Development, Implementation, and Evaluation of an Interaction Design Thinking Course in the Context of Secondary Education

by

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Abstract

Design thinking aims to foster innovation by elevating participants' creative thinking abilities. It usually involves a problem-solving approach to solve complex problems, which can be best achieved through collaborative and human-centered activities. In post-secondary education, design-thinking techniques and practices have been implemented into different curricula as particular skills that need to be learned in the 21st century. However, little work has been conducted to investigate design thinking in secondary education. This thesis reports on a successful development, implementation, and evaluation of an interaction design-thinking curriculum in the context of secondary education. Over the course of three months, 39 students from two schools in grades 9 and 10 participated in the course. Several types of data collection techniques, including in-depth interviews, participant observation, focus group, open-ended questions, questionnaires, and visual method were employed to gather data, and the data was coded for distinguishing core concepts and categories. The results of the study clarify the course benefit for students and inform interaction design educators and researchers about how to best develop, implement, and evaluate a secondary-level course on interaction design thinking.

This study presents several important research contributions. First, it demonstrates how students' design thinking skills can be incorporated into their everyday life experiences and practices. Second, the findings of the study shed light on design thinking evaluation, and how design educators and interaction design practitioners can evaluate participants' design thinking skills and abilities through different data collection methods in depth. Third, this study provides an analytical lens in examining and adapting a design thinking curriculum in the context of secondary education. Furthermore, this study provides four substantial recommendations to design educators for implementation of a design thinking-based curriculum.

Keywords: Design thinking; interaction design; creative problem solving; human-centred design; design thinking assessment; secondary education

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Glossary

Bodystorming	A unique method that spans empathy work, ideation, and prototyping. Bodystorming is a technique of physically experiencing a situation to derive new ideas. It requires setting up an experience - complete with necessary artefacts and people - and physically “testing” it (Bootcamp Bootleg D.School, 2011).
Brainstorming	Brainstorming is a way to generate ideas. The intention of brainstorming is to leverage the collective thinking of the group, by engaging with each other, listening, and building on other ideas (Bootcamp Bootleg D.School, 2011).
Design Cognition	Design cognition in the creative process aims at learning about designers’ complex cognitive actions, and how designers “see, move through, create, and relate to their visual, spatial, and temporal world” (Dillon, 2010).
Design Practice	Design practice is characterized by Schön as "conversation with the situation" or “reflection-in-action” in which designers incorporate their ideas into representational medium, reflect on and modify them (Schön, 1987).
Design Thinking	A human-centered approach to create innovative solution(s) to a problem by following a five-step design process including empathize, define, ideate, prototype and test (Bootcamp Bootleg D.School, 2011).
Interaction Design	The practice of designing interactive digital products, environments, systems, and services (Cooper et. al, 2007).
Interaction Design Thinking Course	A design thinking-based pedagogy in the context of Interaction design.
K-12 Education	A short form for the totality of primary and secondary education, kindergarten (K) and the 1st through the 12th grade (Wikipedia).
Metacognitive Skills (awareness)	“The ability to know where they are in the process and the goal they are moving towards” or “being mindful of the process” (Carroll et al., 2010, p. 41).
Problem Setting	Problem setting in problem-solving activity refers to the process by which we define the decision to be made, the ends to be achieved, and the means that may be chosen (Schon, 1983).
Problem Solving	The process of finding solutions to difficult or complex issues.
Storyboard	A graphic organizer in the form of illustrations or images displayed in sequence for the purpose of pre-visualizing a motion picture, animation, motion graphic or interactive media sequence (Wikipedia).

Chapter 1.

Introduction

1.1. Focus and Motivation behind this Study

In post-secondary education, design-thinking techniques and practices have been implemented into different curricula as particular skills that need to be learned in the 21st century (Akalin and Sezal, 2009; Wormald, 2011; Verea et al., 2005; Lugmayr, 2011; Klein and Phillips, 2009). However, little work has been conducted to investigate design thinking in secondary education. The aim of this thesis is to provide an in-depth description of the development, implementation, and evaluation of an interaction design thinking course in the context of secondary education, and introduce the benefits of the course to design thinking educators and researchers. The second goal of this thesis is to provide a guideline for design educators to implement design thinking practices in their pedagogies. The participants in this study were secondary school students in grades 9 and 10. The reasons behind applying the course in the secondary context are as follows: 1) students had little knowledge of design so the results of the evaluations of their gained skills are more reliable; 2) the original curriculum was developed for the same context and students in the same age range; 3) there is a lack of sufficient research about implementation of design thinking curriculum in the context of secondary education as well as evaluation of students' activities and skills to clarify the potential course benefits. The results of the study call for the need to explicitly develop and implement a design thinking approach in secondary level education to improve the skills of students including problem solving, human-centeredness, collaboration, and creative confidence. One central research question, and three sub research questions will be examined in this thesis to help answer the main research question:

- Main research question: How to best design and implement a secondary school level course on interaction design thinking?

Sub research questions:

- How does an interaction design thinking course benefit senior secondary school students?
- How does an interaction design-thinking course enable students to become design thinkers?
- Which interaction design thinking techniques or practices worked well in the course curriculum?

1.2. Methodology

This thesis takes a case study qualitative approach to examine the aforementioned research questions. Providing an in-depth investigation, analysis, and description of two cases (two identical courses) was the primary reason for choosing a case study methodology for this study. The nature of the research questions required in-depth understanding and description about students' activities and experiences during the course.

In conducting this research, a variety of qualitative techniques were applied to gather data from both cases. The types of data collection techniques that I employed include: in-depth interviews, participant observation, focus groups, open-ended questions, questionnaires, and visual method (document analysis). I synthesized the textual findings according to grounded theory technique that allowed me to conceptualize the findings that answered my research question.

Due to the exploratory nature of this study, construct validity was employed. Construct validity implies "Identifying correct operational measures for the concepts being studied" (Yin, 2009, p. 30). According to Stake (1995) there are two common ways to establish validity: triangulation of information and member checking. During the process of data analysis, multiple sources of data were integrated and triangulated by evidence from other sources. I also adopted member checking in which I presented my observation notes to the course instructor, and asked for comments about my observation notes, and whether he found any difference or misinterpretation of the happenings in the course and activities. Furthermore, I used case study protocol and developed a case study database to increase the reliability of the study.

1.3. Contributions of this Research

This study presents several important research contributions. First, it demonstrates how students' design thinking skills can be incorporated into their everyday life experiences and practices. It differs from previous research on design thinking implementations or evaluations that mainly focused on the implementations or discussed the benefits and outcomes 'within' the course. Second, the findings of the study shed light on design thinking evaluation, and how design educators and interaction design practitioners can evaluate participants' particular design thinking skills and abilities through different data collection methods in depth. Third, this study provides an analytical lens in examining and selecting a design thinking curriculum to teach in the context of secondary education. I pursue several steps to gather, select, develop, and implement the curriculum correctly, as well as evaluate the curriculum outcomes after completing the course. Finally, this study provides four substantial recommendations for design educators for implementation of a design thinking course in secondary education.

1.4. Overview

This thesis has been divided into nine chapters. The second chapter provides an overview of literature on design thinking definitions, applications, techniques, strategies, and assessments in educational contexts.

The third chapter illustrates the reasons behind employing case study methodology for this study. Also, in-depth description of the cases and subunits of analysis, and an overview of the cases and their similarities and differences are presented. In addition, this section provides an in-depth description of the curriculum selection, development, outline, and the general characteristics of the curriculum.

The fourth chapter introduces data collection methods and analysis, including in-depth description of data collection preparations, field procedures, and data analysis processes. The chapter also presents different types of data collection techniques employed, and strategies to increase the reliability and validity of this study.

The findings of this study are presented in chapters 5, 6, and 7. Each chapter provides an answer to one of the above research questions. The findings in chapter 5 mainly describe several benefits that students gained within and outside the course. The next chapter provides findings about students' design thinking skills (problem solving, human-centeredness, collaboration, and creative confidence). In chapter 7, the design thinking techniques and activities that worked well in the course are introduced.

Chapter 8 provides discussion around findings of the study, which include: the benefit of the course for students, the skills they gained in the course, and their preferred techniques and materials. In addition, the chapter provides recommendations for implementation of a design thinking course. Three limitations of the study are introduced in this chapter as well.

Chapter 9 concludes the study and provides information about the study's contributions, along with several suggestions for future work such as involving more schools, investigating students' skills over a longer period of time and other contexts, and investigating the design thinking practices in non-design courses in secondary education.

Chapter 2.

Literature Review

2.1. An Overview of Design Thinking

Design thinking is a specific design practice that aims to foster innovation by elevating participants' creative thinking abilities. It usually involves a problem-solving approach to solving complex problems, which can be best achieved through collaborative and human-centred activities. Design thinking definitions may vary across the literature; however, they hold several commonalities. As Tim Brown and Jocelyn Wyatt explain, "design thinking relies on our ability to be intuitive, to recognize patterns, to construct ideas that have emotional meaning as well as being functional" (Brown and Wyatt, 2010, p. 12). Over the past decade, design thinking approaches became popular across industries, and have been employed in different fields such as business (Brown, 2008), management (Dunne and Martin, 2006), healthcare (Duncan and Breslin, 2009), social innovation (Brown and Wyatt, 2010), and library services (Bell, 2008). These approaches aimed to provide outstanding and human-centered products or services for users.

Design thinking and practices have been incorporated into different curricula in design, engineering, and business fields as particular skills that help students succeed in the 21st century and prepare them for college or a career (Rotherham and Willingham, 2009). These practices in particular help students to read and think critically and change how they solve complex problems. In educational contexts, design thinking skills can be learned through pedagogical approaches that involve problem-based learning, project-based learning and inquiry-based learning in classroom activities (Dyme et al., 2005). These practices are understood by experts to play an important role in different disciplines, such as architecture (Akalin and Sezal, 2009), product design (Verea et al.,

2005) media education (Lugmayr, 2005), and engineering (Todd and Magleby, 2004). Moreover, studies conducted in K-12 education indicate design-based learning could improve students' skills even before the university level. These practices have been implemented in secondary-level education for supporting students' learning of complex respiratory structure (Hmelo, 2000), geography systems and elements (Carroll et al., 2010), interaction design (Dukes and Koch, 2012) as well as the informal education of students in developing a museum visit device (Roussou et al., 2007) or building an eco-playground (Lee et al., 2008). Such pedagogy curricula mostly follow the conventional five stages of the design process: empathize, define, ideate, prototype, and test in an attempt to solve a predefined problem. These curricula mostly focus on the implementation of the practices and evaluation of the outcomes after completion of the course to estimate the benefit and effects of such practices on students' learning outcomes and creative thinking in solving the problem posed.

2.1.1. Design Thinking Origins and Definitions

The term 'Design Thinking' was first introduced by Peter G. Rowe in his book titled Design Thinking, which was published in 1987. The focus of Rowe's book is design thinking in architecture and urban planning. Thus, like the origin of the use of patterns in design, the conception of design thinking arose from the field of architecture, more specifically, the design thinking practices initiated at Stanford University starting in the 1980s, which nowadays continue in the d.school bootleg. The design-thinking practices attempted to provide an innovative process to solve design problems. The final solution to the design problem can be best achieved through a multidisciplinary and collaborative environment that requires thoughtful design process. Design scholars and theorists such as Nigel Cross, Richard Buchanan, Donald Schön, and Tim Brown played a crucial role in forming and conceptualizing design-thinking theories and concepts. Nigel Cross investigates intuition as a unique feature in design and emphasizes the importance of tacit knowledge in the design process. He believed that "design has its own distinct intellectual culture; its own designerly things to know, ways of knowing them, and ways of finding out about them" (Cross, 1999). Richard Buchanan (1992) shifted the design-thinking concept to a more intellectual approach to framing and solving problems for complex design problems, which can be applied to any design discipline. Donald A.

Schön (1983), in his book 'The Reflective Practitioner', explained how professionals think in action, their thought processes and methods of design practices. Tim Brown emphasized the human-centred nature of design thinking and clarified that it is not only "creating products and services human centred, but the process itself is also deeply human" (Brown, 2008). Following Brown, Howard and Melles (2011) defined design thinking thus: "Design thinking denotes a collaborative and human centered problem solving process using a designerly approach to solve wicked problems, extending from products through to services and other design spaces" (Howard and Melles, 2011, p. 152).

Design Thinking Definition by d.school

The Hasso Plattner Institute of Design, known informally as the 'd-school', is a well-known leading school in design thinking and innovation based at Stanford University. According to the d.school's definition, design thinking process is about using a human-centered approach to create innovative solution(s) to a problem by following a five-step design process including empathize, define, ideate, prototype and test. The whole process focuses on developing a d-studio 'mindset', which includes the following characteristics: show, don't tell; focus on human values; craft clarity; embrace experimentation; be mindful of process; bias toward action; and radical collaboration (Bootcamp Bootleg D.School, 2011). The d.school's several steps (modes) of design thinking process are:

- **Empathy**: the empathy mode in design process is the centerpiece of a human-centered design process. In the Empathize mode a designer tries to understand humans within the context of design challenge. Understanding how people do things, their physical and emotional needs, and what is meaningful to them are fundamental in a human-centered design process.
- **Define:** in the define mode, a designer crafts a meaningful and actionable problem statement (point of view) by synthesizing and making sense of the information gathered about user needs and context in the empathy mode.
- **Ideate:** the ideate mode in design process concentrates on idea generation. This step is about incorporating volume and variety in concept generation through visual representations. Ideation provides source material for building prototypes and innovative solutions (final product).
- **Prototype:** the prototype mode aims to explore and generate artefacts that users can experience or interact with. It can be anything that takes a physical form such as a role-playing activity or even a storyboard. Prototype creation

requires iterative process and can be created for the early exploration phase (low-resolution artefact) or the final phase (high-resolution artefact).

- **Test:** the test mode provides another opportunity to gain empathy for the users and understand their opinions by asking about the created prototypes. Unlike the initial empathy mode, the problem and possible solution are framed in this stage, and the prototype can be ideally tested within a real context of the user's life to achieve a better result. Overall, testing provides the chance to improve and refine the solution.

Figure 2.1. provides a visual representation of design thinking process according to the d.school.

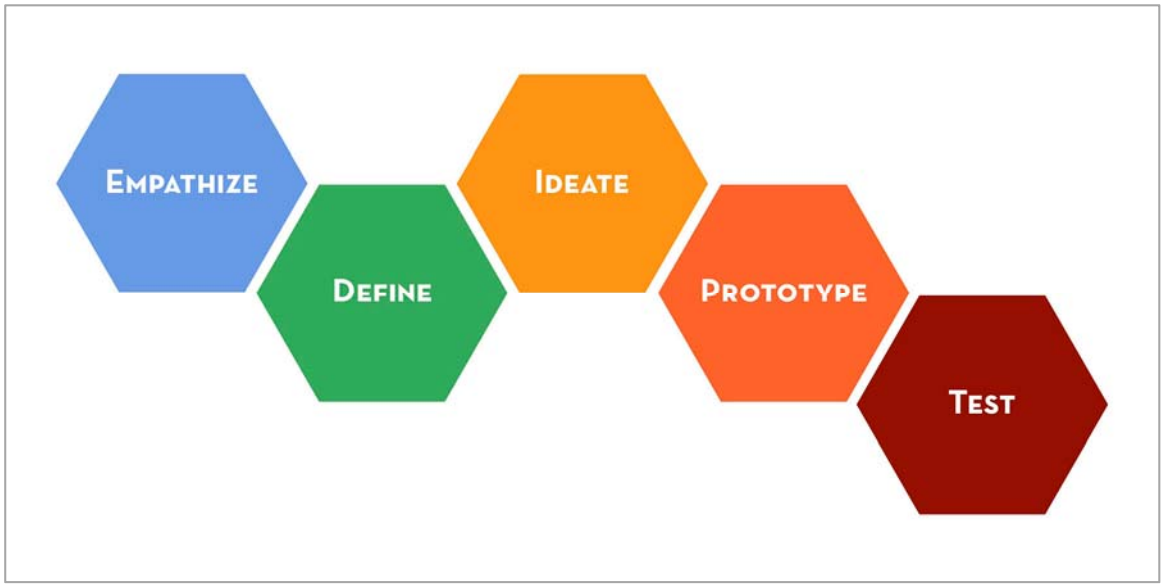

Figure 2.1. Visualization of Design Thinking Process According to the D.School

2.1.2. Design Thinking in Compare to Design Cognition and Design Practice

The design thinking approach aims at developing a d-studio "mindset", which enables non-designers to think like designers. Being involved in a design thinking process provides an opportunity for an individual to gain certain skills and become a design thinker (please refer to section 2.1.3 for more description). Design cognition in the creative process aims at learning about designers' complex cognitive actions, and how designers "see, move through, create, and relate to their visual, spatial, and temporal world" (Dillon, 2010, p. 28). According to Suwa, Purcell, and Gero (1998), cognitive actions can be divided into four categories: physical, perceptual, functional,

and conceptual. In solving a problem during the design process, designers' mental representations of the design problem are wide ranging. In a creative process, designers' cognitive processes incorporate both divergent and convergent forms of thinking. During a problem-solving process, designers' mental representations evolve to reach an innovative and satisfactory design solution. 'Externalization' is an important concept in design cognition, which refers to "the creation and modification of external representations (e.g., drawings or sketches) of the object to be designed" (Bonnardel and Moscardini, 2012). According to Schön (1983), these representations enable designers to engage in a "reflective conversation" with their drawings, which allow them to have better understanding of their design problem, and reach their unique solution.

Design practice is characterized by Schön as "conversation with the situation" or "reflection-in-action" in which designers incorporate their ideas into representational media, reflect on and modify them (Schön, 1987). He argues that design practices are more of an art than science due to the complex 'messy' nature of problem situations. According to Schön, design knowledge is tacit and designers "can best gain access to their knowing-in-action by putting themselves into the mode of doing" (Schön, 1991, p. 2). In design practice, the goal is to create something "non-universal" with a "specific purpose, for a specific situation, for a specific client and user, with specific functions and characteristics, and done within a limited time and with limited resources. Design is about the unique, the particular, or even the ultimate particular. The ultimate particular is the actual final manifested outcome and as such a result of an intentional design process" (Stolterman, 2008, p. 59). In HCI and interaction design, design practice refers to design activities intended to create industry products. According to Green (2009), to define a "professional practice" understanding, three interrelated aspects of practitioners' "activities, experiences, and contexts of practice" are necessary (Green, 2009, p. 7).

2.1.3. Characteristics of Design Thinkers

Tim Brown (2008) identified self-reflexivity as an important outcome of involvement in a design process, and explained how designers are able to "identify themselves as design thinkers who possess a methodology that enables them to come up with a solution that nobody has before" (Brown, 2008). He further discussed five

personality traits that a design thinker should possess: empathy, integrative thinking, optimism, experimentalism, and collaboration (Brown, 2008).

According to Löwgren and Stolterman, design thinkers can make much more deliberate and thoughtful decisions to solve complex design problems. They define the characteristics of a thoughtful designer as: “equipped with appropriate tools for reasoning, which will be more able to sort out what is important, make necessary judgement calls, distinguish true needs for more information from better-safe-than-sorry approaches, and identify fruitful directions in the exploration of possible futures that is called design” (Löwgren and Stolterman, 2004). Further, since every design process is unique, “a designer needs to be critical toward any description of design process, and pay enough attention to appropriate aspects rather than adopt it completely” (Löwgren and Stolterman, 2004, p. 28). According to these statements, in complex design problems a design thinker is equipped with a reflective and critical mind, able to “critically examine assumptions,” and “externalize the actual design thinking through representations” (Löwgren and Stolterman, 2004, p. 28). They conclude that a thoughtful design process cannot be achieved without considering creativity, teamwork, management, social and ethical aspects, and analytical or visual thinking.

Charles Owen (2007) identified creativity as of major importance to design thinking and summarized design thinker characteristics as: 1) conditioned inventiveness that involves both human-centred focuses and environment-centred concerns, 2) ability to visualize and depict ideas, 3) ability to explore multiple solutions to a problem, 4) having system vision, and ability to treat problems as system problems to create a holistic solution, 5) ability to use language as a tool to express their creative process when visuals lack clarity and details, 6) ability to communicate across disciplines and work with other people, 7) avoiding the necessity of choice and searching for alternatives before making the final decision, and 8) ability to work systematically with qualitative information (Owen, 2007, pp. 24-25). He further explained that during a design process, designers are involved in several cognitive processes such as preparation, assimilation, and strategic control (Owen, 2007). These steps are titled differently in the literature, and the best result for the process can be achieved through an iterative rather than a sequential process.

2.1.4. Processes in Design Thinking

The design thinking process often involves an interactive, exploratory, and sometimes chaotic process (Braha and Reich, 2003). The process starts with an abstract specification of a problem or a design 'brief' and an iterative process involved until a final solution is reached (Hatchuel and Weil, 2009). According to Tim Brown, the design thinking process contains three overlapping steps: 1) inspiration or problem setting that motivates the problem-solving process, 2) ideation or the process of creating ideas, and 3) implementation or the process of bringing the innovation into people's everyday lives (Brown, 2010). Furthermore, during the design process, designers are involved in several cognitive processes. According to Kolodner and Wills (1996), three stages are required in the design thinking process: preparation, assimilation, and strategic control. In the preparation phase, designers explore the definition of the problem space, reinterpret and visualize the ideas, and reformulate the problem. In the assimilation phase, the designer synthetizes the data and proposed solution by investing in the design space. In the strategic control phase, designers make decisions through synthesizing the ideas, tasks and processes that were proposed in the previous stages.

Furthermore, some basic elements of design thinking were identified in research by Stempfle and Badke-Schaube (2002), which investigated a theory of what design teams do while designing. These basic elements of design thinking are introduced as cognitive operations in the problem-solving process and involve generation, exploration, comparison, and selection. The first two elements help with exploring and widening a problem space, while the last two narrow down the problem space, and help with selecting an optimal solution. In contrast to the above research, a study by McNeill, Gero, and Warren (1998) suggested that designers spend most of their time analyzing the problem space, and the remaining time synthesizing and evaluating the solution. As the design progresses, the designer engages in a cycle of analysis, synthesis, and evaluation, which is an iterative progress. Similarly, Goldschmidt and Weil (1998) suggested that the process of design thinking is nonlinear and designers follow an iterative process involving a forward (breaking down) and backward (validating) reasoning strategy.

2.1.5. Summary

The above literature plays an important role in understanding the nature of the design thinking process and potential outcomes. Several design scholars and theorists provided definitions, insights and perspectives on design thinking process. According to the literature, design thinking is a collaborative problem-solving and human-centric approach that fosters innovation. The most common steps in a design thinking approach are empathize, define, ideate, prototype, and test.

In secondary and post-secondary education systems, students can benefit from the design thinking process by learning certain skills that enable them to think creatively and critically, to solve complex issues, or to learn a complicated concept. During a design thinking process an individual experiences different cognitive operations including generation, exploration, comparison, and selection (Stempfle and Badke-Schaube, 2002). The first two steps facilitate exploring a problem space, while the last two help with selecting a solution. Some other scholars refer to these cognitive abilities as divergent and convergent thinking (Karnes et al., 1961).

Finally, the above literature indicates that the learning progression during design thinking processes and activities can eventually transform a novice designer into an expert design thinker.

2.2. Design Thinking in Educational Contexts

The focus of 21st century public education will be on innovation, creativity, critical thinking, problem solving, communication, and collaboration. Design thinking and practices have been implemented in different design and non-design curricula. These practices in particular help students to read and think critically and change how they learn and solve complex problems. In educational contexts, design-thinking skills can be learned through pedagogical approaches that involve problem-based learning, project-based learning, and inquiry-based learning in classroom activities (Dyme et al., 2005). This section reviews literature on successful application of design thinking-based pedagogies and its benefits, particularly in post-secondary and K-12 education.

2.2.1. Design Thinking in Post-Secondary Education

The following studies by design thinking scholars provided useful resources and guidelines on how to best develop and implement design thinking-based pedagogy for post-secondary education. In applying appropriate design thinking training in pedagogies, Lau, Ng, and Lee (2009) classified and provided a guideline for design educators in higher education.

Five categories of creative-thinking techniques were classified and introduced in their paper, and the authors acknowledged that 'creativity' cannot be taught but 'creative thinking' can be taught through certain techniques and processes. The first category, 'identifying and mapping attributes', introduces tools for identifying the nature of problems through mapping notes and critical analysis. Some tools such as mind mapping, concept map, and hierarchical method are introduced in this category as cognitive organizational tools. These methods can produce a high number of solutions and break down the problem and its attributions. The second category is 'making possibilities'. The techniques proposed in this section can help students generate numerous ideas that may propose solutions. So the problem may not be solved directly, but can generate alternatives for further considerations. Brainstorming is the most popular and effective creative thinking technique in this category. The third category is called 'changing and shifting perspectives', which explores various perspectives in problem solving. Divergent thinking skills are promoted in this category. Some of the techniques that enable an individual to have a divergent perspective are Six Thinking Hats and Empathizing (a role playing technique). The fourth category, 'making associations and analogical thinking', focuses on alternating and replacing individuals' habitual thinking with something opposite or different. According to this category, in order to create something novel, an already existed thing can be changed through substituting, combining, adapting, magnifying, eliminating, and rearranging. Some of the techniques are Lateral Thinking, Random Words, and the Paradox. The final category, 'probing emotion and the subconscious', considers the role of the individual's subconscious and emotion in creating possible ideas. In all the above-mentioned techniques, the process of thinking in creative design education is emphasised rather than the sudden emergence of an idea (Lau, Ng, and Lee, 2009).

Similarly, a study by Kowaltowski, Bianchi, and de Paiva (2010) provides a useful resource for design and creativity educators by collecting and discussing techniques and strategies that are employed in pedagogies by architecture instructors around the world to stimulate creativity. The authors of the paper argued that techniques such as brainstorming, decision-making or other creativity enhancement methods should intertwine with traditional techniques of prototyping, drafting, drawing to provide innovative products. Winters (2011) proposed a strategy to assist meta-learning and self-awareness of students in their learning progress in art and design education, helping them to become more reflective, productive and self-regulated learners.

Furthermore, problem solving or the inquiry-discovery approach in design thinking can enhance creative abilities and performances of individuals. As Treffinger suggested, “experience with discovery learning enhances creative performance by forcing the learner to manipulate the environment and produce new ideas” (Treffinger, 1980, p. 34). In fact, incorporating both problem-solving and problem-setting approaches in the curriculum can stimulate creativity of students (Davis, 1991; Todd and Magleby, 2004; Karnes et al., 1961). Hence, techniques and practices that promote both convergent and divergent thinking of students (as necessary cognitive skills in creativity performances) are essential in stimulating their creative thinking (Karnes et al., 1961), which can be best encouraged and incorporated in a design-thinking approach.

Benefit of Design Thinking in Post-Secondary Education

The following studies clarified the benefit of design-thinking strategies in post-secondary education. Design thinking-based pedagogies have been developed and implemented in different post-secondary disciplines including architecture (Akalin and Sezal, 2009), industrial design (Wormald, 2011), product design (Verea et al., 2005), media education (Lugmayr, 2011), and sustainable design (Klein and Phillips, 2009).

In a study by Wormald (2011), a new technique was explored in teaching industrial design, which enabled students to participate deeply in ‘pre-brief’ activities, and analyse the findings. The new curriculum was developed with the aim of leading graduate students to be more innovative, and gain better abilities and knowledge for design careers. In contrast to existing industrial design education curricula, where the

main focuses are on problem-solving processes, the introduced technique was focused on identifying opportunities or 'problem setting' to explore the problem space in-depth. Students are encouraged to develop their skills in finding right problems and to see the bigger picture in an early design process. Hence, they spend more time on user research and branding, to gather data, analysis and generate insights for design. The results of the study indicated that the proposed model has valuable potential in leading students to develop innovative ideas.

Another study by Akalin and Sezal (2009) introduced a new approach, which enhanced the process of design thinking in architectural studio-based learning. The study explored traditional sketching in a new form of conceptual mode (three-dimensional sketches) that facilitates communication between students and teachers. The impact of modelling was argued in the study as a medium for cognitive development, which enhanced problem-solving capabilities of students in studio-based learning and gave students opportunities to explore and enrich their ideas and test their hypotheses early in the design process.

The next study by Verea et al. (2005) explored a new interdisciplinary program entitled product design engineering (PDE), which emphasised the significance of teaching design thinking to engineering students to become creative thinkers. Students learned about social responsibility and sustainability by developing projects that addressed social needs, energy consumption, and waste reduction. Students also had the chance to develop design solutions for real world projects. Another important teaching technique in PDE courses was sketching and rendering that enabled students to develop solutions to problems through visual representations of ideas. Besides, the program involved project-based courses that emphasised open-ended problem-solving activities, creative thinking, and user-centered design. The course was found to be appealing to female students who were not interested in engineering education. Overall, students gained multidisciplinary skill sets that provided them with better opportunities in their future careers and in addressing product design problems.

In a study by Klein and Phillips (2009), a new curriculum model was developed and implemented, which introduced sustainable design concepts to industrial design

students. The curriculum model was divided into different categories including low-impact, renewable, recycle, reuse, nontoxic, energy efficiency, quality and durability, life cycle assessment, and social relevancy of product, and was assessed using three different data collection methods. The study introduced a new curriculum that enhanced student understanding of sustainable design as an important parameter in product developments.

Lugmayr et al.'s (2011) design thinking strategy has been adopted as a principal teaching method for a media management course and provided a practical hands-on approach for future design educators. The objective of the course was to teach problem-solving skills to students within a cross-disciplinary team (students and industrial partners), in order to boost their idea generation and creative thinking in the creation of new products in media industries. The intercultural groups improved teamwork and knowledge exchange among students, enabling them to become familiar with different viewpoints and ways of solving problems. Also, the non-lecture format of the course provided an engaging and relaxing atmosphere that fostered creative thinking of students. The course instruction raised awareness about the importance of empathizing with customers rather than thinking about solutions.

2.2.2. Design Thinking in K-12 Education

Similar to post-secondary education, studies of design-based learning in K-12 education saw improvement in students' skills early on or before reaching university-level studies. These types of design-based learning have been implemented into secondary-level education for supporting students' learning of complex respiratory structure (Hmelo et al., 2000), geography systems and elements (Carroll et al., 2010), interaction design (Dukes and Koch, 2012), and product design (Lee and Bichard, 2008). In the study by Hmelo et al. (2000), design thinking helped students to understand the complex respiratory structure (anatomy) and its functions (physiology), through making prototypes. In the study by Carroll et al. (2010), design thinking supported student learning, mainly through active collaborations and iterative processes. Dukes and Koch (2012) explored design thinking in the ninth grade, and concluded that design thinking and practices can help students, regardless of their field of study, to develop their

capabilities. Overall, design thinking curricula mostly focus on implementation of design thinking practices, and evaluation of the outcomes after completion of courses to estimate the potential benefit and results of such practices for students' learning or their critical thinking in solving complex problems.

