were collected using multiple sources: observation notes by the authors, lesson observations, meetings with teachers and the authors, and student-produced artefacts, reflections, and feedback.	In A. Mesquita (Ed.), *Technology for Creativity and Innovation: Tools, Techniques and Applications* (pp. 268-284). Hershey, PA: Information Science Reference.

108. The Ministry of Education in cooperation with the Ministry of Higher Education and the General Establishment of Technical Education and Vocational Training (2004) Saudi Arabia	The development of education	A report focusing on the quality of youth education, presented for discussion at the International Conference of Education organized by the International Education Bureau in cooperation with UNESCO. The report provided an in-depth view of the educational system in Saudi Arabia, particularly general education, supervised by the Ministry of Education. The report presented recommendations to assist states in their efforts to achieve a proper level of youth education and the noble goals of the national educational system.	**Report	Retrieved from http://www.ibe.unesco.org/International/ICE47/English/Natreps/reports/sarabia_en.pdf
109. The Ministry of Education. (2011) USA	Strategic Plan	This source consisted of the main strategic plan objectives used to support the development of the main argument of the thesis: By the will of Allah, the year 1434 H. should witness the fulfillment of the vision held by the Ministry of Education and Training, which can be expressed in the following manner: Engendering a new generation of male and female youth who embody the Islamic values in their per-	**Educational policy document	Retrieved from http://www2.moe.gov.sa/english/Pages/strategic_plan.htm

		sons, both theoretical as well as practical, are equipped with necessary knowledge, skills, and endowed with the right orientations, capable of responding positively to, and interact with the latest developments, and deal with the latest technological innovations with ease and comfort. They should be able to face international competition both at the scientific as well as technological levels to be able to meaningfully participate in overall growth and development. This is to be achieved through an effective and practical system of education which is capable of discovering the potentials and predispositions, and create the spirit of action. All this, in an environment of education and training, charged with the spirit of instruction and edification.		
110. The Qur'an	"And this Qur'an is not such as could ever be produced by other than Allah (Lord of the heavens and the earth), but it is a confirmation of (the revelation) which was before it [i.e. the Taurat (Torah), and the Injeel (Gospel)], and a full explanation of the Book (i.e. laws, decreed for mankind) – wherein there is no doubt – from the Lord of the Alamin (mankind, jinn, and all that exists)." (Qur'an, 10:37). Various chapters from different places of the Quran are explored to:			Madinah Munawwarah, K.S.A: King Fahd complex for the printing of the Holy

	(1) Support the religious aspect of creativity. (2) Review examples of varied types of creativity from an Islamic perspective. (3) Illustrate different types of values embedded in the Qur'anic context with respect to education, technology, and creativity.			Qur'an.
111. Thompson, G., & Lordan, M. (1999) UK	A review of creativity principles applied to engineering design	- Developed an understanding of creativity, invention, innovation, and creative tools. - Discussed the application of creativity principles to engineering design.	**Review of literature	*Proceedings of the Institution of Mechanical Engineers, 213*(1), 17-31. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/213824080?accountid=17287.
112. Vidal, R. V. V. (2007) Denmark	Creativity for problem solvers	The paper presented some of the modern and interdisciplinary concepts about creativity and creative processes, creative tools approaches	**Review of literature	*Ai & Society, 23*(3), 409-432. doi:

		specially related to problem-solving based on related recent publications. The paper also presented the researcher's own experiences using creative tools and approaches to: facilitation of problem-solving processes, strategy development in organizations, design of optimization systems for large scale and complex logistic systems, and creative design of software optimization for complex non-linear systems.		10.1007/s00146-007-0118-1
113. Warner, S. A. (2002) USA	Teaching design: Taking the first steps	The article was an overview of the issues surrounding teaching design and provided strategies on how to teach students thinking like designers. It also emphasized the role of the technology teacher teaching students the processes of design adopting the synergistic approach and for preparing students to think like creative and inventive problem solvers.	**Review of literature	*The Technology Teacher, 62*(4), 7-10. Retrieved from http://ezproxy.waikato.ac.nz/login?url=http://search.proquest.com/docview/235304188?accountid=17287