Benefit of Design Thinking in K-12 Education

According to the following studies, students in K-12 education can benefit from design-thinking practices. In a study by Carroll et al. (2010), design-thinking practices were implemented in a middle school geography class. The study indicates that design thinking is a powerful tool to support learning through active collaborations and iterative processes. The findings of the study provided three key themes. The first theme is design as exploring: students learned to explore different aspects of design problems prior to proposing design solutions. The finding indicates that students had different understandings of the design process, and adopted them in different ways. Design thinking was also found as a tool to foster metacognition skills of students. According to their explanation, metacognitive awareness means "the ability to know where they are in the process and the goal they are moving towards" or "being mindful of the process" (Carroll et al., 2010, p. 41). The second theme, design as connecting, focused on the role of design thinking in developing students' creativity and confidence through active engagement, risk taking, and expressing ideas. Collaboration as a key component of design thinking helped them to solve their design problems together. Students preferred active learning activities, and the design thinking project facilitated their engagement by providing opportunities for them to express their opinions. Also, prototyping was a powerful tool to engage students quickly and effectively. The third theme explained how to connect design thinking to an academic learning environment. Teachers had problems integrating design thinking concepts with geography content, and students had to learn both disciplines in order to make connections between them. Students were not able to make a clear connection between design and geography because they did not have a strong foundation in design thinking or geography (Carroll et al., 2010).

Another study by Dukes and Koch (2012) explored teaching interaction design to teens. The idea behind the study is that design thinking and practices can help students develop their capabilities regardless of their field of study. Over the course of the study,

students became familiar with design thinking tools, through storytelling, presenting, researching, and observation. The reflection and discussion encouraged in the course enabled students to benefit from the variety of ideas proposed in the class. In a study by Lugmayr et al. (2013), the most appreciated benefit that the students gained from the design thinking course was the opportunity to be involved and to learn from an interdisciplinary educational team (media management and applied science), and the human-centric approach of the design. Another study by Hmelo et al. (2000) explored the affordances of design in science learning. The design activities were beneficial for students to understand complex structural, behavioural or functional aspects or components that might be viewed from multiple perspectives. In particular, the course enabled students to gain a deeper and systematic understanding of the complex respiratory system. Finally, in a study by Lee and Bichard (2008), multiple interactions and engagements were encouraged among students and designers to create a new eco-playground near the school. The researchers introduced design thinking to secondary school students and involved them equally in the design process aiming to explore new ways of participation. The study introduced Design Participation, which involved people with different backgrounds in the design process by creating multi-disciplinary collaborations among them.

2.2.3. Summary

The above section focuses on design thinking benefits and results in educational contexts, and provides an overview of design thinking techniques and strategies that stimulate creative thinking of students. Several articles emphasised the importance of applying both problem-solving and problem-setting activities in a design thinking curriculum to stimulate creative thinking of students. Furthermore, in design thinking education, a curriculum's learning outcomes can vary according to type of activities, or the environment that students are involved in. Hence, a design-thinking approach can be adapted to different educational contexts to enhance and encourage certain skills of students.

2.3. Characteristics of an Effective Design Thinking Pedagogy

In this section, I will introduce literature on effective strategies that foster creative thinking and creative performances of students in design-based pedagogies. Also in this section, I will discuss different methods and strategies to assess creative problem solving processes or outcomes. A study by Kowaltowskiy and Cropley (2010) provides a practical guideline for design educators in understanding how teachers recognize functional creativity in students' products, and how their teaching promotes student creativity. In educational discussions, creativity can be studied from four different perspectives: person, process, product, and press. This article focused on product, and how teachers can recognize creativity in products. The creativity criteria that need to be recognized by design education instructors include relevance, effectiveness, novelty, elegance, and genesis. These criteria can be best achieved through a pedagogy that promotes the following strategies: 1) provide students with appropriate practice in solving a design problem, 2) provide systematic training based on real examples, 3) structure practices to improve students' knowledge and skills, 4) narrow down the practices and activities from broad to focused tasks. Also, the study discussed the open-ended nature of design problems as an important factor in creative performances.

Benson and Lunt (2011) identified some key elements to be considered in pedagogies that encourage the creative performance of students: ownership, motivation, space, time, interaction, and collaborations. They also provided some suggestions for creativity-supported curricula: 1) highlight creativity as a goal in activities, 2) encourage students' sense of ownership by enabling them to explore freely, 3) provide hands-on practices, 4) avoid limiting the amount of time as it provides pressure, 5) encourage collaboration and interaction of students. Furthermore, Howard-Jones (2002) suggested a dual-state model of creative cognition, through moving and connecting primary and secondary thinking processes. Primary process thinking or a generative process involves unfocused, less conscious, and free thinking/exploring tasks. Secondary process thinking or analytical process involves focused, critical thinking, logical analysis, exploration, and more conscious activities. This study suggests that self-evaluation in the creative process is essential for independent learning; however it reduces students'

ability to create novel ideas. Second, brainstorming is a suitable technique to use in a self-evaluation approach. Brainstorming avoids criticism but encourages free exploration of ideas. Third, reward and competition may support students' effort, but may not help with generation of novel ideas. Fourth, a design session requires a relaxed and non-competitive environment to foster creativity. Fifth, providing examples is likely to encourage fixation and over-focusing of design. These guidelines were considered while I redesigned and improved the interaction design-thinking curriculum.

2.3.1. Summary

In the above section, I reviewed articles that provide recommendations on qualities and characteristics of an effective design thinking curriculum. Some of these characteristics are employed in my course curriculum to ensure that the curriculum supports creative thinking of students.

In design education, creativity of students can be studied from different perspectives: person, process, product, and press. For the aim of this thesis, I studied students' design thinking skills and performances from the person's point of view. Hence, the creative capacity of students was evaluated according to their own perspective and operations during the course. Finally, some of the above articles were found to be fundamental and will be employed in the discussion section to further investigate and examine findings.

2.4. Design Thinking and Creative Training Assessments

This section provides an overview of different articles that studied and evaluated creative capabilities of students. As discussed in the previous section (2.4) in an educational context, creativity can be studied from four different angles: person, process, product, and press.

In the following paragraph I will review creativity assessment strategies aimed at evaluating *design outcomes*. In a study by Hennessey, Amabile, and Mueller (2011), the Consensual Assessment technique was introduced for assessment of creativity of

products. The technique has been applied in a variety of contexts such as visual products, poetry, essays, and programming. Amabile suggested that the creativity of a product could be assessed based on the independent agreement of experts on its creativity. The technique is based on the assumption that independent raters who are experts in product domain, did not interact with one another and did not train with the researcher, are best able to judge the creativity of products. Similarly, Christiaans (2002) investigated whether human judgement can be employed as a reliable method in assessing creativity. The study is a successful example of creativity assessment of products in the design education procedure. In an experiment the judgements by experts, non-experts, and intermediate experts were compared, based on several criteria: creativity, prototyping, attractiveness, interest, technical quality, quality of examples, and expressiveness. Further, Thang, Sluis-Thiescheffer, and Vermeeren (2008) employed expert assessment as a method to compare the creativity of outcomes for two early design techniques of brainstorming and prototyping. The creativity of solutions was assessed based on five exploratory criteria of novelty, surprise, workability, thoroughness, and relevance. The findings revealed that the brainstorming solutions were novel and surprising, while the prototyping solutions were more informative, relevant and workable. The findings from both studies indicated that in design education and design procedures, expert judges are a reliable resource for assessment of creativity, because unlike art, design includes more objective aspects such as functionality and technical quality. Furthermore, the Stanford d.school offers courses aiming at enhancing creative capacity of students through design-thinking skills development (http://dschool.stanford.edu). Following academic traditions, instructors and classmates often evaluate and judge students' deliverables. Although these methods have academic values, they do not allow a formal assessment or support for whether students' creative abilities or capacities have been enhanced over time.

Several studies investigated and evaluated students' creative skills buildings during the *design processes*. Hawthorne et al. (2014) explored whether an individual can learn creativity over time and how this relates to their thinking process, behaviors, and brain functions. Through a design thinking course and a series of steps including observe, brainstorm, synthetize, prototype, implement, and iteration as necessary, students were involved in an experiential learning environment. The course was

conducted in an interactive studio form, where students built and developed their design thinking skills and creativity confidence through hands-on activities (Hawthorne et al., 2014). In this study, the design thinking creativity test (DTCT) was developed for assessing creativity following the Torrance Tests of Creative Thinking (TTCT) test that reflected problem-solving needs by testing creative ability in a real world scenario. The TTCT includes three picture-based exercises to evaluate mental characteristics of fluency, resistance to premature closure, elaboration, abstractness of titles, and originality (Torrance, 1974). Furthermore, several studies developed certain tools to assess creativity. The Creativity Achievement Questionnaire (CAQ) was developed by Carson et al. (2005) to assess creative productivity across 10 areas including visual arts, music, creative writing, dance, drama, and architecture. Another tool developed by Royalty et al. (2014), the Creativity Agency and Confidence Questionnaire (CACQ), is a self-reported scale questionnaire to evaluate creative self-efficiency of individuals based on perception of their own creative capacity. The research is conducted at The Hasso Plattner Institute of Design at Stanford University (d.school), one of the leading institutes in the problem-solving approach, design thinking field. In this study, individual alumni were considered as the unit of analysis versus the organization (d.school), and the self-efficiency of individuals and their confidence to think and act creatively within the certain domain (creative problem solving) was assessed.

Royalty et al. (2014) defined creative agency as the “individuals’ capacity to effect change in themselves and their situations to support successful creative problem-solving” (Royalty et al., 2014, p. 82). This tool is created based on a framework of a d.school teaching model introduced by Rauth et al. (2010) that “mindsets and creative confidence are built on top of repeated practice and success with discrete techniques such as design thinking process and its various associated methods” (Royalty et al., 2014, p.81). These mindsets include a bias towards action, ongoing collaborations, being human-centered, and an iterative process (Royalty et al., 2014). The competency-based creative agency scale was developed according to data found from a survey and interviews conducted with alumni, and coded for the emerging key competencies. The scale was created directly from those factors that emerged from the study and was tested with d.school students and teachers and non-d.school students. The key competencies found include: creative idea sourcing, comfort with ambiguity, openness,

building creative environments, anti-perfectionism, prototyping, perseverance after failure, creativity facilitation in others, mastery of creative process, knowledge of creative process, and successful creative problem solving (Royalty et al., 2014).

While the above studies focused on the individuals' and final products' creativity assessments, there are certain studies that investigate how to enhance an individual's creative abilities, through appropriate *techniques or processes*. The creative learning technique emphasizes pedagogical processes of teaching and learning rather than outputs or artefacts. According to Pringle (2011), recruiting a visual art practitioner can be beneficial in creative learning and teaching practices. An artist can bring extra value to the existing pedagogic process by having different roles whether as a creative practitioner, a facilitator or a collaborator who engages during an educational period by providing feedback, resources, opportunities for creativity, and flexibility in tasks (Pringle, 2011). Bragg (2011) discussed the opportunities and limitations of exploring visual methods within research, creative learning, or participatory approaches. Visual methods provide a tool for thinking, which is a valuable resource for stimulating students' imagination, reflection, and thinking through hands-on, creative, collaborative activities (Bragg, 2011). The methods also enable youth voices to be heard, encourage tacit knowledge and informal learning, and as a result also encourage self-motivation and self-confidence of students (Bragg, 2011).

A study by Martin (2008) introduced a comprehensive guideline on choosing a variety of research methodologies for researchers of creative learning with children. He recommended: observation scales for evaluating teacher and pupil behaviours; problem-solving scenarios to gain insight from pupil thinking; interactive oral interviews to assess what pupils understand about a specific topic; focus groups to encourage participants to discuss a certain topic based on one another's responses; case studies to investigate a particular case in depth; standardized assessment of cognitive components of creativity, audiotapes, photographs, videotapes; surveys and pilot testing; self-reports where pupils report about their creative thinking and tasks, and analysis of pupil artefacts based on sets of predefined criteria (Martin, 2008). Following his suggestions on employing mixed methods for documenting creative learning, this research benefits from several methods of data collection, as is described further in chapter 4.

2.4.1. Summary

The above section reviewed several articles that studied and evaluated creative thinking and learning of students in different design education contexts. I categorized the articles based on their viewpoints towards creativity assessment (person, process, product, or press). Furthermore, I provided detailed description of the article by Royalty et al. (2014) because I followed the same strategy to evaluate students' creativity confidence in my study. Another important article by Martin (2008) provided a comprehensive guideline for choosing the right data-gathering method to study creative abilities of students. Overall, the above section provides informative instructions on how to best evaluate creativity of students.

2.5. Conclusion

In this chapter, I provided an overview of fundamental literature from prominent scholars on design thinking definitions, processes, and evaluations. Also, I reviewed several articles relevant to design thinking benefits and outcomes in educational contexts, including appropriate techniques and strategies that stimulate creative thinking and abilities of students.

Following that, I reviewed several studies that provide suggestions and recommendations on how to best develop design thinking curricula that support creative thinking of students. In the last section of this chapter, I summarized articles on creativity evaluation of students. All in all, this chapter provides a holistic review of design thinking definitions, applications, techniques, strategies, and assessments in educational contexts.

Chapter 3.

Research Methodology and Research Design

This research aims at investigating how to best design and implement a secondary school-level course on interaction design thinking. To address this question, I undertook a multiple-case approach that examined an interaction design thinking curriculum in two secondary schools (Mulgrave and Stratford Hall secondary schools, located in West Vancouver and Vancouver respectively) for nine weeks. These two case studies provided access to a number of different streams of data about the benefit of the course for students, and imparted skills and experiences that enabled students to become design thinkers. In this chapter I restate my research objective and research questions, and I present an overview of qualitative research and case study research and why they are a good fit in my investigation.

3.1. Research Objective

The goal of this study is to articulate a description of the design and implementation of an interaction design thinking course for secondary level students in grades 9 and 10, and to evaluate the benefit and knowledge students gained in the course. The reason behind working with grades 9 and 10 students is that the original curriculum was developed for this age group. In terms of design and implementation, I hope to provide a more detailed view of techniques, course material, and process that can be employed in such a course by providing reasonable and detailed evidence and explanation. In terms of evaluation, I hope to provide answers to two research questions that investigate the benefit of the course for students and the knowledge they gained as they became design thinkers. In addition, for teachers (particularly those who work in secondary level education), this research is beneficial because it provides a guideline on design and implementation of a design thinking course and helps teachers to realize the

importance of having creative problem solving courses before the university education level. For researchers, this research provides an important step in evaluating the implementation of a creative problem solving course on students' perceptions, knowledge and skills as they become design thinkers and problem solvers. Having employed several data collection techniques such as observation, interview, and document analysis, this research provides a novel and valuable approach to evaluate an (interaction) design thinking course through a variety of research lenses.

3.2. Research Questions

The case study questions and propositions are part of the chain of evidence proposed by Yin (2009). He argues that to increase the reliability of the case study, the researcher needs to maintain a chain of evidence from the research questions to the conclusions of the study. An investigator should be able to follow the logical steps between *research questions, case study protocol, citations to specific evidentiary sources in the case study database, case study database and case study report* (Yin 2009, p. 123). The research questions and the propositions are drawn from the literature review that I conducted before starting the research. The propositions are particularly important in case study research as they orient the data collection and data analysis. The main research goal is to understand how to best design and implement a secondary level course on interaction design thinking. To investigate the interaction design-thinking techniques, practices and results in secondary level education, I am asking the following main research question:

Research question: How to best design and implement a secondary school level course on interaction design thinking?

I began exploring this question by focusing on the following sub-questions:

- Q1: How does an interaction design thinking course benefit senior secondary school students?

To address this question, data was gathered by interviewing students and teachers outside the course, as well as observing students' activities and performances

during the course. The following sub-questions helped us to gather and interpret data: 1) How do students interpret design thinking outside the classroom? 2) How do students apply it to their everyday life? 3) How do students apply it to other courses?

- Q2: How does an interaction design-thinking course enable students to become design thinkers?

To address the second question, data were gathered through observing the students' design thinking activities, specifically on creativity, problem solving, collaboration, and empathy (human-centeredness). In addition, pre and post questionnaires were given to students to complete before and after attending the course. The quantitative multiple-choice questionnaires were employed to evaluate students' creative confidence, and had to be completed individually. The other pre and post questions aimed to evaluate students' improvements on problem solving, empathy, and collaboration skills, and were designed to be completed in groups. Due to the qualitative nature of the analysis undertaken in this study, some of the constructs of interest emerged over time from the data. Nevertheless, the research question I am asking suggests some constructs to look for and ways of probing for them.

- Q3: Which interaction design thinking techniques or practices worked well in the course curriculum?

To address the third research question, I carefully tracked the techniques and materials that we (me and instructor of the course) included or excluded from the original curriculum, and provided reasons why we made that decision. I also interviewed teachers from the course after completing each session to find out about the success or failure of the course materials. In addition, I observed students throughout the course to find out how they performed in activities.

3.3. Methodological Approach

3.3.1. Qualitative Research Approaches

Qualitative research is valuable in understanding the experience of people within their social context from their own perspective. In qualitative research, the role of researcher is critical and primary in the data collection and analysis (Maxwell, 2005). In

addition, qualitative research is conducted in a natural setting, in the real spatio-temporal context in which the phenomenon happens (Creswell, 2007). In conducting qualitative research, the researcher builds a holistic, descriptive and detailed portrait of the situation, events, or phenomenon through data gathered and analysed in words, pictures, or videos. Creswell describes five traditions of inquiry within qualitative research: “narrative research, phenomenology, grounded theory, ethnography and case studies” (Creswell, 2007, p. 53). Each tradition represents different ‘primary objectives’ (Creswell, 2007, p.77), is suitable for different research design, and requires particular data collection and analysis methods. For example, the goal of phenomenological studies is to understand the lived experience of human beings “through the detailed description of the people being studied” (Jenkins, 2007, p. 38). A case study is meant to “investigate a contemporary phenomenon in depth and within its real-life context” (Yin, 2009, p. 18), aiming to develop an in-depth description and analysis of such phenomenon.

3.3.2. Case Study Research Method

The case study is typically classified as a qualitative research method (Hancock and Algozzine, 2006). Although they often involve collecting both quantitative and qualitative types of data, the primary form of analysis is qualitative in nature, aiming at producing rich descriptions and a set of themes and categories arising from the data. A case study is an empirical inquiry that involves an in-depth exploration of a specific phenomenon or ‘bounded system’ within its real-life context by collecting detailed data from multiple sources of information. The data are used to generate a rich description of the case as well as an analysis of themes, issues, or patterns that emerged from the case (Hancock and Algozzine, 2006). Yin described a case study as a method that “allows investigators to retain the holistic and meaningful characteristics of real-life events-such as individual life cycles, small group behavior, organizational and managerial processes, neighborhood change, school performance, international relations, and the maturation of industries” (Yin, 2009, p. 4). Yin further contends that a case study design should be considered when the focus of the study is to answer ‘how’ and ‘why’ questions. Figure 3.1 presents the components of case study research design, according to Yin (2009). Case study is ideally suited to complex, real world phenomena

where it is difficult to isolate specific variables or dependencies and when the boundary between the phenomenon and its context is not clear (Yin, 2009). Furthermore, compared with other qualitative research methods, the case study approach emphasizes investigation of a phenomenon using multiple data sources (Yin, 2009), in order to "ensure that the issue is not explored through one lens, but rather a variety of lenses, which allows for multiple facets of the phenomenon to be revealed and understood" (Baxter and Jack, 2008).

To fulfil the research objectives and examine the research questions asked in Section 3.2, I employed the case study method for in-depth analysis and discussion of data gathered from the course. The information was collected through interviews, observations, questionnaires, and document analysis. Two cases were investigated in my research: (interaction) design thinking courses at Mulgrave and Starford Hall secondary schools. As such, they are "real-world" phenomena. Further, the cases are all bounded systems, as I investigated the process and outcomes of design thinking-based curricula developed as a specific course to be studied, and I have chosen case study methodology as an appropriate approach for my investigation.

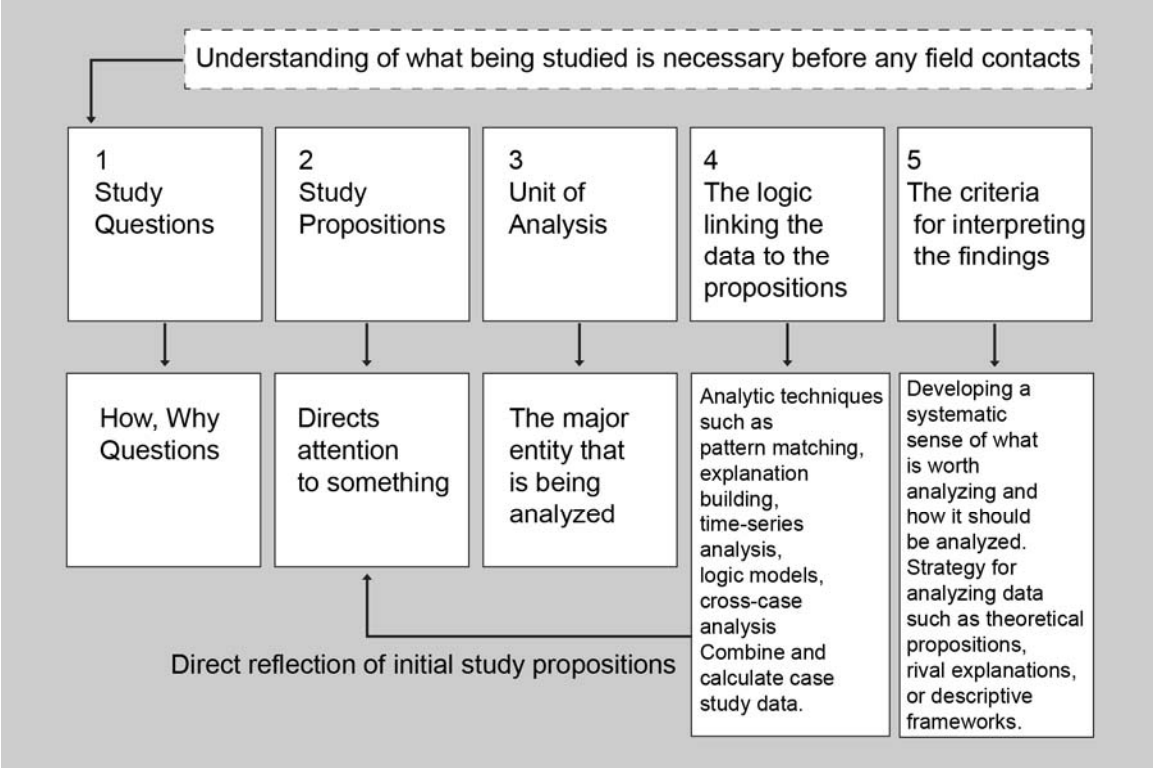

Figure 3.1. Components of case study research design

3.3.3. Different Types of Case Studies

Yin and Stake use different terms to describe different types of case studies. Yin classifies case studies as explanatory, exploratory, or descriptive (Yin, 2009). He also differentiates between single, holistic, and multiple-case studies. Likewise, Stake identifies three types of cases studies, but gives them different names: intrinsic, instrumental, and collective (Stake, 1995). According to Yin (2009), an explanatory case study can be employed to explain the presumed causal links in real-life interventions that are too complex for the survey or for experimental strategies. Exploratory case studies can be used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes. The descriptive case study can be applied to describe an intervention or phenomenon and the real-life context in which it occurs. According to Stake (1995), a single case may be studied as an intrinsic case, in which one can learn more about the details of a specific event or situation. Stake also maintains that a single case may be studied as an instrumental case, where analysis of that case yields insight into a broader phenomenon. The case itself is of secondary interest; it plays a supportive

role, facilitating our understanding of something else. A collective case study involves multiple instrumental case studies and produces both a within-case analysis for each individual study and a cross-case analysis of themes that emerge across all the studies. According to Yin (2009), collective case studies are similar in nature and description to multiple case studies. My research involved a collective case study consisting of two educational cases.

Multiple-Case Study Approach

For the purpose of this study, a multiple-case approach was chosen instead of a single-case approach in order to better understand the phenomenon in question and provide further reliability and generalizability to the findings. Defining the case and unit of analysis of a multiple-case study is a primary and crucial task. Yin (2009) states that a multiple-case study can be either holistic or embedded depending on what needs to be examined to address the questions of study. According to Yin, a holistic multiple-case study considers each case involved as a whole and is only concerned about the global nature of the cases. In contrast, an embedded multiple-case study is used when attention is given to different aspects of a phenomenon, and investigating the phenomenon from both the case and subunit levels, aiming to enrich the understanding of such phenomenon. This study investigates the interaction design thinking techniques and practices, as experienced by senior secondary school students. In this study there are two units of analysis: (1) teachers and (2) students who attended the course. Teachers are defined as individuals who were involved in the educational team to teach the curriculum.

According to Yin, a ‘replication’ design means the multiple cases of a study are treated as multiple experiments instead of multiple respondents in a survey. In addition, Yin (2009) defines two approaches to implementing a “replication” design in multiple case study: literal replication, which assumes the selected cases generate similar results, and theoretical replication, which indicates the selected cases “predict contrasting results but for anticipatable reasons” (Yin, 2009, p. 8). The selection of cases for this study followed a literal replication logic, which is applied when similar results from each case site are predicted (Yin, 2009). Using this method to select sites, each case was chosen based on the possibility of obtaining permission from the secondary school’s

director and school board to teach the course and the ability to involve teachers and students in the course. Due to the limits on the time to conduct multiple cases, and limitations on research funding for this project, two cases were selected: Mulgrave and Stratford Hall secondary (middle year) schools.

3.3.4. Case Study Compare to Other Methods

Other methods might also be suited to my proposed research questions, but I believe the case study is the most appropriate technique for this particular investigation. Since this is an exploratory study rather than confirmatory, quantitative methods that attempt to isolate, measure, and control specific variables in order to test a hypothesis are inappropriate. George and Bennett (2005) argue that case studies can have greater conceptual validity than statistical methods because the detailed and contextual nature of case study investigations makes it easier to identify "analytically equivalent" phenomena across several cases. Furthermore, they explain that case studies are a perfect tool for identifying new variables from the data, from which one can develop new theories (George and Bennett, 2005). Compared with other qualitative methods, such as ethnography and grounded theory, in which an existing phenomenon can be studied over a long period of time, the interaction design thinking-based courses will be developed and explored over a short period of time (2-3 months per school). Thus, the bounded nature of the case study method is suited for addressing my research question.

One of the known limitations of case studies is that while they can uncover the factors that contribute to a particular phenomenon, the method is not well suited to assess how much each factor matters (George and Bennett, 2005). The scope of my particular project, however, does not require this level of detail. My goal is to design and implement an interaction design-thinking curriculum, and I plan to focus on rich description of the within-case reports for each individual case, and address generalizability through the cross-case analysis. In this way, I intend to represent the complexity of the individual cases while also producing results that can be useful to other researchers who are interested in how to design, develop, and evaluate an (interaction) design thinking pedagogy for secondary level education.

3.4. The Cases and Subunits of Analysis

In this study, an embedded multiple-case study was chosen. The cases (larger units of analysis) of the study were defined as interaction design-thinking courses, which occurred during Fall 2014 in two secondary schools, and in each case, instructor, teaching staffs (teachers and administrator) and students involved in the course are different subunits of analysis (for example, the subunit of analysis of the teacher includes the teacher's occupation, role, tasks and activities as a part of the education team). Each case will be described briefly below, including the case site and each subunit of analysis: teacher, students, and course. This study adopted a literal replication design. Each case was chosen following the criteria below:

- Investigator of this research could obtain permission from director and the school board to run the course at schools.
- Investigator of this research could find an experienced and knowledgeable teacher in the design area to collaborate on improving the curriculum and teaching the course.
- The investigator could have access to at least one teacher from the school who is familiar with the school, class, facilities, and students, and being able to be present at every session, in order to help with running the course.
- The schools are identical in terms of goal, strategy, and materials (both are part of International Baccalaureate Program)
- The schools are not restricted to any specific program, gender or ethnicity, and follow traditional educational curriculums.

3.4.1. Mulgrave Secondary School

Mulgrave is a private school located in West Vancouver, British Columbia (BC) and is surrounded by nature (Figure 3.2). It is a traditional-type private school, in which students from pre-kindergarten to grade 12 are enrolled. It is part of the IB (International Baccalaureate) program, a recognized program internationally administered by the International Baccalaureate Organization based in Switzerland, which has authorized 2,000 IB schools around the world and 250 in Canada. The school's mission is: Inspiring Excellence in Education and Life. Mulgrave follows the IB education to equip students to become true global citizens. Hence, cultural, scientific and technological literacy are embedded in a continuous curriculum, from pre-kindergarten to grade 12. All of the

programs (PYP, MYP and DP) purposefully help students develop the skills and attitudes required for them to be contributing and responsible members of their local and global communities. Students take courses in several subject areas: language, humanities (social studies), design, mathematics, arts, science, and physical education. Students in grades 6-9 also take visual arts, performing arts (theatre and music), and life and learning skills (health and careers, learning to learn). Mulgrave also offers advanced programs for students who want to study specific subjects of interest or are aiming for a specific area of study such as creativity, arts and service (CAS); an inclusive sports program, which competes in the Independent Schools Association (ISA); opportunities to take part in provincial, national and international mathematics competitions in grades 7-10; and an outdoor education program that offers experiential learning and an exploration of concepts related to environmental education and sustainability. We implemented the course in the Middle Years Program (MYP), which involved 25 students (both girls and boys) in grade 9.

Figure 3.2. From left to right: Mulgrave and Stratford Hall Secondary Schools

Subunit of Analysis: Teachers

At the Mulgrave school two instructors were involved in teaching the course. Teacher A is a faculty member from SFU, who has experience working with kids and teaching the (interaction) design curriculum, and teacher B is a full-time teacher at Mulgrave School who is teaching design courses. Since our course occurred during the first part of the design course, teacher B was there to help with organizing the class and students, observing students to assess their performance and improvements, and observing the course in general to find out how to employ the design techniques, materials, and process later on in the design course. Teacher A took the main

responsibility of teaching the course, revising and developing the new curriculum, and providing feedback to students. Both teachers were present always and in every session to guide students and help the researcher with implementation of the course. Also, they provided feedback to the researcher after completing each session on what worked and did not work in that session, student's activities and other issues that may have occurred.

Subunit of Analysis: Students

Twenty-five students, both male and female (14 boys and 11 girls), from grade 9 attended the (interaction) design thinking course at Mulgrave School. They had different levels of understanding and experience of design, but most of them had attended a design-based course before. Most of the students were interested and pleased to attend and participate in the course.

Subunit of Analysis: Interaction Design Thinking Course

The curriculum was implemented for nine weeks at Mulgrave School, from September to November 2014. In the design thinking curriculum, a variety of materials and activities were applied. The majority of activities in the curriculum were designed and occurred in a collaborative form, and encouraged discussion, reflection, and a short presentation to the larger group. The course sessions at Mulgrave occurred twice per week in the mornings, each session length took one hour to complete. The overall curriculum materials and settings for each session (research activities excluded) are as follows:

- Week 1 (What is design?): Introduction and ice-breaker; pull apart an object; make an interactive product; introducing sketchbook homework
- Week 2 (Ideas): Sketchbook recap; brainstorming challenge; introducing sketchbook homework
- Week 3 (People and environment): Sketchbook recap; describing an Environment; Understanding an Environment; what is User-Centred Design; sketchbook homework
- Week 4 (On the move): Sketchbook recap; what is ubiquitous computing; bodystorming activity; sketchbook homework
- Week 5 (Services): Sketchbook recap; practicing designer(s); improving services; sketchbook homework

- Week 6 (Solving problems and project intro): Sketchbook recap; recap the process; project introduction; interviewing for ideas; sketching assignment; project work time
- Week 7 & 8 (Project work time): Complete the narrative (for presentation); complete the poster including a description of the problem, the process, the solution
- Week 9 (Final presentation): Final presentation

3.4.2. Case B: Stratford Hall Secondary School

The second site that was selected for this study was Stratford Hall Secondary School located in Vancouver, British Columbia (Figure 3.2). Stratford Hall is a private school, founded in 1999, and is also a thriving International Baccalaureate continuum school, authorized to teach the IB Primary Years, IB Middle Years and IB Diploma Programs. Excellence and confidence are developed through a challenging academic curriculum with further emphasis on creativity, action, and service. The IB Middle Years Program involves grades 6 to 10 students. The new building for the middle year provides students with additional learning space, including a gymnasium, two academic learning floors and a rooftop outdoor space. The school uses Vancouver city parks and Clark Park for physical education classes and play. Also, a beautiful lake is located on the east side of the school, where many school outdoor activities take place, such as sports day, ultimate Frisbee, and an annual Terry Fox run. Students take courses in several subject areas: language (English and Spanish/French), humanities (social studies), mathematics, science, creative arts: music (6-10), visual arts (8-10) and theatre (9-10), physical and outdoor education, and technology. Stratford Hall also offers advanced programs for students who want to study specific subjects of interest or are aiming for a specific area of study. We implemented the course in the Middle Years Program (MYP), which involved 14 students from grades 9 and 10.

Subunit of Analysis: Teachers

At Stratford Hall, there were three teachers who were involved in teaching the course. Teacher A was a faculty member from SFU, with experience working with kids, who taught the (interaction) design curriculum at both Mulgrave and Stratford Hall schools. Teachers B and C were full-time instructors from Stratford Hall, who

collaborated on teaching a tech course for grades 9 and 10 students. Since our course occurred as the first part of the tech course, teachers B and C assisted us in organizing the class, observed students to assess their performance and improvements, and observed the course to find out how to employ the design techniques, materials, and process later on in the tech course. Teacher A took the main responsibility of teaching the course, revising and developing the new curriculum, and providing feedback to students. All three teachers were present in every session to guide students and help the researcher with implementation of the course. Also, they provided feedback to the researcher after completing each session on what worked and what did not work in that session, student's activities and other issues that may have occurred.

Subunit of Analysis: Students

Fourteen male students, from grade 9 and 10 attended the (interaction) design thinking course at Stratford Hall. They had different levels of understanding and experience of design, and most of them had never attend a design-based course before. Most of the students were pleased to attend and participate in the course. However, since the course occurred as part of a tech course, students expected to work with computers in the first session.

Subunit of Analysis: Interaction Design Thinking Course

The curriculum was implemented for nine weeks at Stratford Hall, from October to December 2014. In the design thinking curriculum, a variety of materials and activities were applied. The majority of activities in the curriculum were designed and occurred in a collaborative form, and encouraged discussion, reflection, and a short presentation to the larger group. The course sessions at Stratford Hall occurred once per week in the mornings, and each session took one hour to complete. Overall, the course curriculum, materials and activities were the same as at Mulgrave School.

3.5. Curriculum Selection and Developments

3.5.1. Curriculum Selection

As the first step, I contacted several instructors in different schools in Canada and the United States to ask for their opinions and if they were willing to share their design thinking curriculum with me. The main reason was to develop a curriculum according to an already existing, tested, and validated curriculum rather than designing a new curriculum. I had the chance to talk to instructors from the Henry Ford Learning Institute located in Michigan, Sauder d.studio at the University of British Columbia, and Project Interaction, a program that taught high school students to change their community through design. Several teachers from the above programs and institutes generously shared their curricula with me, so I collected several curricula to investigate, learn from, and further develop for the interaction design thinking course. I found the curricula from the Henry Ford Learning Institute and the Project: Interaction program targeted at secondary school education. The curricula from UBC could not be adjusted and adapted for secondary school education. As the instructor of the course explained: “Each lecture I break down different modes of thinking like analogous, systems, empathic thinking. You may want a course that focuses more on process than mine does: brainstorming, prototyping, iteration, etc.” The curricula from the Henry Ford Learning Institute were well designed and developed, targeted at high school education, and focused on social oriented design thinking and problem solving activities. However, the main reason that I could not employ the curricula was the length of the programs, and the fact that the curricula are connected and developed to be used in different grades. Also, some of the curricula heavily relied on prototyping rather than ideation tasks.

Since I had planned for a short-term curriculum focusing on interaction design, design thinking and problem solving, I found the ‘Project: Interaction’ curriculum appropriate to fulfil the expectations. The original curriculum included a 10-week after-school program that taught high school students in grade 9 to use design to change their communities. The discussions and activities were built around interaction design concepts and techniques.

There are several differences between this study and Project: Interaction: 1) This study is larger in terms of scale and number of students. I implemented this course in two secondary schools and 39 students participated in the course compared to 10 students in Project: Interaction. 2) This course was conducted as part of larger Design and Computer Tech courses, during regular school hours. The original curriculum was conducted as an after school course. 3) This study and thesis is heavily focused on evaluation of the curriculum, the course benefit for students, and skills that they gained as design thinkers. 4) Finally, several extensive changes were found to be necessary and have been made to the original curriculum in order to adapt it to the new context and timeline, and apply research specific activities. These changes and the reasons behind them are explained in the following section (3.5.2).

3.5.2. Curriculum Modifications and Rationales

After I received the curriculum and the 'Project: Interaction' course syllabus, I made several changes to it. First, since the curriculum's lesson plan was introduced to me in the form of blog postings, I had to reorganize the content into a formal course plan. After I collected examples on design thinking curricula, the instructor of the course and I worked together to choose the right curriculum for further modifications and developments. We adapted the curricula to match the learning outcomes of each session with in-class activities. In the original curriculum, the activities introduced did not quite match the learning outcome in each session. In addition, the timeline was an issue because we had several activities to include in the curriculum (research specific activities). The proposed timeline was for a one-hour course per week, and we had to modify the length of some activities and set a new timeline. Furthermore, we strictly followed the design thinking steps so some of the activities were shifted to the earlier or later sessions (e.g., prototyping and interview). Finally, certain activities such as sketchbook homework were revised to align better with other activities in each session, and as a result create a more meaningful activity for students. The final curriculum included eight one-hour sessions, which were scheduled as part of two secondary level courses in design (at Mulgrave School) and Computer Technology (at Stratford Hall School). The following table (3.1) illustrates the major activities employed in the curriculum, the changed made, and the rationales behind the alterations.

	Course material	Modification used	Rationality
Week 1	Ice breaker	Ice-breaker was added to the first part of the session to get to know students through a 'what is your name' and 'what do you think design is'.	1) Get to know students. 2) Review the student-made definition of design and discuss a proper definition for design and interaction design.
	Pull apart an object	Provide students with a variety of physical objects and have them discuss in group: "Who is it for? What is it for? Why does it exist? Are there other types of the same thing?" In the original curriculum images of objects were given to students to write about.	1) Encourage discussion and group work since the beginning of the course. 2) Provide students actual interactive objects to explore.
	Make an 'interactive product'	Change the making prototype activity to making concept to discuss what constitutes an interactive product. Students also were asked to 'tell a story' of the product, covering its purpose and usage.	1) Making prototype activity is out of place considering the design-thinking process. 2) Discuss what constitutes an interactive product.
	Sketch book homework (week 1-6)	Give them a specific question to sketch out their ideas. For example for the second class, they were asked to fill out at least two pages with sketches visually indicative of what skills or interests might make them successful designers.	1) To encourage students to use their sketchbooks more purposefully. 2) To align the sketchbook assignment with in-class activities to connect them. 3) Not leave the activity open-ended.
	Group forming	Forming group was quicker. Creating logo can be done later at home.	Time limitation
Week 2	Sketch book recap (week 2-6)	Students sit around a large table to see one another's work, and lead discussion or draw out points on good ideation.	To discuss and share the sketchbook activity in a larger group.
	Research specific	Spend 25 minutes on problem solving, human-centered, and collaboration questions.	Research purpose
	Brainstorming challenge	Change the Gamestorming activity in the original curriculum to brainstorming activity.	1) Provide a more practical problem solving technique. 2) Time limitation.
Week 3	Describing an Environment	Changed the storytelling to story boarding technique: Students should come up with a description of a common place in the school and their experiences there (instead of a place that they visit every day).	1) To teach students the ideas behind storyboarding technique and how to represent an experience in sequences.
	Understanding an Environment	Observation: In their teams, the entire class will go and experience that space in silence. Share their findings with larger group.	1) To assess a space before and after visiting, and to understand the purposes behind observation technique. 2) Draw out the differences in students' experience and perception of the space.
	What is User-Centered Design?	Using points the students uncovered, discuss how user-centered design becomes important.	1) To recap students' understanding of users and shaping products for them 2) Creating products that fulfill a need.
Week 4	What is ubiquitous computing	Using a scenario on making pancake in different era to define the benefit and limitations of mobile. Recap on what defines 'ubiquitous computing'.	Define ubiquitous computing and the implications for designers.
	Bodystorming	In their groups, students practiced some bodystorming (acting out scenarios; using storytelling technique). Not many changes	The activity is engaging and fun, so is appropriate for their age group.

	Course material	Modification used	Rationality
		happened in compare to the original curriculum but we clarified the purpose of the activity for students.	
Week 5	Practicing Designer	Not much changes from the original curriculum.	1) Gain access to practicing designers 2) Use storytelling techniques to explain design concepts
	Improving Services	With the guidance of guest designer, students will step through the design process and develop an improvement on the existing service and present their improvement to the larger group.	1) Interviewing in the original curriculum is out of place. 2) This activity is connected to their sketchbook homework that was due in week 5.
Week 6	Recap the Process	Revisit the process and ideas we have covered including the concept of user-centered design and design thinking process using visual representations.	1) Recap the design techniques and processes to enable students to employ appropriate techniques for their final project. 2) Show them a holistic view of design process, and how the design stages are connected.
	Interviewing for Ideas	In their groups, students asked one another questions about the last time being frustrated, and write down the responses. Based on the responses, students have a pool of options to work on their final project with.	Find realistic problems based on people's experiences.
	Project Work Time	Students should aim to have: a topic; an idea of what they need to research; a plan for how they will work on their project.	Students have their final projects' topics based on the interview activity.
Week 7	Project Work Time	No major changes from the original curriculum. Students had the entire session to work on their project. By the end of the session, they should have completed their poster.	Having sufficient time to work on description of the problem, the process, and the solution.
	Research specific	Interview the students about the course	Research purpose
Week 8	Final presentation	Have all teams present their work; provide some brief feedback or critique on their works.	1) Enable students to ask questions and reflect on one other's work. 2) Encourage students' critical thinking.
	Research specific	Spend 25 minutes on problem solving, human-centered, and collaboration questions.	Research purpose

Table 3.1. The curriculum changes and rationales

3.5.3. Curriculum Characteristics

There are certain characteristics and design aspects that are considered in development and implementation of the curriculum. Overall, the curriculum is an inquiry-based design thinking process that considers a human-centric approach during the whole process and different activities. According to the literature, design thinking strategies can be applied in teaching curricula such as architecture (Akalin and Sezal,

2009), product design (Verea et al., 2005), and media education (Lugmayr, 2005). Also, design thinking is found to be useful in solving complex problems in a variety of non-design fields including business (Brown, 2008), healthcare (Duncan and Breslin, 2009), social science (Brown and Wyatt, 2010), and library services (Bell, 2008). All in all, a design thinking-base curriculum can be oriented towards solving problems in different subject areas. This curriculum was product and environmental design oriented, which enabled students to explore potential problems that people may face in their everyday life situations, when encountering the problem in certain products or places. We also had an activity that asked students to find problems in existing interactive or non-interactive services. The overall goal of having different design-oriented subject areas was to teach students that design thinking approach and strategies could be used to solve a variety of problems. Having such curricula was beneficial and fundamental to examine students' gained knowledge and abilities when implementing design thinking in solving everyday life problems (please refer to chapter 5 for more explanation). In this course, students' final projects provided solutions for a range of problems including internet-microwave interference at home, messy rooms, breakable trash bins, texting and driving, and traffic problems. The main curriculum's characteristics and elements were as follow:

- The course materials are connected and relevance, so the activities and assignments were more meaningful for students to complete.
- Students learned about the whole design process, not only design techniques or activities. We also recapped the design thinking process in the sixth session to illustrate a holistic view of the design process, and how the design techniques and steps are relevant.
- The course materials and activities followed the same order of the design thinking steps.
- The course materials and concepts were human-centric and encouraged 'design for people'.
- All activities were designed to be completed in teams. Hence, we developed the 'research activities' to be completed in-group and in collaborative forms.
- When searching for the problem to be solved, we introduced students to the interview and observation techniques on purpose, to enable them to find realistic problems. Hence, no pre-defined problems were introduced to students.
- The teaching materials and discussions were all developed around interaction design concepts and definitions. We also provide students with physical

products in the first session to encourage discussion around the topic, and enabled students to explore and identify the products' functionalities.

- In teaching the concepts, we asked questions to understand and assess students' knowledge. We also encouraged critical thinking of students through discussions, asking questions around a topic, or reflection on one another's projects.
- Combinations of verbal and visual instructions were incorporated into the teaching materials (show and tell).

3.6. The Course Outline

In this section, I will provide a detailed description of week-by-week course activities. During the course, the instructor's (Andrew) role was to teach the course lessons and activities, and I was involved as an observer and as an assistant to the teacher. Either one or two schoolteachers were always available during the course sessions to organize the class and students, assess students' performances, and observe the course implementation to find out how to employ the design techniques, materials, and process in future design courses. In most of the activities, students had the chance to learn from one another's works through short presentations. Also, the instructor provided comments or summaries on their works. The course outline is available in appendix A to review.

3.6.1. Interaction Design Thinking: Session 1

Here is the list of activities in the first session:

- Pre-Questionnaire
- Introduction + Ice-breaker
- Pull apart an object
- Make an 'interactive product'
- Sketchbook homework

We started this session by distributing pre-questionnaires (creativity confidence), and asked students to complete them in five minutes. Following that, we introduced the course and ourselves. We also asked students to introduce themselves and to describe

‘what they think design is’. As students announced their thoughts, we wrote down their thoughts on the board, and discussed proper definitions for design and interaction design. In the ‘pull apart an object’ activity, we provided students with a variety of everyday objects and asked them to discuss certain questions in their groups (please refer to the appendix for further details). In the ‘make an interactive product’ activity, we asked students to come up with a concept for an interactive product and to present it to the larger group by telling a story of the product. Finally, in the ‘sketchbook activity’, we distributed sketchbooks, introduced the activity’s purposes, and asked students to complete their first sketchbook assignment for the following week. At the end of the class we distributed snacks to students.

3.6.2. Interaction Design Thinking: Session 2

Here is the list of activities in the second session:

- Sketchbook recap
- Problem-solving question
- Human-centered question
- Collaboration question
- Brainstorming challenge
- Sketchbook homework

We started this session by recapping students’ sketchbook homework. The instructor put all sketches on a large table, and asked students to sit around the table. Students had the chance to see one another’s works while the instructor was discussing their work and providing suggestions for improvements. The next three activities were all research specific. Students completed these activities in their teams as part of their course work (please refer to the appendix for more description). In the ‘brainstorming challenge’, we introduced the activity, its rules, and asked student to brainstorm ‘community’ (visually or textually) in their teams. We later asked them to organize their ideas into categories, and share them with the larger group. Finally, we introduced the sketchbook homework.

3.6.3. Interaction Design Thinking: Session 3

Here is the list of activities in the third session:

- Sketchbook recap
- Describing an environment
- Understanding an environment
- What is user-centered design
- Sketchbook homework

We started this session by reviewing students' sketches. In the second activity (describing an environment), students were asked to come up with a description of a common place in the school without going there through storyboarding technique, and present it to the larger group. To facilitate the presentation process for students, the instructor took a photo of their storyboards and shared it with the class while students presented their ideas. Later, in the 'understanding an environment' activity, the entire class went to experience the same space (a common place in the school) in silence. Students had to bring their sketchbooks to make notes on what they missed in their description. We posted students' findings on a wall to discuss further with the larger group. In the next part, the instructor brought some examples from the visited space, to explain the user-centred design concept. We completed this session by introducing the sketchbook homework.

3.6.4. Interaction Design Thinking: Session 4

Here is the list of activities in the fourth session:

- Sketchbook recap
- What is ubiquitous computing
- Bodystorming (acting out scenarios)
- Sketchbook homework

In this session, students provided some explanation of their sketches first, and then the instructor recapped their sketched ideas. In 'what is ubiquitous computing', students discussed a scenario on how to make pancakes in different times, e.g., nowadays or 20 years ago, and later the instructor defined the concept of ubiquitous

computing, referring to their findings. For the ‘bodystorming’ activity, the instructor introduced the technique, the rules (please refer to appendix A), and assigned students different scenarios to act out accordingly. The scenarios asked students to explore solutions to an identical problem in three different eras (1970s, today and 2030). The instructor clarified the activity’s rules and explained: “You want to be sure you are honest and realistic as possible, so you ‘empathize’, and get a sense of what it is like to be in that era dealing with this scenario.” By the end of the session, we introduced the next sketchbook homework to students.

3.6.5. Interaction Design Thinking: Session 5

Here is the list of activities in the fifth session:

- Sketchbook recap
- Practicing designer
- Improving services
- Sketchbook homework

In the Sketchbook recap, we asked students to share their sketches first, then we discussed services (physical or digital) that they identified. In practicing designer, we invited a guest designer to talk about her/his background and work experiences as an interaction designer, and present one or two user-centred design projects that s/he had done before in detail. The guest designer prepared presentation slides and explained her/his design process step by step. Students had the chance to ask questions afterwards. In the next activity (improving service) students were asked to select one of their team’s sketches from the sketchbook homework, identify what was the touchpoint, and with the guidance of the instructor and the guest designer develop an improvement on the existing touchpoint. Students had to present their improvements to the larger group. Finally, we introduced the next sketchbook homework to students.

3.6.6. Interaction Design Thinking: Session 6

Here is the list of activities in the sixth session:

- Sketchbook recap

- Recap the design process
- Project introduction
- Interviewing for ideas
- Project work time
- Sketching assignment (research specific)

We started this session by providing feedback on students' sketches. Since this was the last sketchbook homework, we called it a 'sketch party'. In the 'recap the design process', the instructor revisited the process and ideas we had covered in the course including design concepts, and research, idea generation, prototyping, and presentation skills through a visual representation. The main purpose to recap the design process was to provide an overview that enabled students to connect the course materials and concepts they learned earlier, before introducing them to the final project. Later, we introduced the final project, where we asked students to choose a problem that they had observed or experienced in the city. Students were encouraged to use the process they had learned to explore generating solutions for the given idea, and producing a story and poster that illustrated their problem, their process and their solution. In the next activity (interviewing for ideas), students were to ask one another certain questions and write down one another's responses. Based on their responses, students had several options to work on their final project with. In the 'project work time', students were asked to plan for their final project, and finalize their projects' topics. By the end of the session, students were given a research specific sketching assignment to complete at home.

3.6.7. Interaction Design Thinking: Session 7

Here is the list of activities in the seventh session:

- Complete narrative for presentation
- Complete poster, including a description of the problem, the process, and the solution.

In this session, students worked on their final projects. While they were working on their projects, they were called over in groups for an interview session. We provided some design tools in advance, and distributed them to students at the beginning of the

session. For the interview sessions, I was sitting outside the classroom, and the instructor called groups one by one to come over for the interview. Also, we provided some snacks but gave them at the end of the session to avoid distractions. Since most of the students could not complete their projects in an hour session, we added an extra session, enabled them to complete their projects.

3.6.8. Interaction Design Thinking: Session 8

Here is the list of activities in the last session:

- Final presentations
- Problem-solving question
- Human-centered question
- Collaboration question

In this session, all the teams presented their projects, and we provided some brief feedback on their works. Students from the other teams also had the chance to provide comments or critiques on presented projects. Similar to the second session, each team completed research activities on design thinking skills including problem solving, human-centeredness, and collaboration. At the end of the session, we thanked them for participating in the course and distributed some snacks.

3.7. Summary

In this chapter, I have illustrated the main reasons why an exploratory qualitative case study was adopted to conduct this study. Providing an in-depth investigation, analysis, and description of the cases is the primary goal of choosing case study methodology for this study. The nature of research questions required in-depth understanding and description about students' activities and experiences during the course. Furthermore, in the above introduction to the cases and subunits of analysis, the overview of the cases and their similarities and differences were clarified. Both cases followed the IB program, which provides programs from pre-kindergarten to grade 12. The number of students involved in the courses varied (25 at Mulgrave compared to 14 at Stratford Hall). However, all students studied in grades 9 and 10, and worked in

groups of 3-4. Table 3.2 presents the similarities and differences between the two cases.

Case	School type	Course type	Teaching team	Number of students and gender	Grade
Case A	Traditional/IB program	Interaction design thinking	2 teachers	25 - male and female	Grade 9
Case B	Traditional/IB program	Interaction design thinking	3 teachers	14 - male	Grades 9 and 10

Table 3.2. The comparison of two cases

In addition, I explained the reasons behind the curriculum selection, the changes applied, general characteristics of the curriculum, and the detailed course outline. Some of these characteristics are as follow: course activities and assignments are connected; the course content followed the same order of design thinking steps; the course content followed a human-centred approach; the course involved collaborative activities and teamwork; the course focused on problem setting in addition to problem-solving activities, and the course encouraged critical thinking of students.

The next chapter will introduce data collection methods and analysis, including data collection preparations, field procedures, and data analysis processes in detail.

Chapter 4.

Data Collection and Analysis

This chapter provide a detailed description of the procedures I used to complete the study. The data collection and analysis for both cases at the Mulgrave and Stratford Hall schools were similar. I provide the description of the field procedures considering both cases in this chapter.

4.1. Data Collection Sources

In conducting this research, a variety of qualitative techniques were applied to gather data from both cases and to synthetize the findings according to grounded theory technique that allowed me to conceptualize the findings that answered my research question. According to Yin (2009), the most commonly used sources of evidence in case study methodology are “documentation, archival records, interviews, direct observation, participant-observation, and physical artefacts” (p. 98). Applying multiple sources of evidence is essential in the case study approach to achieve construct validity. According to Yin, having multiple sources of evidence not only allows a researcher to have a holistic view and “address a broader range of historical and behavioral issues” (Yin, 2009, p. 115), but also facilitates “the development of a converging line of inquiry” through the process of data “triangulation and corroboration” (ibid, pp. 115-116). For this study I applied five different types of data collection techniques:

- Participant observation: involved observing, recording, analyzing, and interpreting student’s behavior and attitudes during the course;
- In-depth semi-structured interviews: involved interviewing teachers about the course;
- Focus groups: involved interviewing a groups of students about the course;

- Pre and post questionnaires: involved both multiple choice and descriptive answers, and mostly occurred as part of the group activities;
- Document analysis: involved gathering and analysis of the pictures of physical artefacts, assignments, and actions in the course.

I found all the sources of information extremely important for triangulation of data, and all of them are viewed as essential sources of information for this study that need to be corroborated and acknowledged by the information found from other sources.

The data collection techniques were employed to answer the research questions in general, but every one was appropriate to answer a particular research question. With regards to the question: 'How does an interaction design thinking course benefit senior secondary school students?', the information was gathered through interviewing students and teachers outside the course, as well as observing students' activities and performance during the course. To address the question: 'How does an interaction design-thinking course enable students to become design thinkers?', data were gathered through observing the students' activities throughout the course, specifically on creativity, problem solving, collaboration, and empathy (human-centeredness). In addition, pre and post questionnaires were completed before and after completing the course. Also a visual-based assignment on design thinking was given to students to further evaluate their understanding of the subject. To address the third research question: 'Which interaction design thinking techniques or practices worked well in the course curriculum?', I carefully tracked the techniques and materials that we included or excluded from the original curriculum, and provided reasons for why we made that decision. I also interviewed teachers from the course after completing each session to find out about the success or failure of the course materials. In addition, I observed students throughout the course to find out how they represented in activities.

4.2. Preparing Data Collection

There are multiple steps that I followed to effectively collect the data. The first one was to develop a case study protocol, the second one was to get permission from the Simon Fraser University Research Ethics Board, the third one was case selection

and the fourth one was to run a pilot study. Each of them is discussed further in the following sections.

4.2.1. Case Study Protocol

In order to guide the data collection process, a case study protocol was developed and used. A case study protocol includes instruments, field procedures and general rules that need to be followed during a data collection process. It is considered as one major means of "increasing the reliability of case study research" (Yin, 2009, p. 79). The protocol helped to determine which data are going to address the research questions posed, along with providing an outline of the procedures used in the field.

The protocol developed for this study includes seven main stages: 1) identifying all data collection techniques that help to address the research questions; 2) applying for permission from SFU's Research Ethics Board to conduct the research; 3) contacting different professionals in the field to discuss the idea and ask for potential curriculum sharing; 4) contacting different instructors for possible collaboration on the project; 5) contacting different school cases to gain access to the potential participants and schools; 6) collaborating on improving and revising the curriculum according to the timeline and strategies; 7) running the necessary pilot studies, to test the questionnaires and questions for interviews.

The relevant descriptions of different stages are presented in the following sections: the first stage in section 4.1; the second stage in section 4.2.2; the third, fourth, fifth, and sixth stages in section 4.2.3, and the seventh stage in section 4.2.4.

4.2.2. Research Ethics

This was an important stage in my study, as I had to make sure that I used appropriate strategies to keep participants away from any potential harm. As the first step, we submitted relevant documents to Simon Fraser Research Ethics Board to get permission to conduct the study. These documents involved study protocol, recruitment strategy, consent and assent forms for parents/teachers and students respectively, to sign and get themselves familiar with the study. Having the study approval from SFU

was an important stage in the study, as I had to present it to the schools in order to get permission from them for running the course. In the next stage, and before starting the course, students' parents were contacted by the school board and asked to sign the consent forms if they explicitly agreed to the participation of their kids in the research. Students also had to read and sign the assent form before participating in the course. The names of students, and participants in the study were disguised in the reports to maintain confidentiality. The collected data were treated as confidential information, and were not shared or discussed with anyone who is irrelevant to this study.

4.2.3. Case Selection

In order to find suitable cases for this study, I employed several strategies. The case selection was completed in different phases for 1) finding curriculum examples, 2) finding an instructor, and 3) finding two schools. I initiated the study by searching for curricula on design thinking, which were implemented and tested in secondary level education for further improvement based on the study criteria and educational context. I contacted several educators and professionals in the field through email, to ask if they could share their curricula with me and to ask for their ideas on an ideal curriculum. I also talked to a design thinking practitioner/educator from Henry Ford Academy, a school for creative studies, who shared his curriculum with me and gave valuable information on design thinking network and people to contact.

In searching for an instructor to teach the curriculum, I contacted an instructor from SFU to book a meeting with him and talk about the possible collaboration on the project. After he agreed to support the project, we worked together to choose the right curriculum and develop and modify it further. The modifications were made attentively to match the learning outcomes of each session with in-class activities, set the timeline to change the assignments in accordance with the tasks completed in each session, and to include or exclude activities in order to better serve students.

The school selection process for this study was more complicated. At the beginning, I intended to work with two public schools (New Westminster and North Surrey public schools). Hence, I started to contact the schools in 2013, met the

principals, and got permission from them to run the course in those schools. For the North Surrey secondary school, I had to get permission from the Surrey school district as well, which in fact allowed me to work with any school in the city of Surrey. The main reason behind selecting the public schools was the similarity of their course curricula and the possibility to implement the interaction design thinking curriculum in similar public schools later. However, a problem occurred in the summer of 2014 when all the teachers from public schools in Metro Vancouver went on strike for quite a long time. In fact, no one knew when the strike would end, and if schools would be open in the fall, at the beginning of the school year. Hence, I contacted private schools to ask for possibilities to implement the curriculum there.

Since private schools usually follow their particular course curricula, I had to narrow down my school selection based on certain criteria. My case selection of private schools followed the pre-defined criteria for secondary schools to be private, traditional, and not be restricted to any particular gender or ethnicity. I reviewed all private schools located in greater Vancouver and selected appropriate ones, and contacted them through email or phone. I sometimes had to send follow-up emails or call them again or leave my number and wait. Also, I talked to school secretaries, school board members, directors, and principals. Hence, I documented the process, including contact information, number of time I contacted them, the person I talked to, the answer I received, and what is the next step. After a month, the Mulgrave School's principal contacted me to have a meeting with the instructor of the course and me to discuss the course in detail. In the meeting we discussed the research goals, curriculum material, mutual expectations and limitations. After I got the permission from the school principal, I met a schoolteacher in order to explain the curriculum to him, visit the classroom, and collaborate on running the course. Overall, he was present throughout the course and facilitated the process, observed student activities, and assisted us when needed.

The next step was to find an identical school to run the course there too. Hence, I contacted the second IB school (Stratford Hall) through email, met the school's director, and got permission from them to run the course there. Again, we had a meeting with two schoolteachers from Stratford Hall to discuss the course, curriculum details, and how to best collaborate on implementing the course.

4.2.4. Pilot Study

A pilot study was carried out before the implementation of the course, mainly for testing the research study questions. The aim of running the pilot study was to practice my interview questions with students, to make sure the interview questions and questionnaires were age-appropriate for them, and to refine the questions according to students' suggestions. A student in grade 9, outside the course, reviewed the interview questions and questionnaire. Also, the questionnaires were presented to my lab mates who have extensive experience in conducting research and running interview sessions. The questionnaire and interview questions were refined a couple of times according to the feedback I received from them. Also, more appropriate words were applied to make sure about the comprehensibility of the texts. The pilot study was limited to the research questions, but not the course curriculum. Due to the complicated process of implementation of the course, I did not have the chance to run a pilot study for the whole course. However, since a different version of the curriculum was implemented before, I had the chance to learn from the experiences of the course implementation, to avoid repeating similar errors, and to learn from the successes and failures of the course to some degree.