114. Warner, S. A. (2010) USA	Creativity and design in technology education	- Explored the nature of creativity and design. - Examined aspects of research on creativity in design and technology education.	**Review of literature	In P. A. Reed. & J. E. LaPorte (Eds.), *Research in Technology Education* (pp. 218-235). Reston, VA: Council on Technology Teacher Education (CTTE). Retrieved from http://www.ctete.org/#!yearbook
115. Warner, S. A. (2011) USA	Providing the context for creativity and design in technology and engineering education	To explore in depth the various aspects of creativity and design in technology education including the properties of creativity and design, the origins of creativity and design, the role of creativity and design in the world of technology, historical precedents for creativity and design in technology education curricula , the importance of creativity and design stand-	**Review of research literature	In S. A. Warner. & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education* (pp. 1-31).

		ards for technological literacy (SfTL), the role of creativity and design in curriculum around the world, and the future of creativity and design within the evolving curricula of technology education		Reston, VA: Council on Technology Teacher Education (CTTE). Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011
116. Webster, A., Campbell, C., & Jane, B. (2006) Australia	Enhancing the creative process for learning in primary technology education	To report on a research project which investigated the impact on children's thinking when a period of non-focused thinking became part of the technology process. The results support the proposition that a child's non-generative/analytical mental state needs to give way to a generative state so that a child can be more fully creative. To document children's ideas during their involvement in a design and technology activity, teachers are urged to provide an incubation period as part of the technological process in the classroom, so that children's creativity can	*The study was conducted in three primary schools across the state of Victoria, Australia: one metropolitan school (Melbourne), one regional school (Geelong area) and one semi-rural school	*International Journal of Technology and Design Education, 16*(3), 221-235. doi: 10.1007/s10798-005-5633-0

		be fostered.	(Mornington Peninsula). Research methods used were informal, semi-structured interviews, and observations of student records presented in the children's My Thinking and Idea Book.	
117. Westberry, R. (2003) USA	Design and problem-solving in technology education	To argue for the need that considering design and problem-solving as an instructional strategy can align the technology education curriculum with the standards for Technological Literacy: Content for the Study of Technology (ITEA, 2000). To argue that design and problem-solving represents a change in the way technology education should be taught.	**Review of literature	In CTTE yearbook, planning committee (Eds.), *Essential Topics for Technology Educators* (pp. 54-68). New York: McGraw-Hill.

		To argue that design and problem-solving is the application of technology education. To argue that the best way for teaching and learning technology education is through the use of processes and procedures of design and problem-solving as an instructional strategy.		Retrieved from http://www.glencoe.com/sites/common_assets/trade_ind_ed/pdfs/ctte_yearbook_2009.pdf
118. Williams, A. (1996) Australia	Curriculum development	Provides topics of what a curriculum is, what the considerations of the curriculum are, and developing and documenting the structure of a technology curriculum suitable for teaching.	**Review of literature and curriculum documents	In J. Williams. & A. Williams (Eds.), *Technology Education for Teachers* (pp. 243-264). Melbourne, Australia: Macmillan.
119. Williams, A., Ostwald, M. J., & Askland, H. H. (2010) Australia	Creativity, design and education: Theories, positions and challenges	This book was useful as it linked previous and contemporary discussions on creativity in psychology, education and design and technology education. It contained two major parts. First they discuss theories, definitions and applications of creativity with relevance	** Book	In A. Williams., M. J Ostwald. & H. H. Askland (Eds.), *Creativity, Design and Educa-*

		to design. In the second part, from chapter two and in a way that distinguishes this book from other studies, they provide 39 perceptions about the place of creativity in design. Thirty-nine technological experts have made their contributions to the understanding of creativity and how it is viewed in design.		*tion: Theories, Positions and Challenges* (pp. 171-180). Canberra, Australia: Australian Learning & Teaching Council.
120. Williams, J. (2000) Australia	Design: The only methodology of technology?	The paper discussed design in technology education, science and technology education in terms of knowledge and processes with an emphasis on technological processes (design, problem-solving, systems approach, invention, and manufacturing).	**Analysis of literature	*International Journal of Technology Education, 11*(2), 48-60.
121. Williams, J. (1996a) Australia	Philosophy of technology education	Curriculum theories provide a rational approach to education and technology education. The academic rationalist discipline-based approach, the competence-based approach, intellectual processes, personal relevance, and social reconstruction were the core of this paper.	** Philosophical and literature review	In J. Williams and A. Williams (Eds.), *Technology Education for Teachers*, (pp. 27-62).

				Melbourne, Australia: Mac-millan.
122. Williams, J. (1996b) Australia	International approaches to technology education	A number of different types of frameworks have been proposed for examining technology education in various countries. Two frame-works are used in this study: one relates to the rationale for technology education, and the second relates to the focus of the curriculum.	**A framework of 16 countries' technology edu-cation curricu-lum	In J. Williams and A. Williams (Ed.), *Technolo-gy Education for Teachers*, (pp. 266-288). Melbourne, Australia: Mac-millan.
123. Williams, J. (2009) Australia	Technological literacy: A multliteracies approach for democracy	To provide a broad view of the current devel-opment of Web 2.0. To provide a new conceptualization of techno-logical literacy as a multliteracy approach in a dynamic way through the pre-existing peda-gogy of design.	**Theoretical paper	*International Journal of Technology and Design Educa-tion*, *19*, 237-254.

124. Williams, J. (2011) The Netherlands	Dispositions as explicit learning goals for engineering and technology education	A new framework proposed for engineering and technology education focused on the development of dispositions.	**Theoretical framework	In M. Barak. & M. Hacker (Eds.), *Fostering Human Development through Engineering and Technology Education*, (pp. 89-102). Rotterdam, Netherlands: Sense publishers.

125. Williams, J. (2011a) Australia and New Zealand	Focus on design and technology: Book A	Provides activities for designing within technology education, the focus of the book on a number of key areas which can be taught in the classroom including: worksheets for students to compete individually and independently, worksheets for students to complete in groups, the basis for a teacher-led discussion, supplementary work to a lesson, pages in an individual portfolio, homework, worksheets for students to complete in the regular teacher's absence. (Units 1 to 12)	***Activity book	Christchurch, New Zealand: User Friendly Resources.

126. Williams, J. (2011b) Australia and New Zealand	Focus on design and technology: Book B	The book provided activities for designing within technology education. The book focuses on a number of key areas which can be taught in the classroom including: worksheets for students to complete individually and independently, worksheets for students to complete in groups, the basis for a teacher-led discussion, supplementary work to a lesson, pages in an individual portfolio, homework, worksheets for students to complete in the regular teacher's absence. (Units 13 to 25)	***Activity book	Christchurch, New Zealand: User Friendly Resources.

127. Wong, Y. L, & Siu, K. W. M. (2012) Hong Kong-China	Is there creativity in design? From a perspective of school design and technology in Hong Kong	(1) To analyse the creative elements in the D&T curriculum in Hong Kong as seen in the exemplar projects on the Education Bureau website. (2) To draw attention to East Asian beliefs and implicit theories, which greatly influence teachers' underlying assumptions about learning and teaching, and at the same time noting that these beliefs may be detrimental to the development of creativity among students. (3) To identify problems and inadequacies in fostering creativity in design at the secondary school level, expecting to raise awareness of the importance of creativity in D&T.	*Analysis of exemplar projects and coursework presented on the website of the Education Bureau of Hong Kong. Forty-six projects and coursework assignments were available for teachers' reference online. The researchers examined the teachers' design briefs and exemplar artifacts completed by the students.	*Asia Pacific Education Review*, *13*(3), 465-474. doi: 10.1007/s12564-012-9208-y

128. Wu, M. H. (2005) UK	On strategy to activate children's creativity with the examination of inventor process of invention	The researcher presented a hypothesis that the mindset operation process is similar in terms of innovation of any discipline or knowledge domain. The distinction of innovated output originated from the disparity of mindset operation elements.	*The study is firstly conducted through semi-constructive in-depth interviews, during which data of the invention process of the inventors were collected. Later, interview data, which includes personal data, patent application, interview transcript, were analyzed through qualitative analysis. Then analytic induction was used to conduct	Paper presented at the Fifth International Primary Design and Technology Conference – Excellence through Enjoyment, Birmingham, England.

			the collective analysis and data categorization so as to sort out links and meanings between data. Finally, grounded theory was used to shape up ideas according to the analyzed data so that mindset operation process, including creative problem-solving and information processing can be located.	
129. Wyse, D., & Spendlove, D.	Partners in creativity: Action research and creative	To explore the outcomes of an approach which aimed to strengthen the evidence base	*Action research on 25 primary	*Education 3-13*, *35*(2), 181-191.