Figure 4.1. Preparation for the course: design tools and research materials

4.3. Field Procedures

Fieldwork involves "active looking, improving memory, informal interviewing, writing detailed field notes, and perhaps most importantly, patience" (DeWalt and DeWalt, 2002, vii). According to Robert K. Yin (2009), every research method can be used for exploratory, descriptive, or explanatory purposes. Exploratory research is

qualitative in nature. It relies on secondary research, such as reviewing literature, or qualitative approaches and primary research, such as surveys, questionnaires, in-depth interviews, participant observation, focus group interviews, case studies, and pilot studies. The objective of an exploratory study is to examine a new phenomenon or situation to clearly identify key issues and variables and to produce a hypothesis or statement explaining how the variables are related. Some techniques such as artefact analysis, photo and diary analysis, contextual analysis, and cultural probes are developed to gather first-hand data.

Several factors are critical to conducting high quality research, including being systematic in the process of collecting information, recording, and analyzing data. In the following sections, I provide the definition, advantages and drawbacks of the data collection methods that are used in my research. These methods include semi-structured interviews, observations, focus groups, pre and post questionnaires, and document analysis.

4.3.1. In-depth Interviews

In-depth interviewing is one of the most popular methods in qualitative research. It "involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation" (Boyce and Neale, 2006. p. 3). The interview is an effective method for learning how people's beliefs and thoughts affect their lives. There are three types of interviews: fully-structured, semi-structured and unstructured. For this research, I used semi-structured interviews in which we had the flexibility to ask additional questions according to the situation; alternatively, to encourage an informal conversation that covers certain questions. The technique was useful in such an exploratory study to provide further information about the research area. Conducting the interviews was beneficial to the post-evaluation stage of inquiry, when I asked further questions in order to understand the overall benefit of the course and to understand what lessons participants learned from the success or failures of the interaction design thinking-based pedagogy. The interviews were performed with four teachers (teacher A was interviewed twice as he was the main instructor in both schools) five times in total, all interviews conducted after

completing the course, and took 15-20 minutes on average per individual to complete. The intention of conducting these interviews were to understand the challenges and concerns involved in the interaction design course, what impressed teachers, workability of the techniques and materials provided in the course, and if the course was beneficial in any ways. For example, the interview questions included:

Semi-structured interview with teachers from the course:

- Do you have any general comment about the course?
- Do you have any comments on techniques and materials we used in the course?
- Do you have any thoughts on individual students that come to your mind in regards to being a design thinker?
- What was the most challenging part in teaching the d-thinking course?
- What worked and what did not work in your opinion?
- What can be enhanced in the future design-thinking course?
- How successful was the course in helping students become design thinkers?

Semi-structured interview with teachers outside the course:

- Do you see any benefit in using the curriculum or part of it in your course?
- Did you have any experience that shows that students may have applied design thinking rules in the (…) course?

Each interview session was voice recorded using digital audio with the permission of participants; the dialogues transcribed for analysis, and then coded using an iterative technique of grounded theory, and synthetized along with the findings from our other qualitative techniques.

4.3.2. Participant Observation

Participant observation is a qualitative inquiry method, which is used as a mainstay in fieldwork in a variety of disciplines. Marshall and Rossman (1995) defined observation as “the systematic description of events, behaviors, and artefacts in the social setting chosen for study” (Marshall and Rossman, 1995, p. 79). The many advantages of participant observation include: enabling researchers to access non-

verbal expressions of feelings; permitting researchers the opportunity to gain information about situations that participants may be unable or unwilling to share; and allowing researchers to determine how interactions and communications between members will unfold (Kawulich, 2005).

In this research study, participant observation was applied in conjunction with the interview method for gathering richer firsthand data from the course. Participant observation involved observing, recording, analyzing, and interpreting students' activities and attitudes in the classroom. The method allowed me to access non-verbal expressions of students; to determine how interactions and communications between group members unfolded. Field notes, as the primary source for analysis, were taken to look for patterns of behavior and ways of interacting, exploring, and learning in the course. Audio or video recordings of the observation sessions were also taken based on the participant's consent. The guideline for documentation of participant observation data consisted of field notes recorded in field notebook. These data are records of what I experienced, what was learned, and what was observed. Field notes included an account of events, what was said in conversation, physical gestures and all other details and observations necessary to the purpose of the study. The participant observation guideline to gather information included but was not limited to the following:

- Design thinking activities (problem solving, empathy, collaboration);
- Design thinking techniques/tool (brainstorming, storytelling, interview, observation, ideate);
- Role of students (participation, collaborations on the project, team work);
- Learnability of the activities (How much time did they spend to complete a task, What were the challenges they encountered in each session);
- Clarification of the course (what questions come up in each course session and group discussions, what challenges do they encounter to complete each task);
- Concept development (What are the proposed solutions to the design problem, the process to achieve the solution, how applicable and innovative each solution is);
- Implementation issues (shape of class, materials, timeline, any other unknown problem).

4.3.3. Focus Group

A focus group is a variation on the one-to-one interview. However, in these groups, the researcher will analyze the dynamics among 'interviewees' including the way they interact and what they discuss – a technique that is impossible in the one-to-one interview. A focus group usually consists of a small group of participants. The researcher acts as a facilitator rather than an interviewer. The facilitator guides the group discussion around a topic that is relevant to the research question; it is important that she or he gives every participant the opportunity to express him/herself.

The focus group sessions with 12 groups (39 students) were conducted after completion of the course, in their regular groups. I acted as an interviewer and facilitator of discussion, and while I encouraged open discussion relevant to the research question, simultaneously, I gave every participant the opportunity to express his/her ideas. Conducting the interviews this way provided a comfortable atmosphere for students to share their thoughts and ideas in their established group. The interview sessions were recorded using digital audio with the permission of participants. The focus group questions included:

- Tell me about an experience of the course that made an impression on you.
- What worked and what did not work well for you in the design-thinking course?
- Have you used design thinking for any problem-solving situations in your daily life? Can you give me an example?
- Have you used design thinking for any problem-solving situations in your other courses? Can you give me an example?
- Anything else you want to tell me related to the course?

4.3.4. Open-ended Questions

The pre and post activity questions were designed to evaluate students' skills gained on human-centeredness, problem solving, and collaboration as three important skills to be learned in a design thinking-based pedagogy. The activity had to be completed during the second and last sessions of the course, in student's original groups, and considering some learning outcome for students: to use observation skills to

reveal details and context clues (human-centeredness), to quickly determine the value of an idea (problem solving). The activity's questions were as follows:

Problem Solving Question:

- In groups of 3-4, what would be the first four steps to design a new digital mouse, mobile phone, chair or wheelchair? (list your answers)

Human-Centered Question:

After reading a short description on Vancouver's traffic problem, in groups of 3-4, students should select one of the following options and try to list all the problems (on paper):

- Issues that people who commute with public transit may face every day in Vancouver?
- Issues that people who commute with their personal vehicle may face every day in Vancouver?
- Issues that people with physical disabilities who commute with public transit may face every day in Vancouver?
- Issues that people with physical disabilities who commute with their personal vehicle may face every day in Vancouver?

In addition to the above questions, students answered individual questions about how they performed and collaborated in the activity. This activity was self-evaluation, enabling students to think about the collaborative work they have done, and to comment on their performance afterwards. The questions given to the students were as follow:

- How did you support the team in this session?
- What have you done well or not well?
- How did other team members help the team?

4.3.5. Questionnaire

The definition of creativity in this study is inspired by the philosophy of Stanford University's d.school as "a state of being and adaptation of personal skill sets that enables an individual to synthesize novel connections and express meaningful outcomes" (Hawthorne et al., 2014, p. 67). According to this definition, creativity of an individual can be assessed through certain mindsets that he/she gains through a design

thinking process. Hence, in this study creativity assessment focuses on ‘persons’, their skill development and their ability to exercise and apply creativity skills effectively in new problem-solving situations (real world scenarios).

Further to the evaluations on human-centeredness, problem solving, and collaboration, a pre and post questionnaire on a five-point scale (not at all confident, a little confident, moderately confident, very confident, completely confident) was given to students to self-evaluate their *creative confidence* before and after completion of the course. The questionnaire was developed based on the research done before by Royalty et al. (2014) to self-evaluate the creative confidence of students (please refer to section 2.4 for further description). The new questionnaire was adapted and developed further considering some changes on 1) the wording of the questions to be appropriate for the age group, and 2) the questions to assess certain activities provided in the interaction design thinking course. The final questionnaire proposed the following questions:

- How confident are you that you could find sources of creative inspiration not obviously related to a given problem?
- How confident are you that you could effectively work on a problem that does not have an obvious solution?
- How confident are you that you could identify and apply ways to enhance your own creativity?
- How confident are you that you could explicitly define or describe your creative process?
- How confident are you that you could use the space or material around you to help you be more creative?
- How confident are you that you could learn from non-traditional resources (such as museums, student clubs, people, etc.) rather than textbooks?
- How confident are you that you could share your work with others before you consider it to be perfect?
- How confident are you when you try/explore an approach to a problem that may not produce the final or best solution?
- How confident are you that you could continue work on a problem after experiencing a significant failure?
- How confident are you that you could solve problems in ways that others would consider creative?

- How confident are you that you could help others be more creative?

4.3.6. Document Analysis

Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic. Document analysis was undertaken in my research to gather first-hand data from student assignments and artefacts created. Physical artefacts found in the study such as posters as well as student assignments were an essential part of the data collection and analysis process, as they provide key insight on student understanding of the design thinking activities, and design thinking process in general. Also, a visual assignment was created and given to students to complete by the end of the course. The goal of the assignment was to analyze student understanding of the design thinking indirectly through visuals. We gave the question in the form of an assignment to be completed at home. The assignment we gave students was to "draw a visual representation of design thinking as you understand it."

4.4. Data Analysis

In this study, several data collection methods (qualitative and quantitative) were used, so different strategies were applied to analyze the data. Coding is a common method used in empirical research for categorizing data that was applied in this study. For case study analysis, making detailed descriptions of the cases is essential. Yin (2009) recommended an iterative data analysis called 'cross-case synthesis', which can be applied to the analysis of multiple cases. In this technique, each single instance is considered as a separate study to be analyzed, and the findings from all cases will be combined to generalize. He also suggested creating a formal database that other investigators can review to help in increasing the reliability of the case study (2009, p. 119). A database includes four components: "notes, documents, tabular materials, and narratives" (Yin, 2009, p. 119). According to Creswell (1998), the data analysis can be achieved through the four steps of 1) categorical aggregation, 2) direct interpretation, 3) established patterns, and 4) naturalistic generalization. In the first step, a database will be established including a collection of components such as notes, documents,

artefacts, and narratives. In direct interpretation, single instance and the meaning behind it will be synthesized and rearranged into categories or new themes (within-case analysis). In the next stage, data from different categories will be synthesized (cross-case synthesis), and patterns will be established accordingly. In this study, I followed a similar process, beginning with the interview transcripts and field notes from the course observations. The coding followed Grounded Theory technique, which involved the research questions asked in Section 3.2 guiding my reflection and analysis to begin with. But other elements that arose during the analysis were incorporated into the codes and concepts developed from the data.

4.4.1. Establishing a Database

Following Yin's recommendation on establishing a database (2009), I transferred my notes to a Word document file after completing each observation session. Some of the course sessions - such as the ones that involved students' presentation - were voice recorded so I transcribed the conversations and added them to the same file document together with my observation notes. In the process of transferring the observation notes, I organized the information following observation guidelines under Section 4.3.2. For the interviews, after each interview session, I transcribed the conversation, and transferred them to a Word document. For the interviews, I followed open coding technique to come up with emergent categories. I also separated the findings from the interviews under each category according to the type of participant (teacher or student).

For the data analysis of pre and post open-ended questions on empathy, problem-solving, and collaboration I followed the open coding technique of the Grounded Theory. The first step towards the analysis was to transfer all the answers gathered from students from paper format to an Excel document (Figure 4.2). This step enabled me to observe all the data in one single document. In addition, the quantitative data found from the questionnaires was also transferred to an Excel sheet for later transfer and analysis using JMP software. Furthermore, I managed images and videos taken from the course sessions. I took pictures of or scanned the visual documents such as students' assignments, posters, and artefacts and saved them in an appropriate folder belong to a specific course session. The pictures and videos taken from students' activities in class

were saved in the same folder. Once I had placed all image and videos in the right folder, I coded the pictures (assignments, camera pictures) and videos based on the initial of participant or group (according to the activity they performed in), the course session, and number of picture. I used letter P for pictures and letter V for videos.

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8
Group name	Name	How did you support the team in this activity?		2. How other team members helped the team in this activity?		3. In your opinion what have you done well or not well?	
		Pre Activity	**Post Activity**	**Pre Activity**	**Post Activity**	**Pre Activity**	**Post Activity**
Peng-A-Mega	**Kealin**	By writing for the second activity. For coming up with ideas	I came up with some of the ideas	We all evenly did the activity by all coming up with ideas	They draw and also came up with ideas too	Yes I believe I came up with good ideas.	talking+collaborating
	Ava		I wrote the ideas and made a majority of them		Isabella or Tessa gave idea; Kealin did not as much.		Inclusion?
	Tessa	We talked collaboratively before putting our ideas down	I made and came up with the designs for the map drawing	They suggested tons of ideas as well as crossed out some of my ideas that weren't as good	Ava wrote most info ; Isabella made it pretty and wrote the key; Kealin an exterior opinion	We finished work quickly; but we got sidetracked a lot	I haveworked with them and well I didn't write lot on the chart
	Isabella	Creating ideas; sparking conversations; thinking critically	I wrote our names…/was the scribe :)	Giving input on ideas; working together	Posed ideas	Create ideas; work with my group	write our names :)
Assimov	**Jack**	Give some ideas during the discussion	Thinking ideas	Write down ideas and give some thoughts	Drawing, speaking, ideas; they did mostly on writing	Well: join the discussion; not: not really much of my idea is valuable.	I did just ok
	Peter	I supported ideas and wrote for the team	Gave ideas	They came up with the steps; They gave me good ideas	Wrote stuff down	I've done well organizing the questions and writing it down; but I should of gave more ideas.	Average
	Emanuele	I added ideas to the team	I helped with ideas and brainstorming	They contributed ideas	They wrote ideas	We did well.	I brainstormed very well
	Aiden	adding problems	I helped brainstorm problems	Adding problems to our group activity	They helped brainstorm ideas and Jo Jo gave moral support	I think we did well in terms of wrighting problems about public transit, there are no problems with that.	We were good at brainstorming problems
	Richard	I supported my team by sharing my	I shared my ideas and helped presenting	The other team member also shared his ideas	They also shared ideas and presented	I've done well with putting our ideas	I co-operated with my group well.
The juan and only	**Jerry**	Writing down ideas	I did a lot of work contributing ideas	Thinking of ideas	Making poster and coming up with ideas	Mediocre	Very well
	Leo	Writer, come up with ideas, teamwork.	I did half of the poster and gathered many ideas for it	Come up with ideas	They helped thinking about ideas and we act together	Well done!	I fully participated the activity; I should focus on one solution instead of list many.
	Sebastian	I added ideas to the list	I gave many ideas to the group	Leo wrote our ideas, and Jerry added ideas	Leo and Jerry also gave ideas, and Leo made the artwork in our poster	I think we did well	I think that we addressed the problme well, and looked at potential solutions, but didn't think much about costs.
Heskey	**Josh**	I came up with ideas and wrote everybody's down	Came up with ideas/Wrote the ideas down	They commented on points made; I came up with all points.	They contributed ideas	I think I thought critically well.	Good at coming up with ideas; bad with time management
	Isaac	I helped with the drawing and also the bullet points	Focused on the task at hand	Answering the specific questions	Helped with the info	I have done well at thinking of ideas and answering questions.	I have given out great information to the subject
	JC	Communicated ideas	I expressed my ideas and contributed in a way creative way	Wrote down what we were saying	Others wrote down ideas	I did a great job of cooperating although sometimes we were a bit off topic.	Been creative
Duct Tape	**Grayson**	Imput ideas, most writing, naming the team	Coming up with ideas	Input ideas; very little writing	Coming up with ideas; moral support	Well: finishing on time; not well: getting distracted	Team work; brainstorming problem
	Jamie	I came up with most of the ideas and wrote a bit.	I was the scribe and wrote bullet points	Grayson mostly wrote but also gave some points too.	The other members told me what to write. Duh!!!	Good: we finished really quickly and we did not really argue; bad: we used a lot of paper	Team work, brainstorming bad: writing legiably
	Eathan		I provided information and support for my group.I also did most of the work.		All but one wrote ideas and helped the team		I worked well and provided good ideas.
	Joanna		I helped create ideas. My ideas could not really be solved though so we did not incorporate it		They helped create ideas		Creating ideas; Making creative and effective solutions
Woonsocket	**Sharon**	I drew our team name; gave ideas…etc. WOONSOCKET	idea;. I wrote down as a scrib;. Gave feedback	They are brainstormed a lot of ideas, which were very creative :)	ideas; drawing	We've done well in the discussion, and generally I think we work well with each other.	We were good at organizing ideas
	Jessica	Very support.	Contributed to drawing/a scribe/IDEAS	They did really good job! They were really creative and they had lots of good ideas.	They did so by giving a lot of ideas.	:(	We were really good at new ideas.
	Angela	I gave suggestions. Shared my experience. Compared with public transit from other places	I kept the answers on topic. I gave good ideas. I was realistic	Shared their experiences; Shared recent news about public transit; helped confirm big problems and minor ones; shared their opinion	Wrote ideas down; gave ideas	Focused more on public transit in china (more experience from here); compared China with Vancouver; asked teammates for their opinion; gave many suggestions	I did well in keeping the problem related and based on traffic in Vancouver; I didn't consider disabled people (although that wasn't the peoble we chose)

Figure 4.2. Organizing Open-ended Question's Data in Excel Sheets

4.4.2. Coding for Categories and Concepts

The goal of categorizing the analysis is to "fracture the text data and rearrange them into categories" (Maxwell, 2005, p.96). The coding and categorizing process in this study followed Grounded Theory analytical techniques of *coding* and *memo writing*, as the first step toward creating abstract concepts from concrete descriptions. The first phase in the coding process included initial coding where initial ideas and concepts are given to segments of the participants' data. I pursued this phase by reading all the text data from interview and observation notes, having the research questions in my mind. While I read through my notes, I assigned a code for each important piece of information. I coded them as an interview (I) datum, or as an observation (O) datum. Also, I used the initial of the participant, if the participant was a student or teacher, and the type of data collected. For example, Em-SI would mean Emmanuelle M., Student, interview session.

This coding system was beneficial as a way to organize and identify each piece of evidence that facilitated the process of finding and reviewing a specific point later during the coding and analysis process. The second phase involved what Charmaz refers to as focused coding (Charmaz, 2006), which is the process of selecting the most significant and or frequent earlier codes and bringing them together via axial coding. Axial coding is the process of finding and connecting the relationships between core categories and subcategories and mapping them to the larger data set. Also, according to Charmaz, memo writing is another crucial step to help with connecting between codes for understanding emerging patterns that informed my research questions. In the following sections, I will describe how coding was employed in relation to the type of data (textual and visual) and how memo writing helped to process the codes towards emerging patterns.

Textual Analysis

The grounded theory's technique of coding employed for analysing the text data included word-by-word and line-by-line coding. I employed line-by-line coding, which required highlighting important sentences that revealed participants' condition/situations,

actions/interactions, and process. Hence, any word or sentence that described the above subject matters was color-coded, and an appropriate label was written and assigned to it. Also, while reading mainly the observation notes, I paid attention to the design thinker characteristics (empathy, problem solving, collaboration, and creative thinking), as four main criteria to be evaluated in the design thinking process. I needed to identify if students would reveal any sign of applying these characteristics in their activities and/or explanations. Also, the initial codes for observation notes were assigned a letter (Q1, Q2, Q3) that helped with dividing the codes for research questions 1, 2, 3. After this step, the data was classified through axial coding and memo writing.

Charmaz (2006) recommended using gerunds (a form that is derived from a verb but that functions as a noun) in coding and memo writing as a tool for detecting actions and sequences. While using gerunds was a helpful way of preserving individuals' perspective, it also enabled me to see and interpret the data from multiple perspectives. I also tried incorporating vivo codes (word expressions used by participants) to align my own interpretation with the actual meaning of their responses. In line-by-line coding, not all sentences were coded because not all of them were found to be beneficial in answering one of the three research questions (see Table 4.1). When coding the text, I had the research questions in my mind, so I assigned each initial code to a certain research question by a number. For example "Q1" means "the first research question".

PG's Responses	Initial Codes
G: Individual students? One thing I have noticed is there is four students in this class that are sort of have been for years and are cross subject areas, disengaged learners, like they are just have been, they just sit back and they don't really engage in what's going on but I have seen them more engaged in this than I have in anything… Me: Do you know what would be the reason? G: No, I suspect that there is a little bit kinaesthetic learning going on when we are doing it this way, lot more movement around and different ways of presenting ideas that are always written, we are an academic prep school so there is a lot of writing here so given them the opportunity to present their ideas in a different format I think was new to them or new for them directed group work, their challenges are they can't sort of focus themselves but when they are in the group which is something they all always seem to be seeking; that sort of settles them down and if they have focused tasks within that group seems to help. So I've certainly noticed that and obviously it's all the other students benefit from that as well but at one point that I was talking to the principle with Martin about I said that I really noticed those guys have been right involved in what's going on, so that's a need I am not sure exactly why I have guesses but you know there is certainly things going on there…	Engaging in class activities compared to last courses (Q1) Having kinaesthetic learning may helped with students' engagement (Q1) Exploring a new format for presenting their ideas (Q1) Working in group helped students to concentrate (Q2) Engaging certain students better in the activities (Q1)

Table 4.1. Organizing Initial Coding of Interview and Observation Notes

Visual Analysis

Pictures and images were an essential part of the data analysis process, as they provide key insights around students' understanding of design thinking techniques and process. An assignment on design thinking was given to students, and the results were analysed to assess students' gained knowledge on design thinking. The visual analysis process was done in parallel with the textual analysis but kept as a separate document. The images were organized and coded according to the respective participant's responses. The key purpose of analysing the images was to understand students' gained knowledge from their own perspective, through their visual-based creations. More specifically, the visual data helped me to analyse data from different perspectives, an important aspect in triangulation of data. I began coding the design thinking assignments based on students' drawings. Specifically, I coded the drawings according to the evidence found in each drawing, such as design tools, techniques, materials,

design cycle, and the sequences in showing the activities. In regards to the artefacts such as posters, I searched for the tools and techniques they applied for solving the design problem as well as aesthetics, and innovation aspects. I also assessed participants' written responses in the assignments. To facilitate the visual analysis, I applied the codes directly on the object, upon which I printed the images and used markers to add quick notes on them. I later transferred the findings from paper into Excel sheets, which enabled me to keep the codes in the same document, and organize them based on each participant's response. Since the images and interview/observation notes were not directly connected at this stage, I kept them as separate files, but combined them for the final stage of analysis, when the categories emerged through memo writing and axial coding.

I would like to highlight this methodological approach, as the observation and interview notes would have been difficult to peruse in depth without referring and triangulating the data considering visual creations.

Memo Writing

Memo writing is an essential step in finding categories in Grounded Theory technique. According to Charmaz (2006), memo writing is "the pivotal intermediate step between data collection and writing drafts of papers" (Charmaz, 2006, p.72). In my study, I used memos in the form of journal entries and conference papers. Journal entries were used as part of the focus coding process and included axial coding techniques. After the initial coding, I defined and selected categories that described actions, and processes through memo writing and focused coding. I also began making connections between different single categories and their subcategories through axial coding. Each memo was written in a specific format, each starting with a title, followed by the description of the possible category or subcategory. I considered a conference paper and presentation that were done during the preliminary data analysis process, that were mainly focused on answering part of the first research question: the benefit of interaction design thinking course for secondary school students (Aflatoony and Wakkary, 2015). All in all, memo writing enabled me to get a comprehensive understanding of the raised categories, and interpret and connect data I found in interviews, observation, open questions, and visual assignments.

4.5. Validity and Reliability

While qualitative methods tend not to have standard tests for validity the way quantitative methods do, there are some established processes for validating qualitative analysis to minimize errors and biases. In this study, due to the exploratory nature of the case study, construct validity was employed. Construct validity implies “Identifying correct operational measures for the concepts being studied” (Yin, 2009, p. 30). According to Stake (1995) there are two common ways to establish validity: triangulation of information and member checking. Triangulation of information is to demonstrate a careful analytical process through the write-up of the research and data analysis, and using evidence from multiple data sources. In member checking, the aim is to take specific parts of the analysis and present it to the participants of the studies to see if it makes sense to them and still reflects their experiences (Yin, 2009). I adopted both of these strategies to address concerns about validity, documenting and supporting my analytical work carefully and sharing the analysis with study participants. In this study, multiple sources of evidence were collected through interviews, observation, open questions, questionnaires, and visual documents. During the process of data analysis, multiple sources of data were integrated and triangulated by evidence from other sources. I also adopted member checking in which I presented my observation notes to the course instructor, and asked for his comments about my observation notes, and if he found any difference or misinterpretation of the happenings in the course and activities. Since he was present throughout the course in both schools, he was a reliable person to ask for ideas and to audit my observation notes.

Yin (2009) also recommends using a case study protocol and developing a case study database to increase the reliability of study. Reliability also depends largely on the quality of the write-up, and convinces readers that the analysis is a coherent interpretation of the data. For the aim of this study, I carefully developed a case study protocol, and followed that before and during the implementation of the course, and data collection process. Also a case study database was built to facilitate the accessibility of the collected data and the findings to other researchers.

4.6. Summary

In this chapter, I have presented six different types of data collection techniques, including in-depth interviews, participant observation, focus groups, open-ended questions, questionnaires, and visual method (document analysis). I also detailed the process involved in preparing the data collection through a case study protocol, selection of cases, and execution of a pilot study. The essential interview questions, observation guide, questionnaires and open questions were also presented in this chapter. Furthermore, the data analysis process for establishing a database and coding strategies were presented, and explained in detail. Finally, several strategies were employed and presented in this chapter to increase the reliability and validity of this study.

Chapter 5.

Findings on the Benefits of an Interaction Design Thinking Course

In this chapter I describe the findings from the initial and focused coding phases of data analysis. The findings are described for both A and B cases, including the findings from the sub-unit analysis of teachers, students, and courses in each case separately. The initial coding phase entails the employment of word-by-word and line-by-line coding to distinguish patterns within the text. The textual data were transcribed from interview and observation sessions. Later, the core categories and concepts emerged from the initial coding themes through the process of focus coding. The focus-coding phase included axial coding and memo-writing of the categories and subcategories. The findings in this chapter mainly answer the first sub-research question: “How does an interaction design thinking course benefit senior secondary school students?” The following section illustrates three main themes that emerged through initial and focused coding of interviews and observations including: interaction design thinking as open exploration, interaction design thinking as connected activities, and interaction design thinking in real-life challenges. The first two subsections explain in-course benefit of the curriculum for students, and the last subsection explains the benefit of the curriculum in solving real-world challenges, outside the course. The findings in this chapter mainly emerged from interview and observation textual data. I provide the summary of the findings in each section separately.

5.1. Theme: Interaction Design Thinking as Open Exploration

This section describes the findings from initial and focused coding of textual data through the grounded theory coding technique. The findings in this section review

different situations, settings and contexts that encouraged students to enact and engage in the course activities. In this section, I highlight the various ways that participants were involved in the course activities and how these strategies were preferred by students and schoolteachers. There are five main categories identified under interaction design thinking as open exploration: visual representations, interactive teaching style, tactile activities, inquiry based activities, and nature of activities. I conclude the section by summarizing the findings that facilitate open exploration by students.

5.1.1. Visual Representations in Design Thinking Education

The first finding under this category illustrates that a coordinated combination of verbal and visual instruction was beneficial for students to learn effectively. Based on my observation at Stratford Hall, at the beginning of the course when we asked students to sketch their ideas, the majority of them preferred to list their ideas instead. It seemed they were not comfortable with sketching their ideas at that point compared to writing them. However, by the end of the course they felt much more comfortable to sketch and show their ideas visually. At the Mulgrave School, students felt more comfortable with drawing their ideas and adding annotations to convey their message clearly. This could be due to the fact that they had some background knowledge in design. Furthermore, having visual activities enabled students to represent their thought processes on paper immediately, helped them to remember the course materials, gave them variety to explore more areas and enabled them to literally see the ideas. This is quite different from how they completed their tasks in other courses and helped them to express their ideas differently. As Is-SI, a grade 9 student, clarified:

> The amount of visuals interpreted into solving…it is immediately portraying thought processes on paper through visuals. She further explained: the amount of drawing helps you remember things like I think I remember everything we have done here!

Another student also expressed her experience in the sketching activity as follows: “It’s like gives more variety to explore more areas with not just speech, but with drawing it out, and when you draw it out it just like you remember it.” Also, to confirm the benefit of visual representation in teaching and learning processes, He-SI (He: name, S: student, I: interview) clarified: “You can see the ideas!” Finally, Ju-TI, a teacher from

Stratford Hall, explained: “I think it’s good for them to be able to sketch out the ideas on paper too, that’s a different way that the brain works.” Overall, visual representations were found to be an important aspect of the curriculum, which enabled students to document and present their thought process through sketching and drawings. While I acknowledge the importance of visual creations by students, according to my observation there were several students who preferred to write down or discuss their ideas throughout the course. As the instructor of the course mentioned, this might be due to the fact that we never emphasised the importance of ‘capturing’ and documenting their process sufficiently. Figure 5.1., provides some examples of visual representations during the design process.

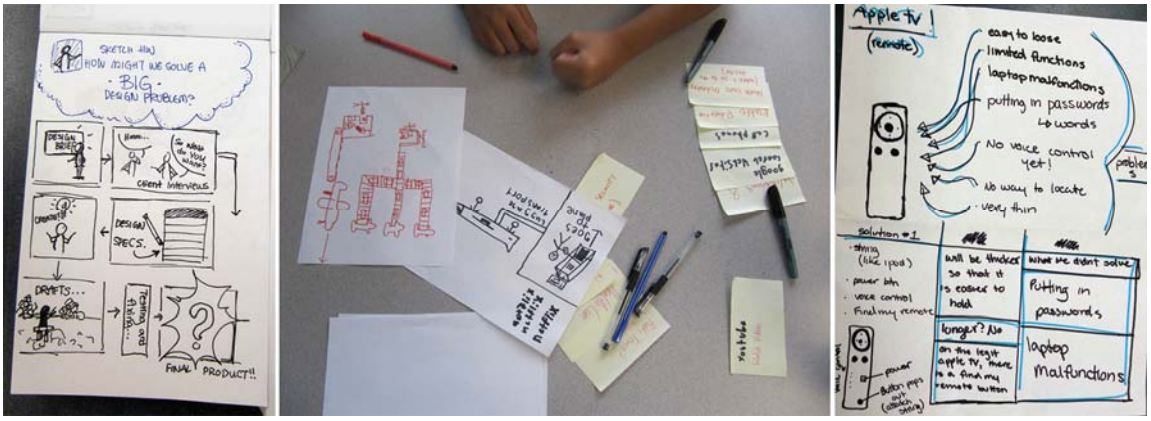

Figure 5.1. Visual representations of students’ design thinking process

5.1.2. Interactive Teaching Style in Design Thinking Education

We aimed to integrate the combination of verbal and visual (show and tell) instructions throughout the course. There was a brand new interactive board available in the classroom, which seemed to be used seldom in other courses. As the instructor of the course described:

> I am surprised by the virtue of I figured given they have projector in each classroom they don’t seem they use it or they don’t use it in a way that helps students, it seems that they play videos just for having multimedia points rather than using it as a tool. Maybe it’s just the matter of given how much I teach with the technology and accustomed with that but it’s something that the teachers at the schools should be using more. That is my thoughts on that one.

Throughout the course, the instructor used his tablet to write or draw the list of activities or the task's instructions and presented them through the interactive board (Figure 5.2). Furthermore, the instructor used the tablet to capture students' works and project them on the wall to facilitate presenting their ideas to the larger group. This strategy saved a lot of time as students had to present their findings in every session. In addition, using the tablet worked greatly in solving problems of students who were distracted easily and lacked concentration by making the information and instructions available throughout each course session. Also using the tool to sketch some ideas in real time while explaining the techniques (e.g., in storyboarding) helped students to get the idea quickly, through a step-by-step process. As Fr-SI, a student in grade 9, explained:

> This is so much better when it is interactive itself because you get to learn much more easily for people who are kinaesthetic and visual and ya rather than someone tell you what to do and in the last seconds is really hard!

Also, several students stated that they found using the tablet, projecting the instructions on the board, and explaining things in a step-by-step format, beneficial. At Stratford Hall, students explained: "I think like examples when he project them on the board really helped"; "what really worked was really projecting the images". Another student agreed: "with the whole step by step things". Likewise, at Mulgrave, one student stated: "I like how Andrew used his tablet". One student mentioned that he liked to have even more visual instruction in the course: "I feel like more visual stuff can be helpful for us, to get everything that you guys are talking about." All in all, from the students' perspective, presenting the course instruction on the board using the tablet was beneficial and helpful in a variety of ways.

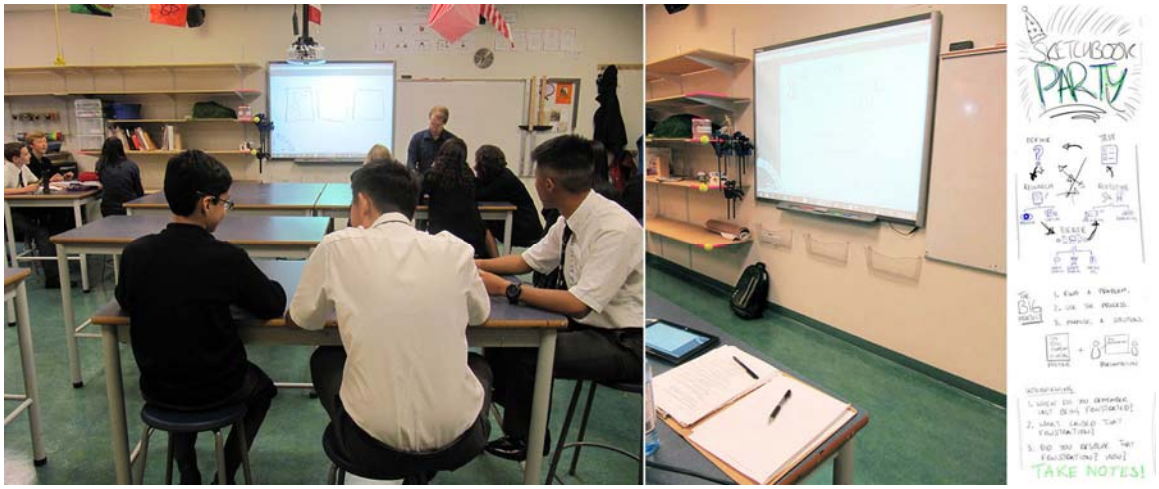

Figure 5.2. Using interactive board extensively in teaching the course materials

5.1.3. Tactile Activities in Design Thinking Education

As is clear in the following statements, students preferred to have hands-on activities in the course (Figure 5.3). As Pa-SI, a student from Stratford Hall, clarified, what worked for him in the course was: "for me I loved the hands-on things and being able to just draw out my ideas or being able to actually do the things instead of just being told about them helps me a lot." To acknowledge that, Em-SI mentioned that "they learned the same skills in a different way; more practical way!" Also, Sa-SI, a student at Mulgrave, explained:

> It was different not using a lot of electronics because normally when we are doing the projects, research and everything it's heavily based around using computers, but with this course it was more hands on and collaborative work.

Av-SI agreed: "which is a lot better!" Finally, the course helped with students' engagement by providing them the opportunity to present their ideas in a different format. As the schoolteacher at Mulgrave expressed:

> One thing I have noticed is there is four students in this class that are sort of have been for years and are cross subject areas, disengaged learners, like they are just have been, they just sit back and they don't really engage in what's going on but I have seen them more engaged in this than I have in anything…I suspect that there is a little bit kinaesthetic learning going on when we are doing it this way, lot more movement around and different ways of presenting ideas that are always written, we are an academic prep school so there is a lot of

writing here so given them the opportunity to present their ideas in a different format.

Figure 5.3. Hands-on activities during the course

5.1.4. Inquiry-Based Activities in Design Thinking Education

Today, in most inquiry-based courses, students work on a given problem and are asked to find an appropriate solution to that problem. However, in this course we encouraged both problem setting and problem solving activities, so students had the chance to conduct research to find real-world issues (Figure 5.4). The schoolteacher from Mulgrave stated his opinion about framing a real problem as follows:

> If you haven't posed and framed the problem you are trying to solve properly you don't really know what it is you are unlikely to get to the solution that solves it! So sort of cutting away sort of what seems to be the fluff of the problem and getting down to the core and what's the real issue and then solve that…the other stuff will take care of themselves…so it's very same sort of thing.

Also, Os-SI, a student in grade 10 from Stratford Hall, explained his idea about problem setting activities and that they did not have such opportunities at school: "Having to design not only we have to figure out what is the problem and we have to figure out the solution to it which normally when you are at school you have to figure out what's the solution to this problem." As Pa-SI said: "like we are giving a problem and we have to find out a solution, and find out the problem just by itself so I think it is cool that you are able to do both." Os-SI agreed: "we were giving both so we were given options

sometimes, so it wasn't like here is your problem go fix it!" All in all, students acknowledged and provided positive feedbacks about being involved the inquiry-base activities.

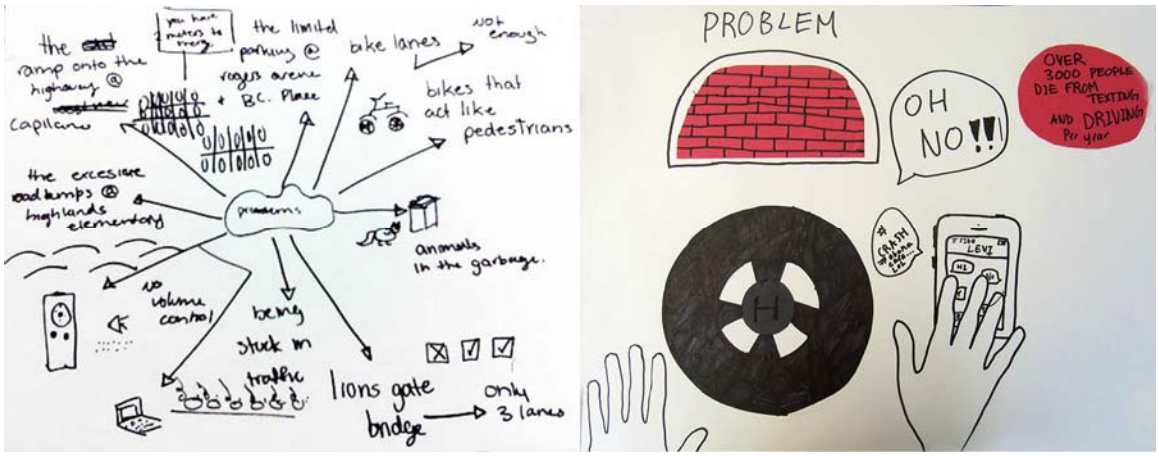

Figure 5.4. Brainstorming as a problem setting activity was encouraged during the course

I found employing both problem-setting and problem-solving activities beneficial for students, however according to my observation there was one team (LE) which struggled through finding a real-world problem, and searched on the Internet to find one. In fact, understanding the meaning of the 'problem' itself can be problematic for this age group. To clarify this, we provided several real-world examples, and explained what we mean by a design problem. Furthermore, I found the interview activity beneficial as the majority of teams could find a topic to work on (a problem to solve).

5.1.5. Nature of Activities in Design Thinking Education

One of the issues that educators may encounter while teaching courses at the high school level is the nature of activities and whether they should restrict the activities or leave them open-ended. As we discussed with the schoolteacher from Mulgrave at the beginning of the course, giving broad topics to students at this age may cause distraction and lack of focus in completing a project. However, we decided not to force students or restrict their choices, as one of the main objectives of the course was to be exploratory in order to encourage the creative thinking of students. As the instructor of the course acknowledged: "I feel like for something more open-ended and to be kind of

creative and exploratory it's hard to be very strict and rules based as meant something to be exploratory."

With regards to this study with secondary school students, we observed and acknowledged that it is important that students take the responsibility to find the right topic (in this case to identify the right problem). Also, I found choosing an appropriate ideation or creation technique to be an important part of the design process by students. Several students indicated that they liked and preferred to freely choose and explore their own topic rather than being assigned to certain tasks. At Mulgrave, student Av-SI explained "like it wasn't set in the stones, we had lots of room with everything in it."

Also, Sa-SI described her opinion about the open-ended nature of the course activities:

> Especially with the final project that you can't get distracted with it that is sort of the point that you really do whatever you want, and then when you choose something you choose something you like, so ya!

Figure 5.5. Students at Mulgrave School were pleased with the open-ended activities

At Stratford Hall, two students mentioned they preferred open-ended activities. Student Js-SI said that she was impressed by having the open-ended activities: "coming up with our own ideas rather than being assigned various choices…because we like had more freedom with our ideas." The second student explained the sense of possession and ownership that he has about their group project: "I like the… like every class I like

the little projects were we like our own thing to present, I think that was cool." Hence, the answers from students were all positive in regards to letting them explore a topic freely rather than assign them some pre-defined tasks. According to my observation in the classroom, it is quite critical to apply a strategy that guides students to complete their tasks. However, spelling out everything can be overwhelming for this age group. With regard to the nature of activities, Av-SI described her experience as follows:

> Like there was not one activity we did that was spelled out for us, It was about working to get the solution and you knew what you want it and it kinda let us get there but you guided us through that and it worked pretty well.

Furthermore, by the end of the course the schoolteacher from Mulgrave also acknowledged the benefit of open-ended activities and further expressed:

> This is sort of being eight weeks focused particularly on ideation and I think that's great the activities were open ended and it was allowed for them to see there are different ways to come up with ideas than just oh I have an idea and that's the best one, right?

Throughout the in-class activities, the instructor walked around the class and was involved in the activities directly in order to guide students in their design processes and the decisions they made. Since the nature of learning activities was open-ended, a close supervision of students and guiding them through the process was important.

5.1.6. Summary

In sum, the initial and focused codes and categories defined as part of conditions and settings of the interaction design thinking course entailed five distinct aspects: visual representation, interactive teaching style, tactile activities, inquiry based activities, and nature of activities. These characteristics were found to be the most desirable and beneficial strategies by students and teachers, which enabled open exploration of concepts through visual, auditory and kinaesthetic teaching and learning activities.

5.2. Theme: Interaction Design Thinking as Connected Activities

Another aspect of the design-thinking course was the techniques and strategies employed and how students adopted and appropriated those strategies in their group projects. The initial and focus codes discussed in this section look at two emergent concepts: teaching design process thoroughly, and diversity of materials and inclusive teaching. I will first describe how teaching the full design thinking process benefited students, followed by the description of diverse techniques and materials employed in the course. The findings here have been discerned from the textual analysis of interview and observation sessions.

5.2.1. Teaching Design Thinking Process Thoroughly

As I talked to the schoolteachers, I found that jumping to a final solution without spending enough time on the design process might be an issue in secondary level education. Students tend to say that: “I have an idea and that’s the best one!” So we developed the curriculum that involves research and ideation activities, as well as creation and evaluation aspects to encourage both divergent and convergent thinking of students. Throughout the course we encouraged students to follow the design thinking steps; e.g., in their final project, we asked them to describe their problem, the process and techniques applied to solve the problem, and the proposed solution to the problem. I found certain evidence of applying design thinking techniques in the majority of projects. As a schoolteacher from Stratford Hall explained:

> I think it was very useful for students to actually walk through the process of design from analyzing things that already exist to coming up with the solutions so they understand that this is a process and that the idea of coming up with the final product is not an instantaneous thing.

She further explained the reason behind the success of the course:

> I think the course is REALLY successful and helping students become design thinkers because you taught them process at the beginning. We observed that they observing and so it wasn’t just about let’s design something now, let’s create. I think you took them through the steps of observe, like I remember I see downstairs in the Foe and looking at

> the steps and making that process of design is about observation and creation, collaboration, planning and execution. So I saw all of those things happening during these weeks so I thought it was really well done again.

Furthermore, by emphasizing the ideation tasks students followed the process of design step by step, without jumping to the final solution immediately. For example, the schoolteacher from Mulgrave stated:

> It's good for me to see some new techniques about just how to go about introducing the whole concept of-the thought process behind the design and not just focusing on you know the product type of thing but looking more at the process and you did an exercise on sort of like empathy, put yourself in the shoes of the person who is going to use this, the group who is gonna use it and that's really worthwhile.

So according to the above findings, following the design process and ideation activities properly was beneficial for students to make thoughtful decisions when solving the design problem. However, as the instructor of the course mentioned, students did not always 'capture' their process due to the fact that we did not sufficiently emphasised the importance of capturing and documenting their process:

> Part of the reason the teams didn't capture the process is that we didn't really in the course illustrate to them that capture is important by the virtue of the fact that it helps you to understand what you have done, I remember talking about it offhand but I don't think we formally introduced like: you capture stuff so you always have reference point, have this piece that you can look back on it say ok this was my thought, this is sort of how above them from here.

5.2.2. Diversity of Materials and Inclusive Teaching

In the interaction design thinking course, applying a variety of techniques and materials, as well as having little tasks and projects every session helped engage students more. Students became familiar with design thinking techniques, such as sketching, storytelling, presenting, researching, observation, and prototyping (Figure 5.6). To acknowledge that, student Av-SI from Mulgrave described her experience: "I like lots of ways we did things." Also, Lu-TI, the schoolteacher from Stratford Hall, explained:

> I thought it was very age appropriate and it was also really interactive, there was a lot of variety during the class time and that really helped

> with engaging the students the entire time that was fantastic really well done!

In addition, focusing on a certain task for a long time is a challenge for this age group. Hence, having little projects and a variety of activities in each session helped students to be on task and be focused. As the same schoolteacher clarified:

> What worked was the constant changing of tasks for them because an hour and 20 minutes is a long time for them to be doing one thing so the fact that they were constantly changing activities worked really well.

Figure 5.6. A variety of design techniques and activities were employed in the course. Clockwise from top left: observation, bodystorming, presentation and prototyping.

Moreover, having a variety of activities enabled students with a wide range of cognitive learning styles to choose the techniques that they found more comfortable to explore. As an example, in the final project every group chose different techniques to

explore a problem and propose a solution. While several techniques were similar in different groups, the design processes followed by the groups were varied. To complete these projects, they applied the techniques or materials that they found appropriate, but not the exact design steps that they learned in the course. Also, outside the course, each student found his/her own process to create an artefact. For example, to answer the question whether he applied the whole process student Em-SI explained: "Well, I didn't really do research, I designed it and built it, but I didn't evaluate it because it was perfect, it works, it is beautiful!" Furthermore, according to my observation, some students preferred certain techniques and activities to other ones. As an example, student SO was very interested in hands-on activities and making things. However, she seemed uninterested in bodystorming activity and performed weakly in that activity. On the other hand, student SE enjoyed acting out in the bodystorming activity, but he did not seem quite interested in hands-on creations or sketching activities.

Team	Mulgrave - Techniques used in the process
DU	Interview, brainstorm, research, prototype (exploring the idea of building pot and conveying heat loss), design their poster.
AS	Interview, brainstorming, discussion, prototype, design their poster.
SO	Problem identification, research, sketch, design their poster.
HE	Interview, storyboard of problem, research, observe and capture, brainstorm ideas, storyboard of solution, prototype, design their poster, evaluate and reflect.
JU	Interview, research, design their poster.
ME	Interview, research (on sport fields, interview people), brainstorm, sketch, prototype, design their poster, test solutions.
WO	Interview, research on the shape of room and how to draw it, storyboard of the problem, design their poster.
Team	Stratford - Techniques used in the process
IN	Interview, research on problem, discussion, design their poster.
LO	Research (on internet), discussion, design their poster.
LE	Research, brainstorm, discussion, sketch and plan ideas, design their poster.
DA	Interview, research (on internet), discussion, design their poster.

Table 5.1. Techniques and tools employed in students' projects

5.2.3. Summary

In sum, by teaching the whole design thinking process and emphasizing the ideation tasks, students followed the process of design step by step, which resolved the issue of jumping to the final solution immediately. Also, a wide range of design activities, from brainstorming to bodystorming to formal presentations, enabled students with different cognitive learning types to succeed in certain design activities. This helped certain students to gain self-confidence, and improve their self-image and motivation that enabled them to perform better in individual and collective activities throughout the course.

5.3. Theme: Interaction Design Thinking in Real-Life Challenges

This section illustrates the findings about successful implementation of the design thinking processes and strategies used in real life situations by students. The initial and focused codes around the course outcomes and achievements had emerged based on participants' descriptions of how they interpreted the course benefits outside the classroom and how they applied it to their everyday life situations and to other courses. In the following sections I illustrate the findings from these specific outcomes and their associated codes.

5.3.1. Applying Design Thinking in Everyday Life Situations

Here, I explain my findings about the application of design thinking in everyday life of students as a common practice when they are doing DIY projects at home. In these cases, they applied design thinking techniques and practices such as sketching, critical thinking, and refining the ideas as they learned in the course. They started applying the skills in making physical artefacts or spaces at home or outside the home such as a den, a table, a pond, and an aquarium. As Gr-SI, a student from Mulgrave, explained, he got permission from his mom to "turn the bedroom downstairs into sort of a man cave or something so I am going through the process and drawing out all the ideas and measuring the room stuff, that's kind of a cool project at home to do it in my spare

time." In addition, students applied the approach to making digital art and artefacts such as building games or digital art. As Pa-SI and SO-SI, both students from Mulgrave, explained:

> At home when I am playing games and stuff live stream and live streaming is pretty much like making a video that's live and people can watch it while you are doing certain things. I incorporate like Photoshop so I am able to put like the design critical thinking skills that I learned here into creating graphics for my live stream channel, for my video stuff that I do so that's nice!
>
> I do like designing like because I do digital art with my tablet and stuff, I sometime go through like designing process was like first I get a brief sketch, and then make it final but then maybe I have to change something….

In addition, as several students clarified, they applied the process to solve problems spontaneously and without thinking about it as a 'problem', but as a 'situation' that needs to be resolved. As Is-SI, a student in grade 9, mentioned, the problem situation is "a conflict and a reason to be unhappy" so she consciously analysed the solutions to the situation, whereas solving those everyday problems occurs mostly in their heads. She said: "given a problem, the first thing you do is analyse the solutions like it's not so much of like I have a problem, now! What do I do?" Furthermore, to solve problems in everyday situations, we found that students are not using any specific planning materials or tools, but they prefer to directly reflect on the problem instead. As Br-SI mentioned: "in choosing homework to do first, saying which one is more important, we plan everything out I do all in my head, I organize my homework, and I write it down." Jo-SI, another student in grade 9, identified the application of design thinking in every project he has done before, and further explained: "basically for any projects we really do researching but we do not really think about doing it, we just do it." A very interesting example of applying design thinking in an ordinary life situation was brought up by Di-SI, a student from Stratford Hall: "I was trying to get on the roof of the garage so I had to brainstorm some materials I needed so I take sort of design the staircase to get to the roof of garage." However, his group criticized him for the unsafe nature of his idea. Some other examples of problem-solving situations in everyday life of students are as follow: building a puzzle, playing a video game, and bringing a jacket on a rainy day. All

and all, students could identify and bring interesting examples relevant to the application of design thinking in making digital and non-digital artefacts at home.

5.3.2. Applying Design Thinking in Other Courses

In addition to the home, students identified and provided appropriate examples of the application of design-thinking processes and techniques in their other courses, which are mostly project-based. However, we found that they might have used these techniques and materials differently compared with the design thinking course. Students explained that they used a similar process in English, math, humanities, science, socials, personal projects, and theater but in different ways. As an example, IS-SI pointed out "in socials as well, the first thing you do is, you know you are not given so many problems but analytical situations." So, as she explained, they were introduced to a situation that required further analysis. In such courses (Socials) the issues presented to students are usually pre-defined, such as 'overfishing', as an example brought by a student. In other courses such as English, they applied the critical thinking to reflect on a passage. As Sh-Is clarified and explained:

> In English you have to read a book, like this year we are reading and we answer a bunch of questions on it, and that sort of the book is the research and then when you are writing it down, it's sort of a solution I guess and also you have to do not really a reflecting paragraph but like a paragraph about what we liked about the book, and what impact did it have.

In this case she identified and compared the process of the design-thinking course with the process they followed in the English course. Another example brought up by a student was in theater: "In theater class we need to create something like a puppet show like you go to researching and like how to design the set and write describing something like that." Also, I found students were applying the design thinking process to 'Personal project', a course taught at Stratford Hall School. Two students from the same course explained their design thinking experience as follow:

> For my personal project right now I am in grade 10 and we are doing the same thing. I have to, I am designing a yoyo, so I had to create the design, I had to sketch out images about what I might like and I had to input those ideas into a program… right now we are just waiting on them to… It's a whole process.

As one of the schoolteachers noted, students voluntarily applied some of the ideation techniques that they learned in his class:

> When we have the regular course they talk about what they're doing and I have seen them using some of the sort of ideation tools that you've shown them in their regular course work here. So any time you can see them transfer skills from a familiar situation which would be what you are doing here to a sort of unfamiliar one or new situation that transfers means that there is something there. So I would say that's pretty good.

Also he explained further that in the same course students self-formed groups to help one another through reflection on each other's works.

> Even though they do the project individually they've already self-formed into groups to help each other… kind of just like a design team so I am gonna work on this but in some point I am going back to you guys and ask you here is what I am doing right? So that's really neat to see that they are actually using, they have got a plan to use what you have shown them… .

Further to my investigation on the benefit of design thinking in other educational contexts, I found design thinking techniques in other courses such as literature or history, which may parallel one another in terms of the skill sets needed and learning outcomes. For instance, the storytelling technique purposes in a design course are to describe a product's functions and usage. However, in history, storytelling can be implemented to analyze literature and to engage peers in discussion of historical events.

5.3.3. Summary

In sum, the findings around the course outcomes and achievements had emerged based on participants' descriptions of how they interpreted the course benefit outside the classroom: in everyday life situations or other courses. The findings indicate that the course offered distinctive benefits in transferring the knowledge gained from the educational context to everyday life situations. Such pedagogy helped students to develop their own design-based meta-cognitive strategies that enabled them to solve unknown problems. We also found that students tended to apply and transfer design thinking techniques and strategies in everyday life situations and other courses 'voluntarily'.

Chapter 6.

Findings About Evaluation of Design Thinking Skills

In this chapter I give an overview of the findings that answered my second research question: “How an interaction design-thinking course enables students to become design thinkers?” The findings were established through the pre and post course activities that involved certain questions to evaluate students’ skills gained in the course. Furthermore, pre and post questionnaires on a five-point scale were given to students to self-evaluate their creative confidence before and after completion of the course. In addition to these research activities, I observed students’ activities and attitudes to access non-verbal expressions of students following an observation guideline to gather certain data. Please refer to section 4.3 for more descriptions on data collection methods.

In this chapter, I will overview the findings for each design thinking skill, including human-centeredness, problem solving, collaboration, and creativity confidence. In the last sub section, I will illustrate the findings about students’ perceptions of design thinking, for which the data was collected and synthesised through a drawing assignment.

6.1. Problem-Solving Skills

In this sub section, I illustrate the findings from the pre and post open questions, my own observation throughout the course, and I provide the final result on whether students improved their problem-solving skills in this course.

6.1.1. Findings from Pre and Post Questions

This activity was completed in students' original teams as part of their in-class activity. An identical question was given to students before and after completing the course. The question aimed to measure their understanding of the design thinking process on how to solve a problem in a series of design steps. To understand the level of knowledge gained, I narrowed down the question by asking them about the four 'first steps' in making things rather than the whole process. The question was as follows: 'In a group of 3 to 4, please list the 4 first specific steps that you will use in the process of making a new digital mouse, mobile phone, chair or wheelchair.'

I coded the answers according to which process in design thinking process they referred to in each answer. I also evaluated their pre and post answers quantitatively to help further in understanding if their knowledge of design improved. So I rated the provided answers from 1 to 3, from weak to strong answer. The answers considered four main qualities that were observed in the answers: *correct terminology, correct design thinking steps, focusing on 4 first steps, and improved knowledge in general*. The following tables (6.1, 6.2) illustrate the coding from pre and post activity, as well as the design process steps that provide information on the correctness of answers.

Group	Pre activity	Post activity	Design process steps
Wo	Understanding user; Restrictions; Research; Creativity	Personalized; Uniqueness; Iteration	Incorrect design steps in pre and post activity
So	-	Research; Ideate; Prototype; Test; Iteration; Final product	Correct design steps In post activity; Not 4 first steps
Du	Research; Design; Product; Test	Research; Design; Prototype; Reflection; Test	Correct design steps in post activity; Not 4 first steps
He	Understanding user; Research; Ideation; Product; Test	Understanding user; Research; Prototype; Final product	Correct design steps but missing steps; Not 4 first steps
Ju	Research; Research on products; Ideation; Planning	Research on products; Research; Sketch; Prototype; Final design	Correct design steps but missing steps; Not 4 first steps; Improved in post activity
Me	Research on products; Plan Gather materials; Final product	Research; Brainstorming; Analyse; Create	Correct design process But missing steps; Improved in post activity
As	Research on material; Research on tech; Final product/test; Test	Identify problem; Understanding users; Research; Ideation	Correct design steps in post activity; Improved in post activity

Table 6.1. Problem solving coding according to the pre and post answers from Mulgrave School students

Group	Pre activity	Post activity	Design process steps
Lo	Design; Prototype; Test Iteration	Understanding users; Design; Research; Create	Correct design process but missing steps; Not 4 first steps
Da	Define the goal; Buy material; Create design/plan; Final product	Identify problem; Identify goals; Create prototypes Selection	Correct design steps in post activity; Improved much in post activity
Le	Invent; Sketching components; Build/test; Iteration	Identify problem; Ideation Selection (pick the best idea/exclude weak ideas)	Correct design steps in post activity; Improved much in post activity
In	Appearance; Material; Gather materials; Creation	Identify problem; Research Ideation; Propose a solution	Correct design steps in post activity; Improved much in post activity; Not 4 first steps

Table 6.2. Problem solving coding according to the pre and post answers from Stratford Hall School students

Group	Correct Terminology in post activity	Correct design thinking steps in post activity	Focus on 4 first steps in post activity	Improved knowledge in post activity
Wo	1	1	1	1
So	3	3	2	-
Du	3	3	2	3
He	3	2	2	2
Ju	3	2	2	2
Me	2	3	2	3
As	3	3	3	3
Lo	2	2	2	2
Da	3	2	3	3
Le	3	3	3	3
In	3	3	2	3

Table 6.3. Ranking group's answers on problem solving process

Note. 1= weak answer 2= average answer 3= strong answer

Here, I will describe the findings from the problem-solving activity. The findings illustrate that students could use correct terminologies in the post activity in comparison with the pre activity. Table 6.3 indicates that 8 groups out of 11 could provide correct design terminology in post activity. As an example, group IN used general descriptions when listing the design steps in the pre activity (Table 6.4). They could provide correct terminology when answering the post activity question:

Pre activity answers	Post activity answers
1. What will it look like 2. What is it made out of 3. Gather materials 4. Put chair together	1. Identify problem 2. Research existing products 3. Ideate 4. Propose a solution

Table 6.4. An example of answers in pre and post activity provided by IN group

Also, some general terms such as 'Research' or 'Design' are repeated in pre and post activity (e.g., create various designs of the phone), where it was not quite clear what they referred to.

Another example shows that some groups improved their knowledge considerably in post activity in compare to the pre activity. The findings in table 6.3

illustrate that 6 out of 11 groups could provide correct answers in the post activity. As an example, in the answers from LE group, the pre activity answers were very broad and did not indicate any knowledge of design. The post activity's answers on the other hand were very specific and explained the design thinking process correctly and in detail (Table 6.5).

Pre activity answers	Post activity answers
1. Define the purpose of da (sic) chair	1. Discover the problem you are trying to solve with the chair.
2. Buy parts for da chair from local Ikea	2. Create design specifications, what must it apply to?
3. Create design and plan for the chair	3. Create multiple prototype designs and chose one
4. BUILD DA CHAIR	4. Compare chosen design with the design specifications

Table 6.5. An example of answers provided in pre and post activity by LE group

In regards to listing the steps, not many groups did it correctly. In fact only three groups could identify the four 'first steps' accurately and the others provided more general answers on the whole design process stages. The problem here might be due to lack of understanding of students, or lack of clarity in the assignment description. We might have to emphasise more on the four 'first steps' when we introduce the activity. Finally, 6 groups out of 11 could improve their knowledge in post activity in comparison to pre activity (Table 6.3). One group's (SO) team members were absent in the first activity so although they provided correct answers, it was not possible to evaluate their knowledge and skills improvements in the post activity.