(2007) UK	partnerships	for the work of Creative Partnerships. (The Creative Partnerships initiative in England).	and secondary schools	doi: 10.1080/03004270701312034
130. Yatt, B. (2011) USA	Defining creativity and design	To provide working definitions and elaborations of key concepts for a better understanding of the relationships among these concepts and the teaching of technology. The definitions dealt with the context of technology and engineering, and design, art, and craft.	**Review of literature	In S. A. Warner. & P. R. Gemmill (Eds.), *Creativity and Design in Technology & Engineering Education* (pp. 32-68). Reston, VA: Council on Technology Teacher Education (CTTE). Retrieved from http://www.ctete.org/#!yearbook/vstc8=2011
131. Yeh, Y., & Wu, J. (2006)	The cognitive process of pupils' technological crea-	To investigate pupils' self-awareness along with their self-evaluation of their cognitive	* Qualitative research	*Creativity Research Journal*,

Taiwan	tivity	processes when they were performing problem-solving tasks involving technological creativity.	A technological creativity test – Treasure Hunt on a Deserted Island – and a structured interview questionnaire with 14 items. Thirty-six participants 4^{th} to 6^{th} grades (18 girls and 18 boys)	*18*(2), 213-227. doi:10.1207/s15326934crj1802_7
132. Zubrowski, B. (2002) USA	Integrating science into design and technology projects: Using a standard model in the design process	(1) To emphasise a variety of pedagogical approaches to introduce elementary and middle school students to the processes and content of technological know-how and knowledge. (2) To propose a pedagogical model ("standard model" – a case study of a 4^{th} grade class) which can be used to help students develop some basic scientific understanding, which can then be applied to making a	**Critical review of research	*Journal of Technology Education, 13*(2), 48-67. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournals/JTE/v13n2/pdf

		more effective design.		/zubrowski.pdf
133. Zuga, K. F. (1989) USA	Relating technology education goals to curriculum planning	To provide considerations of the technology education goals related to curriculum planning, curriculum design theories: academic, technical, intellectual processes, personal relevance, and social reconstruction.	**Review of research literature	*Journal of Technology Education*, *1*(1), 34-58. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournals/JTE/v1n1/pdf/zugascii.pdf
134. Zuga, K. (1992) USA	Social reconstruction curriculum and technology education	Zuga explored social reconstruction with regard to schools, curriculum, and technology education. The explorations related to (a) what was meant by social reconstruction, the way in which it was implemented in experimental schools, and the legacy of social reconstruction. (b) the role of processes in technology education curriculum, providing ideas for organizing a social reconstruction curriculum	**Review of research	*Journal of Technology Education, 3*(2), 48-58. Retrieved from http://scholar.lib.vt.edu.ezproxy.waikato.ac.nz/ejournal

		orientation in technology education, and listing examples of what a social reconstruction curriculum orientation in technology education is not.		s/JTE/v3n2/pdf/zuga.pdf
135. Zuga, K. F. (1997) USA	An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research	To shed light on technology education issues in the United States with respect to research done on the subject. To call for the implementation and integration of a constructivist approach which he saw is a must in teaching technology education to all children.	**Critical analytical review of research	*International Journal of Technology and Design Education, 7*, 203-217.

Note: **The symbol *** indicates primary research studies which examined the real world. A primary research study consists of first and second order constructs (Schutz, 1973). A first order construct study examines the real world which reflects participants' understandings as reported in the primary studies. A second order construct study presents the interpretations of participants' understandings made by researchers of primary studies.
The symbol ** indicates secondary research studies. A secondary research study represents the author's own interpretation of previous literature or research projects and is not directly obtained from real life contexts. A secondary research study presents the author's understanding and interpretation of other primary studies and/or research literature.
The symbol *** indicates various activity books selected to support the development of the theoretical framework model thesis for implementation planning in Saudi Arabia.