All in all, in terms of problem-solving skills I could identify clear improvements in students' knowledge in the majority of the groups. Students could refer to terminology such as user research, user understanding, problem identification and proposing solutions. They also displayed diverse understanding of the design process by providing comprehensive answers in the post activity. However, it is easier to identify Stratford Hall students' knowledge improvements when comparing post activity answers to pre activity answers due to the fact that they did not have any design experience in advance. At Mulgrave, since students had some degree of design knowledge, it is more difficult to clarify if they had improved their knowledge significantly. However, their previous design experience emphasised making prototypes, with less emphasis on problem identification

and ideation process. Hence, it is still very clear that they gained knowledge and improved certain skills in this course.

6.1.2. Findings from Observations

In this sub category I will explain the findings from the open coding of each school separately, and later will provide the final results according to the focus coding analysis. In addition, I observed students' skill improvements on problem solving every session when they were involved in activities, and compared their abilities in problem solving at the beginning and at the end of the course. So here I provide information on students' gradual changes and skills gained throughout the course.

Mulgrave Findings

In the first session students came up with fairly random ideas in the concept development activity. More specifically, they could come up with unique concepts, but the purposes and functions were quite random, abstract, and very fanciful. As they did not follow any design process steps, they could not explain why/how they came up with those ideas and the applicability of the concepts were an issue. In the third session and during the observation activity, students could come up with more realistic problems that they encountered in the space. However, there were two groups (JU, WO) that mentioned positive aspects of the space but not the problems. In week 4, in the bodystorming activity, the proposed solutions provided were all very reasonable, and comprehensible. In week 5, in the improving service activity, students improved the online services without finding a real problem (problem setting). This may be due in part to the fact that they chose pretty well designed interactive services such as YouTube. Overall, four groups improved the services without finding a real problem; two groups proposed solutions to a defined problem, and one group found the problem without proposing any solution. In those cases the improvements were suggested for services, they all were reasonable and applicable. In week 6 and 7, students started to work on their final projects according to the problems they found in the interview activity. There were two groups that were still confused about which problem to pick up (WO, HU). All groups could come up with acceptable problems to work with by the end of session 7. The following table indicates the problem and solutions proposed by students and if they

were feasible. Overall, 5 groups out of 7 could propose tangible and workable solutions to the problems proposed (Table 6.6).

Team	Problem	Solution	Problem solving skills
DU	Handles of pans are hot	Create a step on handle	Feasible solution; followed the design process
AS	Truck accidents on Vancouver highways	De-icing system at the wheels	Not workable solution; fairly random idea
SO	Mulgrave traffic and routes	Create two separate lines for both senior and junior from the highway	Feasible solution; followed the design process; considered both the implementation and financial issues
HE	Animal goes to trash/condo space	Bear bin- incorporating strong material in making the bin	Feasible solution; followed the design process and techniques
JU	Traffic problem around the bridge	Build a new bridge from West Van to UBC	Not workable solution; fairly random idea
ME	Find a parking lot when going for sport	Built a new parking lot at Mulgrave	Feasible solution; did not consider the environmental issues in the solution
WO	Messy room	A chair with bar hooks to hang clothing on	Feasible solution; paid attention to the details in design and safety issues

Table 6.6. Problems and solutions proposed by students in final project

Stratford Hall Findings

I encountered the same issue with Stratford Hall students with regard to their problem solving skills. In the first session, in the make an interactive product activity, the proposed concepts did not quite involve any problem or solution, and the ideas moved to the realm of fantasy versus actuality. In week 3, in the understanding an environment activity, students found realistic problems in the space and share it with the larger group. In week 4, in the bodystorming activity, the solutions students found were reasonable and thoughtful and considered existing technologies and how they could be evolved in the future. They also considered interactions/relationships between people and how those can be changed over time. They also paid attention to problems they faced with technologies such as problems with word recognition systems when using sound recognition technology. In week 5, in the improving service activity, students went through four steps of design thinking well but they found the solutions quickly without digging into the design process or alternative solutions. They found quite reasonable problems based on their everyday experience, but the solution lacked further

exploration. In week 6, in the interview activity, all students came up with real problems they face in everyday life. However, for finding the problem to work with in their final project, one group (LO) had difficulties in understanding the nature of problems, so they found some solutions each time and said: “we want to improve or change this product!” Finally, by providing examples of potential problems around them, they went back on task and found a realistic problem to work on. However, they came up with the problem of texting and driving, which was found on the internet. Overall, two groups found feasible solutions and two groups found quite workable solutions at Stratford Hall, as illustrated in Table 6.7.

Team	Problem	Solution	Originality of idea
IN	Internet and Microwave interference	Use a solar path that use UV to cook food	Quite a feasible solution; no attention paid to details.
LO	Texting and driving	Intelligent phone to pass an update to the speedometer to slow down the car while texting	Quite a feasible solution; no attention paid to details.
LE	Having less space for agriculture	Food print farm in multi-level building	Feasible solution; they paid attention to the process and the details.
DA	Increase the memory capacity in people	An app that assess the type of learner and provide appropriate learning program.	Feasible solution; they paid attention to the process and the details; considered findings from the research.

Table 6.7. Problem and solution proposed by students in final project

Findings from both Schools

According to the findings from both sessions, there was a gradual improvement in students’ problem solving skills. In the first session, almost no group could find a realistic problem or solution for the ‘making concept of an interactive product’ activity. Over the course, as observed during provided activities, students showed strong improvements in learning problem-solving skills and processes. In their final project, the majority of them did well in proposing an acceptable solution; however a couple of solutions were not workable. Based on my observation, certain groups that followed the design processes more seriously and employed design techniques were more successful in providing more feasible or acceptable solutions. On the other hand, the

other groups provided more original solutions and ideas; however these were not feasible.

6.1.3. Summary of Findings

According to findings from both pre/post course activities and my own observations, the majority of students could improve their problem solving skills. Students could identify and use design terminology in post activity. They also provided a clear understanding of what was the problem and what was the appropriate solution to the problem. Students employed design techniques and processes; however, they showed different understanding of design process and picked different techniques to explore the process. In the final project, 7 out of 10 students could provide acceptable and feasible solutions to the problem they introduced. All in all, students who followed the design thinking process precisely could come up with more acceptable results in their final project.

6.2. Human-Centred Skills

In this subsection, I illustrate the findings from the pre and post course questions, and my own observation throughout the course. I provide the final results on whether students improved their human-centred (empathy) skills in this course.

6.2.1. Findings from Pre and Post Questions

In the pre and post activity I asked students to pick certain users from a list provided to them, and list the problem that the person may face when using public transportation (Please refer to section 4.3.4 for more information). Table 6.8 illustrates results of open coding for the answers received from students in pre and post activity. In addition to these results of open coding, the types of questions selected by students and the number of answers provided by students are illustrated in the table. The findings indicate that depending on the question that students selected (A, B, C, D), they paid more attention to the user's feelings and problems in each situation in post activity. In other words, they shifted their focus towards people, and people's interactions in post

activity. For example, students found issues when people interact in public transportation (in question A or C); paid attention to driving issues and problems that people face while interacting with other people (e.g., jaywalkers, careless drivers, fast/slow drivers) (in question B or D), and considered problems that disabled people face when using public transportation or driving their personal cars, such as their movements in crowds (in question C or D). In addition, the majority of groups (except two groups: AS and LE) provided more answers in the post activity in comparison to the pre activity, which may be an indicator that they enhanced their empathy and human-centred view towards people's problems.

Group	Pre activity	Question/ Number of answers	Post activity	Question/ Number of answers
WO	Health (2); Frequency (2); Environment (1); Interaction (1); Schedule (1)	A / 7	Weather/environment (1); Interaction (2); Schedule (3); Route (1); Other issues (1)	A / 8
SO	-	-	Schedule (1); Health issue (1); Facility (1); Route (1); Interaction (1)	A / 5
DU	Time consuming ; Route (2); Frequency; Health; Environment	B / 6	Schedule (2); Interactions (3) Time consuming; Other issues	A / 7
HE	Schedule; Route; Interactions (2)	A / 4	Interactions; Facility (2); Time consuming	C / 4
JU	Route (2); Upgrading (2)	B / 4	Interactions; Schedule (2); Cost; Facility	A / 6
ME	Schedule; Health issue (2) Cost; Driving issue	B / 5	Schedule; Route (3); Time consuming (3); Cost; Health issue (1); Upgrade (2); Driving Issues (3)	B / 13
AS	Cost; Interactions (2); Facility (2); Time consuming; Health issues; Weather/environment (2)	A / 9	Weather; Time consuming; Movements (2)	D / 4
DA	Schedule ; Time consuming (3); Facility (3); Route; Health issue; Interactions	C / 10	Route (4); Driving issues (6); Weather/environment (3); Time consuming	B / 14
LO	Time consuming; Cost; Interactions (2) Frequency; Route; Schedule	A / 8	Interactions; Time consuming (2); Driving issues (4); Cost (2)	B / 9
LE	Time consuming; Interactions (2); Facility (2); Cost; Route; Schedule	A / 8	Upgrade; Driving issues (3); Weather/environment; Time consuming	B / 6
IN	Interactions (3); Schedule; Time consuming	A / 6	Time consuming; Driving issues (4); Upgrade; Route	B / 7

Table 6.8. Open coding of students' answers on human-centeredness

6.2.2. Findings from Observations

To evaluate students' human-centred knowledge gained in the course, I observed their activities and their project's outcomes. I will provide the overview of my observation findings for Mulgrave and Stratford Hall respectively in the following paragraphs:

In the week one activity, students at Mulgrave came up with quite abstract ideas, and did not consider real problems or empathy with people. In the second week, in the brainstorming challenge activity, they mostly involved their own insights rather than other people's experiences and insights. In the third week, in the observation activity (Understanding an environment) students started to pay attention to the environment as well as people in the space. As one group explained their findings: "There was a group of people there until we interrupted them having their discussion". By session 5, in interview activity, students paid even more attention to people and their problem. In their final project, they proposed solutions according to the problem they found earlier on through interviewing one another. Overall, the majority of projects indicated a high level of user consideration and developed appropriate design solutions for them.

At Stratford Hall, in week 7, there were two teams which worked heavily on the computer to find a problem to work on. I believe the problem they found and the proposed solution did not consider a certain group of people but referred to society in general. Overall, two teams' final projects (LE and DA) showed evidences of empathy and understanding people's problems and needs in the design process evidently. The other two projects lacked certain details and evidence, so the levels of empathy and human understanding in those projects are quite vague.

6.2.3. Summary

The findings from the pre and post questions and observations revealed some level of improvements in students' human-centeredness skills. In the answers provided in post activities, student clearly showed that their focus shifted towards people, people's interactions, and people's activities. Throughout the course students comprehended the reasons behind user-centred design and designing for people in certain activities such

as observation and interview. In the final project, they showed some level of understanding of empathy and human-centeredness when designing for people.

6.3. Collaboration Skills

In this section, I provide the findings from the pre and post course questions, and my own observation throughout the course. This section also provides the final results on whether students improved their collaboration skills in this course.

6.3.1. Findings from Pre and Post Questions

In the pre and post activity I asked students to give feedback on how they worked together in their previous activity (Please refer to section 4.3.4 for more information). The following tables (6.9, 6.10) illustrate the results from pre and post activity at Mulgrave and Stratford Hall schools respectively.

Students at Mulgrave School showed cognitive improvements and awareness with teamwork. Certain terminology such as *teamwork, participation, collaboration, and inclusion* are utilized in the post activity answers. Students clearly expressed their thoughts on acceptance or rejection of other team member's ideas. Also, they improved certain skills in teamwork such as time management, concentration, and sharing tasks equally. Although the team members tried to share the tasks equally in most cases, sometimes lack of respect for everyone's opinions and leadership in teams were problematic issues. In some groups such as WO, certain group members provided clear but general description of their understanding of teamwork; however they never showed it due to indolence or lack of interest. As an example, to answer the question: In your opinion what have you done well or not well? Sarah said, "We've done well in the discussion, and generally I think we work well with each other". However, she was the only person who was silent and did not show any interest in the discussions or sharing her ideas.

In addition, teams with more than three team members had difficulty in sharing tasks equally. Although they never complained about such issues during the course

activities and this problem was not quite obvious in my observations, certain information provided by students confirmed the lack of satisfaction regarding teamwork. As an example, one team member from Du said: “The other members told me what to write. Duh!!!”

At Stratford Hall, I found several issues in teamwork and collaboration such as a leadership problem in DA and LE groups, and lack of respect in group IN. This may be due in part to the fact that they may not have known how to share their tasks and discuss ideas in ways to promote equality. Also, there were certain students who liked to be a leader in these groups. Furthermore, accepting or rejecting one another’s ideas in a respectful manner was an issue in some groups. Group (LE) increased their level of understanding and showed more interest in the post activity by providing detailed descriptions of each member’s tasks in the group. However, since this group had a leadership problem (student Tr tended to lead the group, make the decisions, and guide all the group activities), one student was idle in some activities.

Group	1. How did you support the team in this activity?	2. How other team members helped the team in this activity?	3. In your opinion what have you done well or not well?
Me	Shared their works equally in the post activity by dividing the tasks equally (every one focused on certain task). In pre activity they worked as a group and accepted others’ ideas better. In post activity although they shared the tasks, one member made the majority of decisions (Student A: I made and came up with the designs for the map drawing)	Equal collaboration and dividing tasks in post activity. In contributing ideas/discussion there were some dominant ideas from student A. One student was not involved in discussions much. (e.g. “Sara wrote most info; Stella made it pretty and wrote the key; Mona an exterior opinion”).	In post activity they employed terminologies such as collaboration or inclusion, which represent their perceptions on teamwork in compare to the pre activity.
As	In post activity, they came up with more relevant terminologies such as brainstorming ideas in compare to the pre activity. Some team members haven’t done much due to the number of team (five); they used general terminologies such as “thinking ideas”.	Since they were in team of five when completing the post activity, not everyone contributed deeply. So they tried to make up their responsibilities: “gave moral support”. Not quite specific in explaining who did what in the activity.	This group did well in brainstorming ideas and discussions as a team. Since there were five team members in the group, some did not have enough chance to collaborate on creating the poster, etc. (e.g., “I co-operated with my group well. But not designing the poster”).

Group	1. How did you support the team in this activity?	2. How other team members helped the team in this activity?	3. In your opinion what have you done well or not well?
Ju	Used more terminologies such as contributing ideas in contrast to writing down ideas. Improved their percipience of teamwork.	Shared the tasks better in post activity. They show their awareness of collaboration (e.g., "we act together")	They participated fully in the group work, and increased their interests in working together. Time management and distraction were some issues in general but they did not mention it.
He	Everyone focused on a certain task in the post activity. They divided/shared the tasks very equally.	Evidence of increasing their understanding of collaboration in post activity. (e.g., "I came up with all points" in pre activity versus "they contributed ideas" in post activity.)	Time management was an issue for this group and they mentioned that in the post activity. Also, they had problem in discussing irrelevant issues in pre activity, which was solved in post activity "I did a great job of cooperating although sometimes we were a bit off topic".
Du	Equal sharing of tasks in post activity, but lacked the percipience of teamwork in general (e.g., "I did most of the work! I helped create ideas. My ideas could not really be solved though so we did not incorporate it")	Evidence of inequality in team work; all but one wrote ideas and helped the team and although they seemed to work well together, they lacked intimacy in teamwork (e.g., "the other members told me what to write. Duh!")	Overall, team members mentioned they did well in teamwork and brainstorming ideas. They had no issue with time management and distractions in pre and post activity.
Wo	Overall they improved the way they collaborated. They provided more details about their contribution in post activity. For example in pre activity a team member provide an explanation: "very support!" In post activity he said: "I contributed to drawing."	General terminologies were used; Did not provide very specific answers in the pre and post activity.	They did not specify their tasks in their group, and talked about ideation tasks in general. They had no collaborative issues in pre activity, and gave more positive responses, e.g., "We've done well in the discussion, and generally I think we work well with each other."
So	All team members involved in the discussion and contributed well in communicating ideas in the post activity.	All collaborated well, one team member contributed in discussions and idea sharing. They paid attention to the details and elaborated their ideas.	In pre activity they weren't able to concentrate, so they talked about irrelevant things. Certain members contributed more than others. In post activity, they could manage their time, e.g., "we were able to brainstorm quickly." but had problem accepting/ sharing everyone's ideas e.g., "I've done well trying to put input, but I think I did not try to combine everyone's ideas that well."

Table 6.9. Summary of findings from pre and post questions-Mulgrave School

Group	1. How did you support the team in this activity?	2. How other team members helped the team in this activity?	3. In your opinion what have you done well or not well?
DA	This team had some issue in collaboration and an individual person led the team; e.g., "I contributed my ideas into the project at hand. Somewhat took a leadership role." All answers were quite general due to the fact that they did not share the tasks in hand quite well.	It is not quite clear who completed what task as two students both mentioned "I wrote down the ideas". They have good understanding of contribution and group work as they showed in the post activity.	Some of the positive aspects that they mentioned in pre activity include completing task on time and staying on task. In the post activity, they focused on general aspects such as handwriting. According to my observation, one team member was not quite interested in doing the activity but he stated: "participating a lot."
LE	In this team, one team member was idle; e.g., he gave answers like: "moral support" in pre activity and "listening to ideas" in post activity. On the other hand one team member tended to lead the group: "I drove the team with ideas when they had none."	Provided more detailed description of tasks and team member's roles in post activity; e.g., one student descried in post activity that "Peter was very productive most of the time, Cameron did not participate much and distracted Peter" in comparison to the pre activity that he answered only "well".	They provided more specific explanation on what they did well or not in the post activity; e.g., "I feel like we got our ideas out well but staying on track after was tough" in comparison to "Everything" in pre activity. One student said he was the most interested person in the group.
LO	They collaborated on generating the ideas but their answers are quite general like: "I contributed ideas."	They used general terminologies such as gave ideas, came up with ideas, made ideas. Hard to distinguish their tasks and roles in pre and post activity.	This group had problem explaining what they did well in the group; overall they were not very concentrated according to my observation. Some statements such as "I think I have done well because there wasn't much to do" and "I didn't have enough ideas" and "Yes", represent lack of interest or contribution in the post activity.
IN	This group contributed well in pre and post activity: As one student explained in the pre activity: "I gave my ideas and built upon other's ideas to make them better". In post activity he said: "I gave my ideas and critiqued other's ideas". In general they found a good strategy to contribute and generate ideas.	This group lacks respect and intimacy in the team. They have some issues in collaboration as well. As one student explained in the post activity: "They gave other ideas and argued with and against me".	This group went off task sometimes in the pre activity, and improved their skills to stay on task in the post activity. They desired more accurate or relevant ideas, which was achievable through better collaboration in the group.

Table 6.10. Summary of findings from pre and post questions-Stratford Hall School

6.3.2. Findings from Observations and Interviews

In the Mulgrave School case, some students had problems with concentration and distractions when working in their groups during the first session. During the second session, students started to collaborate with their group members better but still some students had problems in the way they involved others with teamwork. For example, during activity two, one student (SE) shared his opinion on the work of another group with them instead of working with his own team. In general, several students tended to work individually within their groups and we had to encourage them to share their ideas with their group members. During the third session, students collaborated and were more involved with others in the activities in comparison to the previous sessions. It was evident, on average, they felt more comfortable with sharing their ideas, and found different ways to collaborate. During week 5, the students collaborated really well with each other in the bodystorming activity. For the final project, each team found a unique strategy to collaborate on the tasks. As an example, in group So, while two team members were working on brainstorming, discussing the solutions and writing them down, the third member was working on a visual representation of the proposed ideas. In another example, during the final presentation a team member from group Hu who did not contribute in explaining their work tried to help by pointing at the visuals, while other ones were presenting the ideas. Although the majority of the students collaborated well, several teams had one member who tended to dominate.

In the Stratford Hall case, certain issues appeared early during session two regarding leadership in the groups. As an example, in the ideation task, a student from DA group wrote down his ideas on a paper and later asked other team members if they liked the ideas. So the collaboration process meant asking about the other one's opinions on the provided concepts. Overall, two groups did well in terms of collaboration and discussion in their groups and documenting their ideas. In the other two groups, a certain member listed the ideas and asked other team members to acknowledge or accept the ideas. Hence, they sometimes had a leader and sometimes shared certain tasks more equally in their groups. In session three, students started to find better strategies to work in their teams. In the bodystorming activity, I observed a high level of engagement from students in their teams, and they enjoyed acting out and being

involved in the activity in general. The effectiveness of the activity can be due to the playful nature of it. In week seven, one group (DA) still had issues in collaboration because a particular team member was leaning heavily on other members. However, they worked on the research, discussion, and designing the poster well so they were very advanced in comparison to other teams. The fourth team member was sitting almost separately and did some research on his own. He was not involved in their discussions and group work. On the other hand, in terms of involvement in presentation, only group DA's team members collaborated well in presenting their ideas. In the other groups, either one or two students did not talk at all or they participated only to answer other students' questions afterwards.

According to the Mulgrave schoolteacher's statement, group work helped students to focus on tasks:

> I think was new to them or new for them directed group work, their challenges are they can't sort of focus themselves but when they are in the group which is something they all always seem to be seeking, that sort of settles them down and if they have focused tasks within that group seems to help.

One student mentioned the group work worked well for him: "I thought group work worked really well because usually in other courses we do not get to as a group it's all individual works so it's really cool to work in the group". Another student suggested: "Maybe not staying in the same group for the whole thing".

6.3.3. Summary

The following tables (6.11, 6.12) illustrate my findings about students' collaboration on different activities throughout the course and in pre and post activities. The findings indicate different levels of involvements from students, so that by the end of the course they all improved their collaborative skills to some degree.

Overall, students found different strategies for collaborating on activities throughout the course. Some groups had problems with equal participation of team members due to the fact that one team member tried to lead the group or make the final decisions. In those cases, team members decided to contribute on some level but not in

all design steps and activities. Another issue that students faced was how to collaborate equally and share the tasks to be fair for everyone. In some cases students shared a task, e.g., a drawing to be completed by all team members in which the final creation lacked certain quality. Size of the teams was another issue. Overall, teams with more than 3-4 team members faced some issues in collaboration and some team members were left idle. Finally, I believe that the variety of techniques and activities enabled all students to be engaged in teamwork at some point in the course. For example, I observed a student who did not involve well in brainstorming activity but he performed really well during bodystorming activity. In the following tables, I summarize the findings about the collaborations in each team separately according to the data gathered through the pre/post activity and observation.

Group	Have they improved their teamwork skills?
ME	They improved their perception and understanding of group work in general but the way they collaborated was questionable. They split their tasks equally, e.g., each person dedicated her/his time to complete a certain task. They discussed the ideas in-group before deciding on the final solution but a certain group member (Av) led the group and her ideas were dominant. Hence, although they performed well and did not face any serious issues in collaboration, not everyone's opinions were respected or employed equally in the team.
AS	In this group, certain group members did not collaborate actively due to the size of the team. They shared their ideas in discussion but in creation and hands-on activities, almost three team members were idle.
JU	This group improved their percipience of teamwork in post activity and over the course. They used certain terminology as evidence to show/support their awareness about the teamwork. They also enhanced their interests in teamwork by the end of the course and in the post activity.
HE	This group divided their tasks equally, so for example they left certain tasks to be completed by other team members. They also increased their understanding of group work in general, and could improve certain skills such as time management and concentration over the course and in the post activity.
DU	This group shared their tasks in post activity equally, but they lacked percipience of teamwork in general. There were certain sentences from students that showed lack of respect for everyone's opinion and lack of intimacy among team members in the post activity. However, they did not have any particular issues in sharing and completing their tasks in the course.
WO	This group improved their percipience of teamwork to some degree but they did not share the tasks equally in team. They could not provide any specific answers on their certain role/task in the team. They had better perspective and positive responses in pre-activity. Hence in general although they did not mention the potential problem they faced in sharing the tasks, they could not provide acceptable evidence on their successful collaboration.
SO	They showed their cognitive improvements in teamwork, and improved certain skills in post activity such as concentration on tasks and time management. Overall, they did well in teamwork, but mainly in exchanging ideas and providing reflection on the ideas. One team member was idle when it came to creation, writing, etc.

Table 6.11. Findings on students' collaboration in Mulgrave School

Group	Have they improved their teamwork skills?
DA	This group had problems in collaboration because one person (TR) tended to lead the group. Although they had a good understanding of group work, general answers provided in the post activity indicated a lack of equal sharing and participating in the group activities. Overall, they have completed all the tasks during the course successfully.
LE	This group increased/showed their interest and provided more detailed answers in the post activity. The detailed answers indicate equal sharing of the tasks. However, there is one group member who was idle and could not provide reasonable answers about his role in the group.
LO	This group provided non-detailed and general responses in pre and post activity. It is hard to distinguish their tasks and roles in pre and post activity. In the post activity, they showed lack of interest in what they were doing and did not provide strong opinions or evidence about their understanding of group work. However, throughout the course they showed some level of improvements in teamwork.
IN	This group collaborated reasonably well in ideation and reflection but they argued and missed respect and intimacy in the group. They improved their skills to be on task in the post activity, but they could not come up with the best ideas that they desired, due to serious issues they had in discussing ideas in a positive and productive manner. This issue was not obvious in my observations.

Table 6.12. Findings on students' collaboration in Stratford Hall School

6.4. Creativity Confidence Skills

In this sub section, I provide the findings from the pre and post course questionnaires, which clarify whether students improved their creative confidences after completing the course. According to Royalty et al. (2014), teaching design thinking and creative problem solving is aimed at enhancing student's creative confidence. The questionnaire is a self-assessment tool to capture creative self-efficacy of students, and was developed based on the study done by Royalty et al. (2014). Please refer to section 4.3.5 for more description. In the following section I provide the statistical results from the questionnaires for students at Mulgrave and Stratford Hall secondary schools.

6.4.1. Statistical Results

The analysis of pre and post course questionnaire answers was completed separately for each group of students. The pre and post questionnaire was developed based on five-point scale answers: 1) not at all confident, 2) a little confident, 3) moderately confident, 4) very confident, 5) completely confident (please refer to section 4.3.5 for more information). The graphs in Figure 6.1 and 6.2 show the average scores of answers for question 1 to 11, from Mulgrave School and Stratford Hall students respectively.

The results of the study indicate various average ratings for each question, for a total number of N=25 participants from Mulgrave school and N=10 participants from Stratford Hall school. Due to the absence of several Stratford students at the beginning of the course, the numbers of answers are fewer than the actual number of students who participated in the course (14 students). To analyse the data, I used JMP statistical software based on two sample T-tests for independent samples.

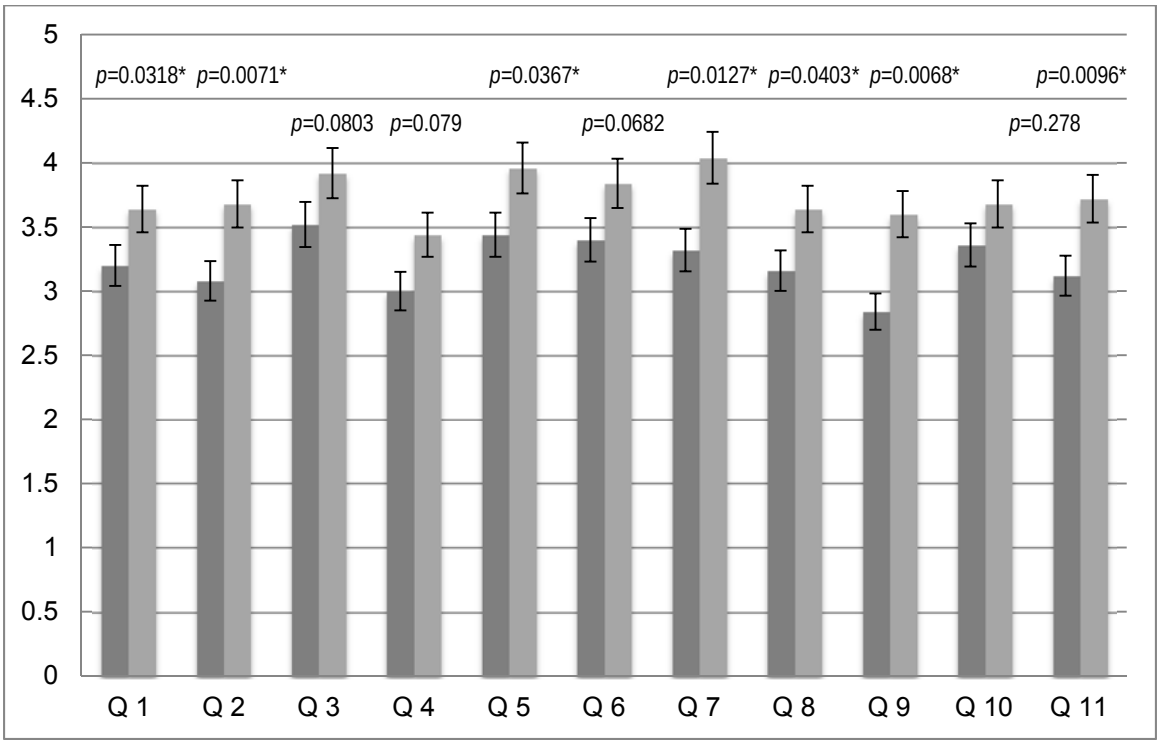

Figure 6.1. Creative confidence result from Mulgrave students

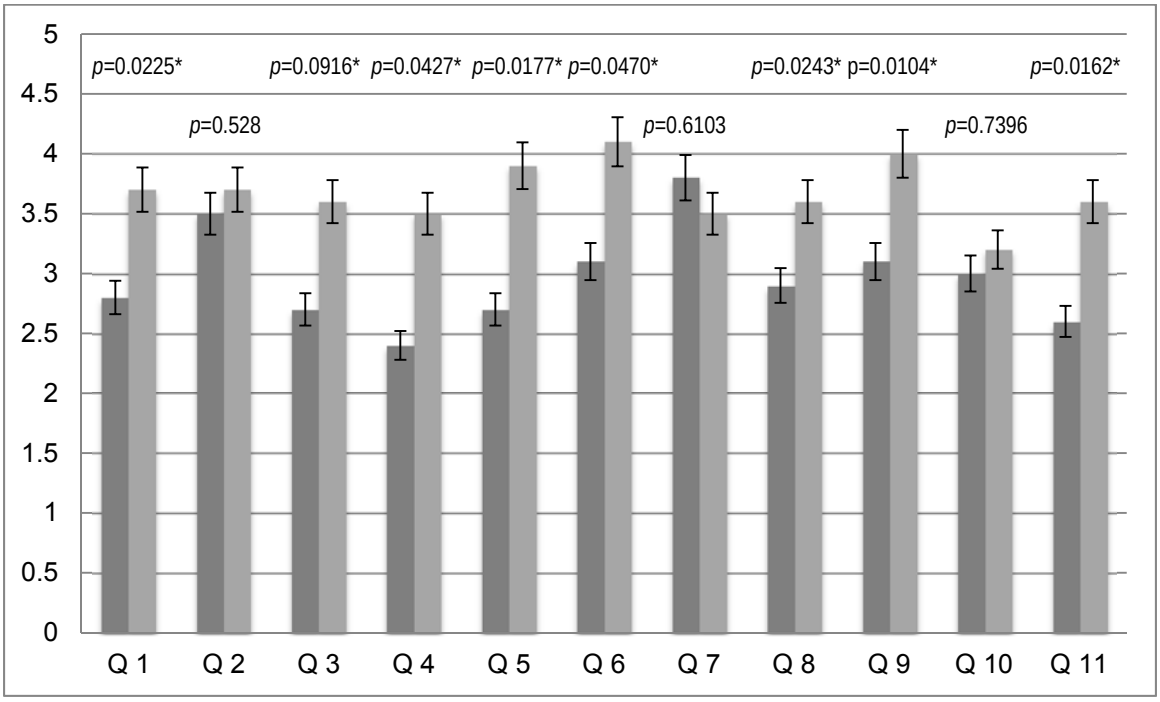

Figure 6.2. Creative confidence result from Stratford Hall students

Overall, the answers from Mulgrave students, the between-subject contrast for questions 1,2,5,7, 8, 9, and 11 reached the specified significant level (p= .0318; p= .0071; p= .0367; p= .0127; p= .00403; p= .0068; and p= .0096), but the answers to questions 3, 4, 6, and 10 did not reach a significant level (p= .0803; p= .079; p= .0682; and p= .0278). In answers from Stratford Hall students, the between-subject contrast for questions 1, 3, 4, 5, 6, 8, 9, and 11 reached the specified significant level (p= .0225; p= .0916; p= .0427; p= .0177; p= .0470; p= .0243; p= .0104; p= .0162), but the answers provided for questions 2, 7, and 10 did not reach a significant level (p= .528; p= .6103; p= .7396).

More specifically, as an example, in Mulgrave students' answers, the result of the T-test for question one (five-point scale) after completing the course (M= *3.64, SD= .75*) scored significantly higher than the pre course evaluation (*M=3.2, SD= 0.645), t* (24)=.0318, p< .01. Also, the Stratford Hall students' answers for question 1 (five-point scale), scored significantly higher in post course evaluation (*M= 3.70, SD= .674*) in comparison to the pre course evaluation (*M=2.80, SD= .918), t* (9)= .0225, p< .01. The following table provides the statistical results for the pre and post questionnaire for each

school separately. The significant results of the analysis in numbers of questions illustrate students' improvements in certain skills. However, there are 3-4 questions in each school that did not meet significance level according to the test (Table 6.13, 6.14). The T-test results will be discussed and clarified in chapter 8, to reflect on the answers provided by students.

Mulgrave answers	Pre question		Post question		p-value
	Mean	Std	Mean	Std	
Question 1	3.2	0.645	3.64	0.757	0.0318*
Question 2	3.08	0.759	3.68	0.748	0.0071*
Question 3	3.52	0.871	3.92	0.702	0.0803
Question 4	3	0.81	3.44	0.91	0.079
Question 5	3.44	0.76	3.96	0.93	0.0367*
Question 6	3.40	0.166	3.84	0.166	0.0682
Question 7	3.32	0.196	4.04	0.196	0.0127*
Question 8	3.16	0.80	3.64	0.81	0.0403*
Question 9	2.84	0.19	3.60	0.19	0.0068*
Question 10	3.36	1.11	3.68	0.945	0.278
Question 11	3.12	0.832	3.72	0.737	0.0096*

Table 6.13. T-test results for Mulgrave students

Stratford Hall answers	Pre question		Post question		p -value
	Mean	Std	Mean	Std	
Question 1	2.80	0.918	3.70	0.674	0.0225*
Question 2	3.50	0.707	3.70	0.674	0.528
Question 3	2.70	0.263	3.60	0.263	0.0916*
Question 4	2.40	0.40	3.50	0.41	0.0427*
Question 5	2.70	0.268	3.90	0.324	0.0177*
Question 6	3.10	0.331	4.10	0.331	0.0470*
Question 7	3.80	1.229	3.50	1.354	0.6103
Question 8	2.90	0.201	3.60	0.201	0.0243*
Question 9	3.100	0.567	4.00	0.816	0.0104*
Question 10	3.00	0.421	3.20	0.416	0.7396
Question 11	2.60	0.966	3.60	0.699	0.0162*

Table 6.14. T-test results for Stratford Hall students

6.5. Students' Perception of Design Thinking

In this section I illustrate the findings about students' overall understanding of design thinking. In week 5, for the sketchbook activity, we asked students to draw their understanding of the problem solving process: 'Given what we have covered so far, how might you go about solving a big design problem? Sketch out your process.' Students could identify the design thinking process and steps clearly and provided evidence that proved their level of understanding. Here is some of the feedback from the instructor on the students' sketchbook assignments:

> People have identified whole variety of different parts of the design process, and to the very levels of specificity: to define the problem, who the client is, prototyping and production. Similarly we have got things that come to play that are important to do in team: cooperation, and time management (important for your project-time management thing involve).

> Sketch out ideas visually, sort of combo of notes and visuals: because it gives you more to talk about. Without even reading the text we start to guess what this is about which is good to see.

> An example of way too many arrows: confusing but honestly this is how the design process often works out!

In addition to the sketchbook assignment, students had the chance to draw their understanding of design thinking at home. In session 6, we gave an assignment to students and asked them to complete it at home. In this assignment we asked student to 'draw a visual representation of design-thinking as you understand it'. After I collected the assignments from 24 students, I coded students' drawing following visual analysis technique (please refer to section 4.4.2 for more information regarding the coding). I summarize the findings in the following section:

- Students used specific design vocabulary and terminology such as brainstorming and iteration. Hence, they showed a level of understanding about the design thinking process. However, there were some students who used odd wording for certain techniques or steps (e.g., "notes activity" instead of "brainstorming").
- Students created an understandable representation of the design process through both visual drawings and annotations. A couple of sketches lacked annotation so their opinion and meanings behind the visual drawings were unclear.

- Students illustrated the iterations in design thinking processes through connecting different steps by arrows. However some students illustrated a linear process in connecting design thinking steps.
- Students showed a lack of understanding about research activities in their drawings. They used the word ‘research’ as a general term to understand people’s opinions or to research on the computer.
- Students illustrated similar ‘design process’ in their drawings and the ‘thought process’ they followed in their final projects. As an example, student Em mentioned in the interview that he does not like to get feedback from people on his work. Hence, his visual drawing and final project lacked a reflection step in the design process and was only focused on creative ideations and finding solutions in ways that were not connected.
- Some of the drawings illustrated quite a disconnected understanding of human-centered and used some steps in a contrary fashion. For example, for the first step they illustrated “defining the problem” and then “research on the problem” or “user”. Hence, general perception of the design process was quite different in some cases.
- Some drawings missed certain steps in the design process or the process steps lacked appropriate connections.
- A couple of students did not quite understand the reason behind defining a problem in the design thinking process. For example they mentioned: “I am bored what can I design?” or “we need ideas”.
- One student illustrated the design process by providing an example.

Although students displayed quite diverse understandings of the design process, all of them had an acceptable level of comprehension. Also, during the course and in the final project, students brought evidence that represented their understanding of design process in a variety of ways. They explained their design process and steps that they proceed through clearly (please refer to section 5.2 for more information).

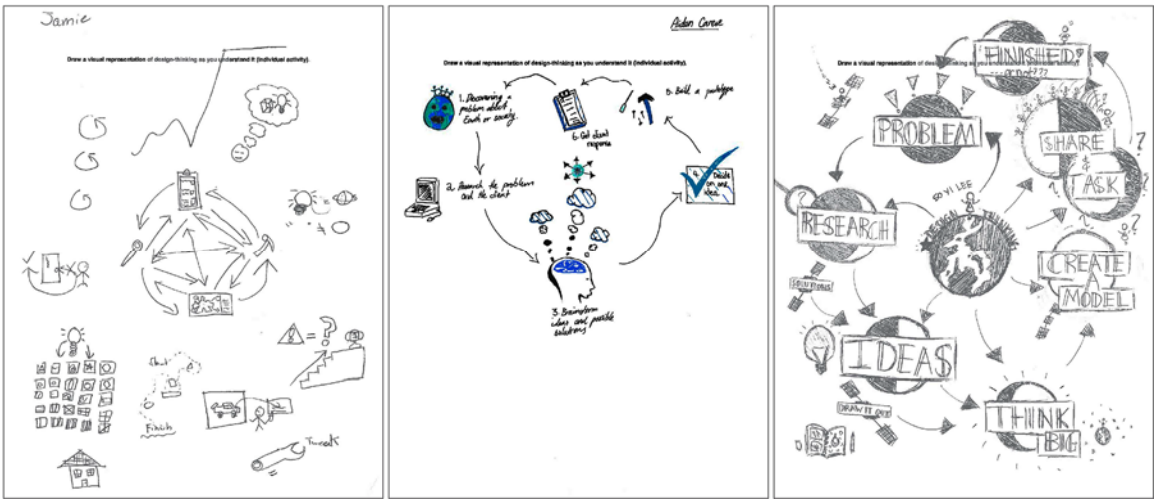

Figure 6.3. The visual representations of design thinking process by students

6.5.1. Summary of Findings

The findings from students' sketches showed different levels of understanding of the design thinking process. Overall, students used appropriate terminology, illustrated the design steps well and connected the steps appropriately through drawings and annotations. However, they showed quite different levels of comprehension by shifting the steps around or providing greater or fewer numbers of steps in a design process. Also, certain tasks or techniques were excluded intentionally in some cases due to the lack of understanding or acceptance of the task as an important step that need to be completed in a design thinking process.

Chapter 7.

Findings About Effective Course Materials

In this chapter I give an overview of the findings that answered the third research question: “Which interaction design thinking techniques or practices worked well in the course curriculum?” The findings were established through interview sessions with students and teachers, as well as observation of how students performed in every activity during the course. I will first provide an overview of the common findings for each activity, and later will summarize the findings according to three main categories: heuristic process, real-world applications, and characterized consequences.

7.1. Interaction Design Thinking Curriculum Material

7.1.1. Sketchbook Activity

The sketchbook activity worked better at Mulgrave than at Stratford Hall. Teachers and students suggested completing the sketchbook activities in-class rather than at home (Figure 7.1). Completing the activity in-class could help students organize their assignments better, and have the ideation and creation going on at the same time. Having more formal discussions early on around ‘what sketching is’ could be helpful for students to take the activity more seriously.

Students provided comments about having this activity as part of their in-class homework: “I think sketching should be during the class you know so you have some ideas right there and you build them at the time… the sketch can be done later though it’s disconnected with what you are doing.” Several students mentioned they liked the activity and one of them explained that she found the questions broad: “Sometimes the questions for sketches was a little bit broad, so we actually had to think about it, it was a

good thing but hard to finish"; "I enjoyed our little note pads, little small homework sketches still we had to do. I thought that worked really well", and "It was really cool having to draw the ideas into the notebook, I just didn't think I have to bring it because I really have bad organization." According to the course instructor, the sketching did not work quite as well for Stratford Hall students:

> Things like sketching didn't work out well for this group they just forgot about it, they didn't bring it into the class, having them sketching in the class, working on sketching and developing that will be little bit further specially with this group would have been good.

He also explained that introducing the assignment clearly and having more formal discussions around the activity could be beneficial:

> There was varying level of sort of understanding what the sketching was and would be nice to have a bit more formal discussion early about what sketching was…

> I'd also be curious about trying to integrate more about sketching, and just getting sketching done as a practice, because we had them do the sketchbook homework but again we never really formally… I think in the first week we had a five-minute discussion what sketching is and that was about it. By the virtue of time that was not enough time again. So having them do a nice sketching activity where they get the sense of ok why we sketch and this is sort of how we go about sketching if we are not a good drawer or so on so forth.

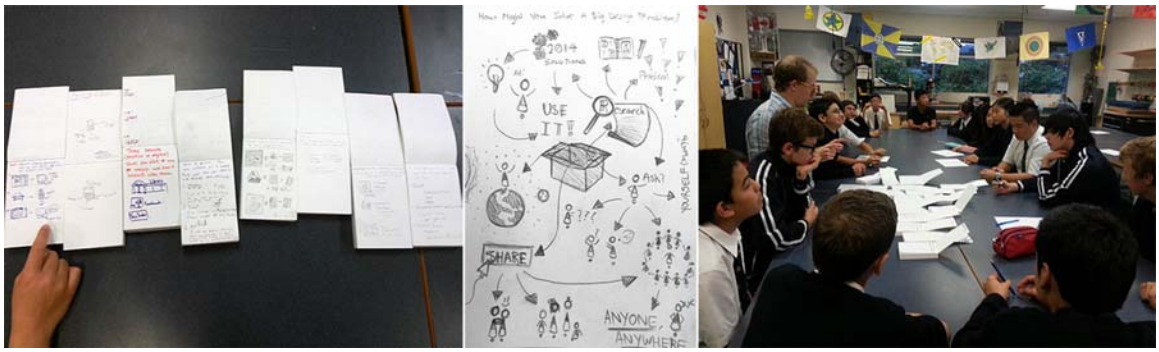

Figure 7.1. Recapping sketches at the beginning of each session

All in all, students found the sketchbook questions broad, they sometimes forgot to bring their sketchbooks, and they did not quite understand the main purposes behind doing the sketchbook activity. Hence, having narrower questions, completing the activity in class, and introducing the activity in a more formal way could be beneficial.

7.1.2. Observation Activity

Observation activity was successful in engaging students and the findings represent that students paid attention to the details when observing the space, and provided examples of what they had not noticed before. One reason might be the fact that students enjoyed going for a trip: as one student stated: “I actually liked the little field trip to the Foe, because I got to see like more fittings because I was like be in the trips.” Another student explained his experience as follows:

> You guys taught us to look at things we may not have noticed before like we went to Foe and marked down things we never notice, but when we take a close look at them we see that they are always there…

In addition to the students, teachers acknowledged the success of the activity, and explained their opinion about the activity as follow:

> I remember the observation task actually worked out surprisingly well for me, I was kind of concerned if they were just chatty, but they spent a serious time looking at the space and actually came up with good results.

> I think the observation task worked really well, I remember them actually getting really super engaged to that one, and actually doing a really good job with that one, which was really surprising to me given they’re difficulty focusing otherwise so we take them out, and we walk them down and was like ok find the stuff that you don’t really pay attention to and they did actually; they bright which was pleasantly surprising about learning to carefully look at thing that haven't noticed before.

All in all, based on the above findings and my own observation, the activity was very successful. The following images show students who were involved in the activity to observe their school (Figure 7.2).

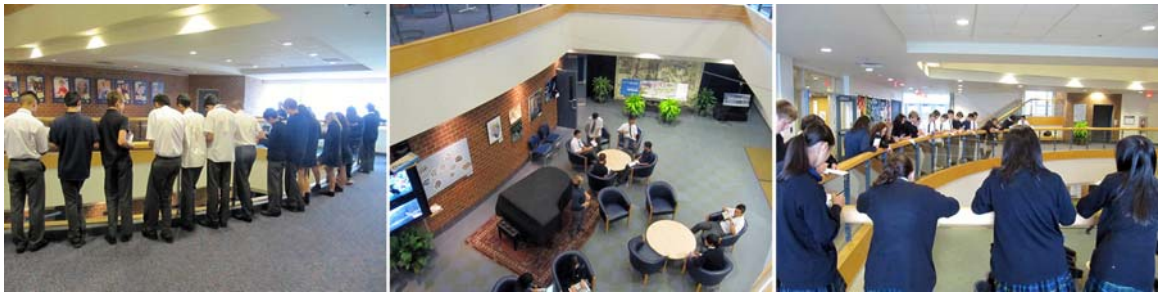

Figure 7.2. Student took part in the observation activity and later shared their findings with a larger group

7.1.3. Practicing Designer

This activity was very beneficial for students to understand the design process and steps that a designer follows, and in fact how practical and applicable the course materials can be for them. The guest designer talked about her/his experiences as a designer, and introduced one or two interaction design projects that s/he has completed before (Figure 7.3). Several students from both schools explained their experience of having a guest speaker in the course as follow: “you can see how they use it in real life situation”; “I think that having the guest speaker was pretty cool because it kind of shows that you know what we are learning here can actually be put into like a job and I thought that was really cool”; “once the guest came in it was good to see the products that she actually designed herself to like make a connection between what you can actually do when you are looking at the person doing that”; “I really like that she shared how it was liked to be like a designer”, and “I think like a lot of what we have sort of discussing was sort of theoretical but then when he came like here is the pre…application but when you are going to use this.”

Figure 7.3. Guest speakers described their design experiences in industry as product designers

7.1.4. Brainstorming Activity

The brainstorming activity was beneficial for students to see how to categorize their ideas and narrow them down according to certain criteria (Figure 7.4). Students explored their ideas through different forms. I found using different forms in brainstorming quite beneficial for them, which enabled them to switch between drawings or writings, whichever they felt more comfortable to work with. One student mentioned she liked and was impressed by brainstorming activities: “Like how we did brainstorming I guess I like in a short amount of time and present it to the class”. Overall, leaving students to explore their ideas freely seemed reasonable for this age group.

Figure 7.4. Students involved in brainstorming activity

7.1.5. Interview Activity

Interviewing helped with finding real problems based on everyday life experiences of students. We asked them to interview for potential problems, and take

notes on two particular things: 1) try to pick a situation and problem; 2) what was the actual cause of the problem; and 3) did they resolve the problem?

In the interview activity, many personal problems came out such as “I get frustrated with my mom!” or another student mentioned: “I never get frustrated! So I have no answer for the questions so what should I do now?” We had to go around and suggest they think about environmental issues, not necessary problems with persons. The instructor explained his idea about the interview activity as follows:

> Interviewing I felt a little out of place I think mostly because the way we ended up using, it didn’t quite make sense, I think otherwise the material wise or technique wise was ok.

Overall, the interview activity was beneficial for them to get familiar with research techniques in the human-centred process of design thinking. However, more clarification and adjusting of the interview questions could be beneficial.

7.1.6. Bodystorming Activity

This activity was successful. Bodystorming is a playful activity and seemed very age appropriate. Students were excited, they engaged deeply in the activity, and they acted out well (Figure 7.5). Also the activity “seems pretty simple!” as one student explained it to me. Students could come up with appropriate solutions for each problem-based scenario we assigned to them (Please refer to appendix A, Bodystorming, for more information). However, this activity required careful supervision of students. While rehearsing their actions and due to the nature of the activity, students got excited and started to move around the class, use stuff they found in the room, and sometime played in a way that brought safety concerns. Also, students asked us if they could use the space outside the classroom, so having a bigger space would be beneficial for students when rehearsing and playing. The Mulgrave schoolteacher confirmed the success of the activity and mentioned: “it works well, and I am thinking of how to use it in future courses.”

While the majority of student enjoyed this activity, one student (SO) commented that: “the time travel thinking, different times with different scenarios it was kind of difficult to think about right away”.

Figure 7.5. Student role-playing in Bodystorming activity

7.1.7. Field Trip

The field trip to the School of Interactive Arts and Technology (SIAT) at Simon Fraser University was successful according to Stratford Hall teacher feedback. SIAT is an interdisciplinary research-focused school where technologies, artists, designers and theorists collaborate in innovative research and study. The undergraduate program includes design studios where students collaboratively work with interactive applications or study human experiences of technology to generate creative design theories and approaches.

Stratford Hall students had the chance to talk to undergraduate students at SIAT, visited several places such as the library, fabrication lab, sound and theatre rooms, and were involved in a problem-solving workshop held by SIAT staff and a faculty member (Figure 7.6). However, we could not have the field trip for Mulgrave students due to several problems (e.g., distance from the school) so the findings of this section are limited to the Stratford Hall visit. As the school teachers mentioned:

> Overall I thought it was quite well done I love the field trip as well. I think that was well done and two of them said to me after I want apply here when I graduating from high school. Ya! so two of the were highly affected, especially for those who wanna do more hands-on stuff that was really good because it opened their eyes to the possibilities of other educational opportunities right? and careers, which is good.

I think going to SIAT was really excellent, couple of students were asked me about admission requirements and everything, so a couple of them changed their mind about possible career path so that was very important, we should definitely do that more often.

Figure 7.6. Students visited SIAT and participated in a problem-solving workshop

7.1.8. Reflections

Reflections and discussions were encouraged throughout the course, which enabled students to benefit from the variety of ideas and become critical thinkers. The reflection and discussion activities were encouraged both in teaching and presentations. While teaching the design concepts, the instructor encouraged discussion and active learning of student by asking several questions. As an example, the following dialogue illustrates discussions around the concept of 'mobile versus desktop devices':

Andrew: How many of you use your desktop machine for homework?

Students1: Depend on what type of homework we are looking at, like getting type of research, for example if we have a research program like…

Andrew: so for looking stuff up is relatively easy on the phones. How many of you use YouTube on your phone interchangeably?

Student: I can't even get Internet on my mobile phone…

Student 2: For using Word can we use it on mobile device?

Student 1: No.

Student 2: why not?

Student 1: Unless we have a Surface…

Student 2: or iPad?

Student 1: iPad doesn't have Word…

Andrew: Let step beyond Word but some sort of text editing… would you write your paper on mobile device?

Student 1: no, it is hard to type…

Andrew: Ok, so you've got this affordance of we are expecting there would be a keyboard, so typing in the keyboard will be easier to type, so when we are talking about long type, using the desktop machine hens to be a preference. Anything else you use for mobile device versus mobile?

Student 2: video editing

Student 1: for video editing you definitely need desktop or laptop…

In addition, students had the chance to provide feedback on one another's works during the presentation time. Throughout the course, they learned how to provide constructive feedback and asked reasonable questions when discussing a proposed solution. While I found reflection from students beneficial for them to grow their critical thinking, they started to lose their respectful manners sometimes. Here is a comment from the schoolteacher in the final session asking students to behave more professionally:

> We do appreciate that you are passionate on the side however this is a respectful place of sharing ideas so if you have question or comments keep them in respectful tone and not in an argumentative one because it really doesn't help to argue.

Hence, leaving students to discuss one another's ideas freely required careful supervision and interruption from teachers when needed. Finally, students sometimes discussed a certain project to show their intellectual superiority as the course instructor stated:

> Student TR asked questions to demonstrate intellectual superiority, other groups felt like treating by him… pulling out problems that obviously have no answer due to the limited time for completing the project… asking question to pull apart the proposed solution.

7.2. Summary

Here, I provide the summary of the qualities and characteristics of design thinking techniques and activities that are considered suitable, appropriate or successful according to the students' and teachers' feedback. Based on the above findings, the

selected techniques included the following characteristics: *heuristic processes, real-world applications,* and *characterized consequences.* According to my observation and interview sessions with student and teachers, bodystorming, observation, and field trip were found to be successful due to their heuristic and playful natures to fully engage students. In fact, in those activities I did not observe any particular issue in students' engagement or lack of concentration and the majority of them were satisfied for being involved in the activity.

Furthermore, students preferred certain activities that clearly illustrate the practical implementation of the techniques or activities that they were learning during the course. For example, students were pleased to have the guest speaker, observed the environment, or went for the SIAT tour, due to the fact that they found these activities applicable in real-world situations (Figure 7.7). These activities make their learning experiences even more meaningful as they could connect their knowledge and experiences gained in the classroom into the world at large.

Finally, students learned when they had a reason to learn; in other words when they could clearly see the learning outcomes of an activity. As an example, students did not perform well in the sketchbook activity because they were not quite sure about the main reasons and outcomes behind the assignments. On the contrary, in the observation activity students knew the outcomes and expectations clearly before attending the activity (find missing parts of the space descriptions). Hence, they were more determined and performed much better during this activity.

Figure 7.7. Students were satisfied when attending the field trip and observation activity, and having a guest speaker in the course.

Chapter 8.

Discussion

In the previous three chapters, I described the various dimensions of the course development, implementation, and evaluation according to the course settings, strategies, and outcomes. In this chapter I discuss how these dimensions fit within a design education context, specifically outlining the categories and subcategories that answer the main research question of this study: 'How to best design and implement a secondary school level course on interaction design thinking'. I follow this with a description of how these dimensions interrelate and influence each other, in the form of qualitative description. The second half of this chapter includes a discussion of the recommendations for design educators on implementation of an interaction design thinking course in secondary level education as well as a description of limitations of the study.

8.1. An Overview of Findings about the Course Benefit

The real benefits of design thinking processes or activities for students depend on how educators employ them in their curricula. In the following section I provide the summary of findings for the first research question that investigated the benefit of interaction design thinking for secondary school students. The main three categories that I found substantial include: interaction design thinking as open exploration, interaction design thinking as connected activities, and interaction design thinking in real-life challenges. The findings explain the benefit that students gained in the course and outside the course when applying their skills to other contexts voluntarily. The following table summarizes the benefits that students gained throughout the course:

Benefit of the IDT	Subcategories	Description	Results
IDT as open exploration	Visual representations	This category speaks to the coordinated combination of verbal and visual instruction in completing in-course activities.	Helped students to remember things. Gave them variety to explore more ideas. Enabled them to clearly see the ideas.
	Interactive teaching style	This category represents show and tell aspects of the course beneficial for students in a variety of ways.	Resolved time management issues. Resolved distractions issues. Provided clear instructions.
	Tactile activities	This category explains the importance of hands-on activities as a different form of learning in the course	Do the things instead of being told about them. Learned the skills practically. Engaged disengaged learners. Present ideas in different format.
	Inquiry-based activities	This category illustrates having both problem setting and problem solving activities in the course.	Identified the right problems. Had option to choose the direction. Creative thinking.
	Open-ended nature of activities	This category emphasizes the importance of open-ended activities in the course	Gave more freedom to choose desirable topics. Encouraged sense of possession and ownership in students. Encouraged critical thinking of students.
IDT as connected activities	Teaching DT process thoroughly	This category explains the importance of following the whole design thinking process and steps in a project properly.	Students made thoughtful decisions. Encouraged divergent and convergent thinking.
	Diverse materials	This category emphasizes the importance of having a variety of activities in the course.	Engaged student with different learning styles. Enabled students to select appropriate techniques.
	Small tasks and projects	This category emphasizes the importance of having small projects in the course.	Helped to be on task and be focused.
IDT in real-life challenges	DT in everyday life situations	This category illustrates the application of design thinking in everyday life situation of students	Solved simple to complex issues in everyday life situations. Transferred the knowledge gained in the course to everyday life situations.
	DT in other courses	This category represents an extensive application of DT in other courses voluntarily	Solved simple to complex issues in other courses. Transferred the knowledge gained from design to other courses. Critical thinking.

Table 8.1. Benefits of the Interaction design thinking course for students

8.1.1. IDT Benefits Inside the Classroom

There are certain skills and knowledge that students gained in the course. These skills are illustrated in the above table under IDT as open exploration and IDT as connected activities. In the first category, the visual representation helped students to remember things, to explore more ideas, and to literally see their ideas. The interactive teaching style enabled students to resolve distraction issues by providing clear instructions on how to complete an activity. Hands-on activities engaged certain students better, helped them to learn certain practical skills, and enabled them to present their ideas in different formats. The inquiry-based activities enabled students to identify right problems, and to choose their own direction in their project, which kept them motivated and responsible to complete their projects. According to a study by Runco and Chand (1995), motivation was found to be an important aspect of creative thinking, which can be facilitated through problem-setting activities. While I acknowledge the importance of problem-setting activities, I also found open-ended activities beneficial and motivational in the creative problem solving process. According to the findings, the open-ended nature of activities gave more freedom to students to choose their desirable topics, and as a result encouraged a sense of ownership of their projects. It also engaged students critical thinking throughout the course because students had to made correct decisions in every step of the project.

In the second category, the findings revealed the importance of connected activities in the course. Teaching the whole design process enabled students to effectively coordinate their thinking and actions, in order to improve their understanding of the problem areas and to propose a workable solution to the problem. Hence, according to this category, spending an adequate amount of time in design process and activities before rushing into a solution was found to be essential, which enabled students to make thoughtful decisions before rushing to a solution. Here, I refer back to Schön's (1983) argument about the ignorance of problem setting in problem-solving activity, which can lead to a crisis of confidence in professional knowledge and expertise when dealing with real-world practice situations. He valued the insight of direct involvement with the situation, and introduced the important notion of "reflection" into the centre of professional practices and learning processes in general. According to his idea,

through “reflection-in-action” or “our knowledge is in our action” (Schön, 1983, p. 49) we can gain verifiable insights into our thought processes and, as a result, in our professional practices. According to Schön, a reflective practitioner “carries out an experiment, which serves to generate both a new understanding of the phenomenon and a change in the situation” (Schön, 1983, p. 68).

Furthermore, according to Karnes et al. (1961), promoting both convergent and divergent thinking of students is essential in stimulating their creative thinking. In this study I found that teaching the whole design process (comprising both problem-solving and problem-setting approaches) encouraged creative thinking of students. This phenomenon emerged in students’ final projects, when thoroughly learning about the design thinking process and steps. As I explained in section 6.1, in final projects, the majority of students did well in proposing an acceptable solution. According to my findings, certain groups that followed the design processes more precisely and employed design techniques were more successful in providing more feasible or acceptable solutions. The findings revealed that students who did not follow the design process thoroughly, could not propose an acceptable solution to the problem they found, although in some cases their ideas were found to be interesting or novel by the larger group. These groups usually received some negative comments and questions from the larger group to clarify their proposed idea.

In addition, the variety of materials engaged students with different learning styles in the course activities, and enabled them to select appropriate techniques and materials for their projects. These varieties enabled all students with different skills and interests to become involved in some activities at some point. As an example, there was a student (SO) who performed well in sketching, making things and in general hands-on activities; however she hadn’t shown much interest when it came to the bodystorming activity. In contrast, a student (SE) who enjoyed role-playing in the bodystorming activity didn’t show much interest in hands-on creation or sketching activities. These two students were both active and were interested in the course, however it seemed each of them was attracted to certain activities, and as a result needed to be involved in those in order to perform better. The application of learning styles of secondary students was studied and discussed before by Keefe (1987) through consideration of views of style,

personalized education, significance of the style concept, school-wide implementation, and classroom applications (Keefe, 1987). Although the application of different learning styles was not the primary goal of this study, the findings revealed that having variety in course materials provides options to students with different learning capacities to be involved and engaged in classroom activities. The suggestion here is to provide a range of variation to ensure that even the most non-engaged student would find her/his desirable activity or assignment.

Applying appropriate strategies and materials to keep students on task is beneficial in any course lesson, but I found them fundamental when teaching to secondary level students. Having smaller projects and activities helped students to be focused, engaged in activities, and interested in doing things. I found this strategy quite essential for this age group due to the fact that they lose their concentration easily in longer classes. Distraction at this age became an even stronger issue when considering access to technological devices. Although students weren't allowed to use any digital devices during the course, I observed them losing concentration and interest when an activity became longer. Hence, dividing a class into shorter segments by having smaller tasks can be beneficial to keeping students interested and engaged in activities.

8.1.2. IDT Benefits Outside of the Classroom

The findings from the last category (IDT in real-life challenges) revealed that the interaction design thinking course offered distinctive benefits for students to transfer their gained knowledge from 'familiar' to 'unfamiliar' contexts: from the course to everyday life situations and other non-design courses. The course enabled students to enhance their meta-cognitive skills and design thinking knowledge and employ those in solving unknown problems. I found that students tended to apply and transfer design thinking techniques and strategies in everyday life situations and other courses *voluntarily* -- important evidence that indicates whether students learned the skills and are able to use them in future problem-solving situations.

According to Löwgren and Stolterman (2004), design thinkers can make much more deliberate and thoughtful decisions to solve complex design problems. I found this

characteristic clearly enhanced in students' decision-making process. In their everyday life situations and their other courses, students applied the design thinking process and strategies extensively to solve easy to complex issues. Furthermore, students enhanced their awareness of their own knowledge, and transferred the knowledge gained in the course to new and unfamiliar situations. These activities required critically thinking to analyse and solve simple to complex problem situations.

In addition, students were able to choose their own topics to solve real life-centred matters. Hence, they learned that the process of solving a problem could be applicable to a wide range of subject areas. Having such experience motivated students to engage and learn even more in the course, because they had a forward-looking expectation that the knowledge gained in the course could be applicable to their life outside the school, and enable them to make deliberate decisions in any complex situations that they might encounter in everyday life situations. As mentioned earlier, the course curriculum was product and environmental design-oriented, and the overall goal of having different design oriented subject areas was to teach students that design thinking strategies can be applicable to solve a variety of types of problems. Having such a curriculum was beneficial and fundamental to examine students' gained knowledge and abilities when implementing design thinking in solving everyday life problems.

8.2. An Overview of Findings about Design Thinking Skills

According to the findings in the last chapter, students enhanced their design thinking skills during this course. In this section, I provide an overview of the design thinking skills of students that I evaluated during the course, and discuss the potential reasons for the failure or success of each. There were four main skills that I aimed to evaluate: problem solving, human-centeredness, collaboration, and creative confidence. These skills are considered substantial characteristics of a design thinker according to several studies (Owen, 2007; Royalty et al., 2014) so I focused on evaluating these skills in particular. However, I found that other students' skills were enhanced including critical thinking and thoughtfulness on design decisions, which I explain further in this section.

According to my findings, students enhanced their problem-solving skills and processes in the course. However, certain groups which followed the design thinking steps and process more seriously were more successful in providing *feasible and acceptable* design solutions. Here, I would like to refer back to my findings in Chapter 5.2 that suggested following design thinking process and steps properly as connected activities. As the instructor of the course mentioned (please refer to section 5.2.1), students did not always '*capture*' their process due to the fact that we never emphasised the importance of documenting the process enough. This might be an issue for certain groups which provided more general and not quite workable solutions (team AS and JU in particular). While we guided them through the design thinking steps and process, documenting those steps and thinking processes was not emphasised enough in this course. As a result we observed students who discussed in their group and shared their ideas but did not capture most of it. The lack of involving in gathering and documenting the ideas could be an issue for those teams which introduced non-workable solutions (team AS and JU in particular).

The findings about human-centeredness skills revealed some level of improvement in students' perception of human-centred design as I explained in section 6.2. Students clearly showed that their focus shifted towards people, people's interactions, and people's activities. Throughout the course and in the final project, they showed some level of understanding of empathy and human-centeredness when designing for people. However, according to the findings from students' sketches in section 6.5, students showed different levels of understanding of the design thinking process and human-centeredness activities by shifting the steps around or providing the research and empathy activity after finding the problems. In those cases, the problems were introduced according to their own preferences rather than observing real issues in people's everyday life situations.

Group LE highly considered human-centeredness in the problem-setting process. They also provided an innovative and detailed solution, dealing with sustainable design, which was quite advanced considering their age and knowledge. One group member explained environmental issues in their presentation

> Because many farms these days admitted to using quite a lot of extra fertilizers and waters are the problems as well as pesticides and the problem is it goes very often to the environment and causes alterations and hurt other species.

Another group (DA) also emphasized human centeredness in the problem-setting process. They came up with the concept of an application which evaluates peoples' learning styles and proposes best tips on how to learn a topic. When discussing the idea with the larger group, they also could provide reasonable solutions for the decision they made, so they showed their reflective thinking in their decision-making process.

These two groups were always on task, asked questions during the class, participated well in activities, and most importantly they did not refer to the computer when searching for problems to work on. Instead, they discussed heavily the issues they encountered in everyday life situations, listed them and narrowed down the ideas to pick an appropriate problem. In contrast, there were two teams (LO and IN), which worked heavily on the computer, and seemed not as focused. They generally had trouble focusing on what the task in hand was, and tried to find a potential problem to work on through researching the web. As I explained earlier in section 3.5, we developed an interview activity, which was aiming to help students finding realistic problems by interviewing one another. All in all, groups that completed that activity more precisely could come up with acceptable problems to pursue in their final project.

In terms of collaboration, students improved their understanding of group work throughout the course and found unique strategies to collaborate on different activities. However, three main issues were found with teamwork including: *group leadership, sharing tasks equally, and size of the teams*. Overall, providing some tips on how to collaborate in teams can be beneficial. Also, talking to certain students who tend to lead the team can be beneficial by accepting their abilities and asking them to give other team members a chance to contribute their opinions. As a schoolteacher from Mulgrave School mentioned, in another design course, students started to get together as teams voluntarily, in order to get peer feedback from one another and collaborate on their tasks. This revealed that they were satisfied with their teamwork activities, and accepted the benefits of being involved in teams to complete a project in collaboration.

The findings about the creativity confidence of students were significance for the majority of questions; however there were certain questions in each school that did not reach the significant level. Here, I will discuss more the possible causes behind the results. The answers provided from Mulgrave students did not reach a significant level in questions 3, 4, 6, and 10. These questions asked about students' creative confidence improvement in:

- Identify and apply ways to enhance their own creativity (question 3).
- Explicitly define or describe their creative process (question 4).
- Learn from non-traditional resources (such as museums, student clubs, people, etc.) rather than textbooks (question 6).
- Solve problems in ways that others consider them creative (question 10).

The answers provided from Stratford Hall students did not reach a significant level in questions 2, 7, and 10. These questions asked about students' creative confidence improvement in:

- Effectively work on a problem that does not have an obvious solution (question 2).
- Share their work with others before consider it to be perfect (question 7).
- Solve problems in ways that others consider them creative (question 10).

In regards to questions 3, 4, and 10, one assumption that I have is the fact that I employed an unfamiliar or generic word - 'creativity' - to ask about their skills. Although the main outcome of being involved in a design thinking process is 'to become creative', we never explained that clearly to students in this course. As a result, the meaning of the sentences may have been too vague or generic for students so they provided low rates in their answers. As was explained earlier, design thinking is a creative problem-solving process aimed at "developing creativity and innovation in students and enhancing their creative confidence" (Royalty et al, 2014, p.79). However, the term creativity is not necessarily embedded or explained in a design thinking process or certain design activities. In the original study by Royalty et al. (2014), the participants involved in the study were defined as "d.school alumnus who had taken at least one d.school course… and nearly all participants had been graduate students at Stanford University… participants had been out of school and employed full-time from zero to a maximum of 5

years" (Royalty et al, 2014, p. 83). Taking into consideration students' age and educational context (d.school), I believe they had a clear idea that the design thinking process had led them to be creative thinkers. In this study, students were not clearly informed about the outcomes of being involved in the design thinking process at the beginning of the course. Hence, this clearly was an issue when it came to answering the pre and post questions about creativity.

In regards to question 6, I asked students if they were comfortable learning from non-traditional resources such as museums or student clubs rather than textbooks. However, at Mulgrave, students did not have the chance to go for a field trip. Hence, I assume that might be problematic because they did not have the chance to learn from academic resources outside their school. In contrast, Stratford Hall students visited SIAT and had the chance to talk to undergraduate students, discuss their projects, and visited several learning places such as the library, fabrication lab, sound and theatre rooms. Some students decided to explore undergraduate study in SIAT after visiting SIAT and learning about the future career opportunities. As a result, their post questionnaire answers reached a significant result.

Finally, there were certain examples in final projects that represented superior and futuristic thinking of students in problem-setting and problem-solving activities. Students paid attention to details when proposing the solutions, and considered different aspects in solving the proposed problem. Stratford Hall teachers acknowledged these skills and characteristics of students as follow:

> The one who just spoke very clearly about high-rise farming concept, I think that was quite out of the box thinking for someone his age. Most students focused on apps or things already exist but he is thinking outside the box and he is thinking not about his personal needs but he is thinking in a global context, so that stood out for me.

The above group (LE) members were interested in the course in general, followed the design steps properly, and often completed their sketchbook assignment. Even though they were behind one session due to forgetting their problem (they were called out by other teachers and they never consistently had more than one or two group members present), they came up with the challenge to deal with pretty quickly and they had a nice and productive discussion in the group. They talked about if they really found

the right problem, they were doing much on the research in the team, they were talking through finding solutions, and potential ways to explore the problem. They documented their process in their sketchbook to follow it properly later. As a result, I see their success in five main characteristics: 1) spending adequate amount of time in the problem-setting process, 2) constructive discussions and reflections on the proposed ideas in their team, 3) documenting their process properly, 4) being active participants in the course activities, 5) not heavily using computer and digital devices during the course. These characteristics were observed and found to be essential in other successful teams as well.

8.3. An Overview of Findings about Effective Course Materials

In the following section I provide an overview of findings for the third research question that investigated the techniques or practices that were employed in the course curriculum (Please refer to chapter 7 and the appendix for more explanation of the course materials). According to the findings in chapter 7, three characteristics are essential when choosing techniques and strategies to employ in a design thinking curriculum: *heuristic processes, real-world applications,* and *characterized consequences.* In other words, a design thinking curriculum that targeted secondary education requires using these qualities in order to engage students in all activities. Students in this age group lose their concentration, interest and engagement quite easily. As a result applying appropriate course materials and activities that engage them well are fundamental in developing and implementing a design thinking course successfully. The following table summarizes each category, following with a short description for each, and examples of successful activities.

Successful course material's characteristics	Description	Example of techniques
Heuristic processes	This category explains the importance of having exploratory and playful activities in a design thinking curriculum.	Observation activity, bodystorming activity
Real-world applications	This category explains the importance of connecting students' learning experiences to real world scenarios.	Field trip, Guest speaker, Observation activity
Characterized consequences	This category speaks to the importance of providing a clear description of potential outcomes of an activity.	Observation activity

Table 8.2. Characteristics of successful course materials

According to the findings, having such activities and instruction encourages *active participation of students*, and *deep learning* of the course concepts. In all the above activities, students were more determined to complete the activities, performed better in the activities, and provided outstanding results in the form of assignment or presentation. In the heuristic processes category, students enjoyed activities that enabled them to explore a concept by physical involvement in the activity. The real-world applications speak to the necessity of connecting the course content to the outside world in order to make course content more comprehensible for students. With regards to the third category (characterized consequences), as I mentioned earlier, clarifying an activity's expecting outcomes for students is substantial. Lacking such explanation may result in failure as we experienced in the sketchbook activity. Also, as I explained in section 5.1.2, providing clear and step-by-step instruction on how to complete an activity through visual representations is beneficial for this age group. Hence, I found clarity substantial in both *course instructions and course outcomes*, which can encourage students' active participation, and concentration.

In addition, I found employing certain strategies in teaching the course beneficial to encourage students' deep learning. As an example, the instructor encouraged critical thinking of students though reflection and discussions throughout the course. He provided certain questions to students to evaluate and ensure their understanding of concepts and as a result their *deep learning*. I found this strategy successful in encouraging students' critical thinking and active participation in the course activities. Asking questions about potential issues that students encountered during the course

also helped them to understand the issue in an indirect way. This strategy enabled them to be reflective and critical thinkers about their own learning processes as well.

8.4. Recommendation for Implementation

According to my findings in chapter 5, 6, and 7, in this section I will provide several recommendations for design educators when implementing an interaction design thinking course in secondary level education. Here, I basically synthesized what worked and what did not worked in this course according to the findings, and presented them as three main suggestions under three categories for further clarifications.

8.4.1. Provide an Interactive Heuristic Approach to Learning

This category speaks to the nature of materials and instructions provided in the course. According to the findings in chapter 5, visual representations, tactile activities, and nature of activities were beneficial and essential in teaching the course. Also, as I explained in chapter 7, an important characteristic of the favoured design thinking techniques was their heuristic process, which engaged students through playful and exploratory processes. Visual representations enabled students to remember things, explore more ideas, and clearly see their ideas. The tactile activities engaged disengaged students, and enabled students to learn and present their ideas in different format. The open-ended nature of activities gave more freedom to students to choose their own path, so encouraged a sense of possession and ownership as well as critical thinking of students. All in all, the most important benefit of providing an interactive and heuristic approach in the course was to fully engage students in the activities.

8.4.2. Provide Connection between Course Contents and Real-Life Situations

This category explains the importance of connection between the course materials and content as well as the real-world scenarios. According to the findings in chapter 5, teaching the *whole design thinking process, diverse materials, and small tasks* were beneficial for students in a variety of ways (please refer to section 8.1 for the

overview of benefits). The findings represent the whole course as a chain of activities that pursue the same learning goal and outcome. Lack of connection in any way (among different assignments, concepts, activities) can result in distraction and confusion in students' learning progression. In addition, according to the findings in chapter 7, an important characteristic of students' preferred design thinking techniques was its *real-world applications*. This category explains the importance of connecting student's experience to real world scenarios. Students are typically curious with active minds that constantly seek answers to their questions. Connecting course contents to real-life situations can answer many of their questions by providing the best, more tangible answers. Overall, creating relevant and connected course activities inside and outside the course, made the learning process and contents more meaningful for students.

8.4.3. Provide Clear Instructions and Descriptions of Learning Outcomes

According to the findings, it is necessary to clearly explain how to complete an activity, and what are the expecting outcomes. In chapter 5, I provide findings about the *interactive teaching style* throughout the course, and how this strategy resolved students' distraction issues and improved time management. One of the most prominent issues when working with secondary school students is their distraction and lack of focus. Hence, the show and tell style of teaching engaged students better by providing clear instruction on certain activities. Also, according to the findings in chapter 7, one of the most important characteristics of the successful course material (observation activity) was its characterized consequence. In the observation activity, the instructor provided a clear description of why we are doing this activity, what we expect you to bring back from the observation activity, how are they supposed to do the activity, and what is the next step after completing the activity. So students had a clear plan in their mind about how to accomplish the task and why. In contrast, lack of sufficient explanation about certain tasks or activities can cause students' lack of interest, engagement or motivation in completing an activity as we experienced and observed in the sketchbook activity. Also, providing the instruction early on before starting an activity can save time in the learning progression, and can prevent any potential confusion.

8.4.4. Avoid Postponing Assignments to be Completed Later

One main issue that we encountered during the course was the unfinished assignments of students that we asked them to complete at home. Here, I refer back to the sketchbook activity as the least successful one in this course. Students provided some explanation as to why the sketchbook activity did not work, and why they preferred to complete the assignment in the classroom. According to their feedback, they either forgot to bring it to the class, lost it, or didn't know which day they supposed to bring it exactly. The last problem was due to the incorporation of the interaction design thinking course and other courses (Design course at Mulgrave, and Computer Tech at Stratford Hall), which resulted in the course taking place during the time schedule of the larger courses. Also, one student explained that: "the sketch can be done later though it's disconnected with what you are doing". According to his statement, although he faced no issue in completing it at home, and bringing it back to school, he saw the disconnection between the activity and the course materials. This issue can be explained further under section 8.4.2, as part of the connectivity of activities. All in all, leaving the assignments to be completed later at home can be problematic due to the lack of students' organizational skills. As one student suggested to me, the solution to the lost sketches can be: "maybe like you keep the sketches for us". Although this issue seems perhaps less important or generic to students of different ages, it should be mentioned because of its repetition in the findings and students' comments.

8.5. Limitations of the Study

In this study different types of data sources were employed to verify and extend the data, and to increase the reliability of the evidence from interview sessions. Also both analytical and statistical generalizations were employed to evaluate the data in the case study approach. However, in this section I present three main limitations of this study: firstly, acquaintance of Mulgrave students with design; secondly, assessment of students' learning outcomes according to schools' IB assessment frameworks; and thirdly, incorporation of the design thinking techniques to the IB framework.

In regards to the first limitation, I gathered students' information on their background knowledge on design, and I found that students in Mulgrave attended a design course previously. However, after I talked to the schoolteacher, I found that the course content emphasised the final product and prototyping rather than ideations. Also, the course was not heavily focused on problem setting and problem solving. Considering this, I had to be careful when observing students and when evaluating their course outcomes to find the evidences of applying the knowledge that they gained in this course.

The main challenges that schoolteachers in fact faced in the course was the assessment of students' learning outcome based on the IB model. The interaction design thinking course occurred as part of a larger course in both schools, so that required decisive evaluation of learning outcomes by teachers. As two schoolteachers clearly explained:

> For us probably the coordination of IB assessment with the course because IB assessment was a lot of times you create the assessment before you start planning the lessons so for us to create the assessment after kind of knowing what was going to happen and not being in control of content, we knew what the content was because you had provided as detailed outline of the content but still we didn't know what is going to look like at the end so the challenging part is how do we now create an IB assessment for something that we are not teaching.

> The most challenging was incorporating what you were teaching or what Andrew was teaching into the curriculum and our assessments really, so figuring out ways of assessing their learning through the IB model, that's what they actually learning the content is what you are teaching to students in the course.

Finally, incorporating the course content to the IB framework was a challenge for schoolteachers in addition to the assessments. As one of them explained in detail:

> The most challenging thing is going to be how do I incorporate more of this methodology within the IB curricular framework that we are sort of stuck in because it's still very rigid curriculum and there are assessment methodologies and well we don't like to sort of teach to the test sort of thing when you know that at the end the IB is gonna assess them in a certain way.

8.6. Summary

In this section I provided an overview and discussion about the findings of this study: the benefit of the course for students, the skills they gained in the course, and their preferred techniques and materials. In addition, based on the findings, I provided some recommendation for a design thinking course implementation, which included an interactive heuristic approach to learning, connected and relevant course materials, and clear instructions and description of learning outcomes to students. Finally, I described three limitations that we faced in the course implementation and evaluations. These limitations were acquaintance of Mulgrave students with design, assessment of students' learning outcomes according to the IB assessment frameworks, and incorporation of the design thinking techniques in the IB model.

Chapter 9.

Conclusion

This thesis undertook a descriptive and multiple case study approach to explore design thinking techniques and practices in two secondary schools. In this thesis, I developed, implemented, and evaluated an interaction design thinking curriculum. Design thinking provides substantial skills that need to be learned in the 21st century, and design thinking practices have been implemented in different curricula at the post-secondary level. However little work has been conducted to investigate design thinking in secondary-level education. The findings revealed the course benefit for students, and provided suggestions on successful development and implementation of a design thinking course in secondary level education. Furthermore, the study introduced different data gathering and analysis techniques to evaluate design thinking skills of students throughout the course.

This thesis extends the prior work that implemented design thinking in secondary education. Several studies implemented design thinking to support students' learning of complex respiratory structure (Hmelo et al., 2000), geography systems and elements (Carroll et al., 2010), interaction design (Dukes and Koch, 2012), and product design (Lee and Bichard, 2008). Overall, in the above studies design thinking curricula mostly focused on implementation of design thinking practices, and evaluation of the outcomes after completion of courses to estimate potential benefits and results of such practices on students' learning or their critical thinking in solving complex problems. While this study is similar to the previous studies in terms of general goals of implementation and evaluation of design thinking, it provides new insights on the evaluation of design thinking skills of students outside the classroom, when applied to real-life situations. Also, as I explained earlier, I adapted the course curriculum from 'Project: Interaction' by Dukes and Koch (2012). The main reason behind adapting an already conducted

curriculum versus developing a new one was to fulfil the main goal of the research question of this study, to understand how to *best* design and implement a course. By adapting an already tested curriculum, I learned from the previous failures and improved the course content according to the new larger context. I collaborated and discussed with the course instructor and schoolteachers to evaluate the curriculum and apply necessary changes to be appropriate for the new context. As I explained earlier, this study is larger in terms of scale and number of students. I implemented this course in two secondary schools (Mulgrave and Stratford Hall) and 39 students and 4 teachers participated in the course. Also, this course was conducted as a part of larger courses during the regular school hours, which was beneficial for students as they attended the course with fresh minds in the morning and were eager to learn and participate in the activities.

In addition, this study is heavily focused on evaluation of the curriculum, course benefits for students, and their gained skills during the course as *design thinkers*. I consider my role in this course as an evaluator who observed the course activities in order to come up with resolutions about failure or success of the course. Furthermore, by employing appropriate data-collection techniques and research strategies throughout the course, I evaluated four design thinking skills of students (problem solving, human-centeredness, collaboration, and creative confidence). I found using these techniques insightful for design thinking scholars and educators and valuable to follow in future studies. Similar to some other studies, I evaluated the course benefit for students. However, I moved it further by investigating the course benefit outside of the classroom through asking students to explain how they applied those skills in everyday life situations.

Each chapter of this thesis provides detailed description of the study steps or outcomes. Providing an in-depth investigation, analysis, and description of the cases is the primary goal of choosing case study methodology for this study. The nature of research questions required in-depth understanding and description of students' activities and experiences during the course. I also provided detailed descriptions about the curriculum selection, development, and the characteristics of the curriculum in chapter 3. In chapter 4, I presented different types of data collection techniques, and the

detailed description of the process involved in preparing the data collection through a case study protocol, selection of cases, and execution of a pilot study. The essential interview question, observation guide, questionnaires and open questions were also presented in this chapter. Furthermore, the data analysis process for establishing a database and coding strategies was presented, and explained in detail.

The findings of this study were presented in three different chapters for providing more detailed descriptions on each finding. The findings in chapter 5 indicate that the course was beneficial for students in transferring their knowledge gained from the educational context to everyday life situations. Such pedagogy helped students to develop their own design-based meta-cognitive strategies that enabled them to solve unknown problems. I also found that students tended to apply and transfer design thinking techniques and strategies in everyday life situations and other courses 'voluntarily'. Also, five different course strategies were found to be the most desirable and beneficial, which enabled open exploration of concepts through visual, auditory, and kinaesthetic teaching and learning activities. These strategies motivated certain students to engage and perform better in individual and collective activities throughout the course.

The findings about students' design thinking skills (problem solving, human-centeredness, collaboration, and creative confidence) were presented in chapter 6 of this thesis. The findings indicate different levels and ways of activity involvement and skills enhancement by students, so that by the end of the course they all improved these skills to certain degree. They showed quite different levels of comprehension about the design process. Finally, according to the student and teacher feedback, certain design thinking techniques and activities were preferred and considered suitable. These techniques involved certain qualities including heuristic processes, real-world applications, and characterized consequences.

Finally, in chapter 8, I provided discussion around findings of the study, which included the benefit of the course for students, the skills they gained in the course, and their preferred techniques and materials. In addition, based on the findings I provided some recommendations for a design thinking course implementation, which include an interactive heuristic approach to learning, connected and relevant course materials, and

clear instructions and description of learning outcomes to students. Finally, I described three limitations that we faced in the course implementation and evaluations.

9.1. Contributions of the Study

Although this study was not extensive enough to understand the full benefits of an interaction design courses over a long period of time, it still presents several important research contributions.

First, this study demonstrates how students' skills were incorporated into their everyday life experiences and practices. It differs from previous research on design thinking implementations or evaluations. Previous research mainly focused on presenting the design thinking process and activities, and discussed the benefit or outcomes 'within' courses. While this study discussed several benefits that students gained within the classroom, it also provided clear descriptions about the benefits that students gained from the course by investigating design thinking abilities in solving their problems in everyday life situations or other courses.

Second, the findings of this study shed light on design thinking evaluation, and how design thinking educators and researchers can evaluate participants' skills and abilities during and after completion of a course. In particular, in this study applying several data collection techniques and strategies allowed for better triangulation of data.

Third, in this study I provide an analytical lens in examining and selecting a design thinking curriculum to teach to high school students. I pursued several steps to gather, select, develop, and implement the curriculum, as well as evaluate the curriculum outcomes after completing the course. Hence, I provided certain substantial characteristics of successful design thinking strategies and techniques that aimed at motivating, engaging, and attracting students in course content.

Apart from this, according to the findings of this study, I provided four main recommendations for design educators when implementing a design thinking-based pedagogy in the context of secondary education. These recommendations include:

provide an interactive heuristic approach to learning, provide connected and relevant course materials, provide clear instructions and descriptions of learning outcomes, and avoid postponing assignments to be completed later.

9.2. Future Work

There are several directions for extending this work.

First, it would be worthwhile to continue this work and involve more schools or cases. I originally intended to collaborate on this project with two public schools, which I had to cancel due to a teachers' strike in the last summer. Since these schools were larger in scale, and students might not have any experiences in design or critical thinking, I see potential in investigating the curriculum and evaluating the results for students' design thinking abilities there.

Secondly, future work can investigate students' skills in their everyday life situations further, by evaluating their abilities in a longer period of time; for example over a year through an ethnography study. Also, their skills can be investigated in other contexts outside their home or schools, thus getting more valuable findings in a longer period of time.

Third, the design thinking practices can be employed and investigated in non-design courses in secondary level education. As I have provided some preliminary findings in this course, design thinking approach is beneficial when applied in other courses. However, it would be worthwhile to investigate how to apply the techniques and practices in non-design courses. Also, providing some recommendations for schoolteachers on the implementations of design thinking techniques or practices in non-design courses would be beneficial in future studies.

References

Aflatoony, L., Wakkary, R. (2015). Thoughtful Thinkers: Secondary Schoolers' Learning about Design Thinking, *Proceeding of LearnxDesign 2015*, ABM-media and the Authors Press, Illinois, USA.

Akalin, A., Sezal, I. (2009). The Importance of Conceptual and Concrete Modelling in Architectural Design Education, *JADE, 28 (1),* 14-24.

Bell, S. J. (2008). Design Thinking. *American Libraries*, Jan/Feb, 45-49.

Benson , C., Lunt, J. (2011). We're Creative on a Friday Afternoon: Investigating Children's Perceptions of their Experience of Design & Technology in Relation to Creativity, *J Sci Educ Technol, 20 (1),* 679-687.

Bonnardel, N., Moscardini, L. (2012). Toward a situated cognition approach to design: Effect of emotional context on designers' ideas, *Proceedings of ECCE '12*, ACM Press, Edinburgh, United Kingdom, 15-21.

Bootcamp Bootleg D.School (2011). Available at http://dschool.stanford.edu/wp-content/uploads/2011/03/BootcampBootleg2010v2SLIM.pdf, Hassno Platner & Institute of Design at Standford University.

Bragg, S. (2011). Now it's up to us to interpret it: Youth voice and visual methods in creative learning and research, In P. Thomson, J. Sefton-Green (Ed.), *Research Creative Learning*, Routledge Press, 88-103.

Braha, D., Reich, Y. (2003). Topological structures for modeling engineering design processes. *Research in Engineering Design, 14 (1),* 185–199.

Brown, T. (2008). Design Thinking. *Harvard Business Review*, 84-92.

Brown, B. T., Wyatt, J. (2010). Design Thinking for Social Innovation. *Stanford Social Innovation Review,* Winter, 30-35.

Buchanan, R. (1992). Wicked Problems in Design Thinking. *Design Issues, 8 (2),* 5- 21.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., Hornstein, M. (2010). Destination, imagination & the fires within: design thinking in a middle school classroom, *JADE, 29 (1),* 37-53.

Carson, S.H., Peterson, J.B., Higgins, D.M. (2005). Reliability, validity, and factor structure of the creative achievement questionnaire. *Creat Res J, 17(1),* 37-50.

Charmaz, K. (2006). Constructing Grounded Theory: A Practical Guide through Qualitative Analysis, Introducing Qualitative Methods series. (1st ed.). Thousand Oaks: Sage Publications.

Christiaans, H. C. M. (2002). Creativity as a Design Criterion, *Creativity Research Journal, 14 (1),* 41-54.

Cooper, A., Reimann, R., Cronin, D. (2007). About Face 3: The Essentials of Interaction Design, Indianapolis, Indiana: Willey.

Creswell, J. W. (1998). Qualitative Inquiry and Research Design: Choosing Among Five Traditions, Thousand Oaks: Sage Publications. 47-72.

Cropley, D., Cropley, A. (2010). Recognizing and fostering creativity in technological design education, *Int J Technol Des Educ, 20 (1),* 345-358.

Cross, N, (1999). Design Research: A Disciplined Conversation, *Design issue, 15 (1),* 5-10.

Davis, G. A. (1991). *Teaching creativity thinking*, Handbook of gifted education, Boston, MA: Allyn & Bacon.

Dillon, M.R. (2010). Dynamic Design: Cognitive Processes in Design Sketching, *Indiana Undergraduate Journal of Cognitive Science, 5 (1),* 28-43.

Dukes, C., Koch, K. (2012). Crafting a delightful experience: Teaching Interaction Design to Teens*, Interactions*, *19 (2),* ACM, NY, 46-50.

Duncan, A. K., Breslin, M. A. (2009). Innovating health care delivery: the design of health services. *Journal of Business Strategy, 30 (2),* 13-20.

Dunne, D., Martin, R. (2006). Design Thinking and How It Will Change Management Education: An Interview and Discussion. *Management Learning, 5 (4),* 512- 523.

Dym, C.L., Agoging, A.M., Eris, O., Frey, D., Leifer, L.J. (2005). Engineering Design Thinking, Teaching, and Learning, *Journal of Engineering Education, 94 (1),* 103-120.

Green, B. (2009). *Introduction: Understanding and researching professional practice,* in Green, B. (ed). Understanding and researching professional practice: Sense Publishers, 1-18.

Goldschmidt, G., Weil, M. (1998). Contents and structure in design reasoning. *Design Issues, 14*, 85-100.

Hawthorne, G., Quintin, E. M., Saggar, M., Bott, N., Keinitz, E., Liu, N., Chien, Y. H., Hong, D., Royalty, A., and Reiss, A. L., (2014). Impact and Sustainability of Creative Capacity Building: The Cognitive, Behavioral, and Neural Correlates of Increasing Creative Capacity, In H. Plattner et al. (eds.), Design Thinking Research, Understanding Innovation, Springer International Publishing Switzerland, 65-77.

Hennessey, B.A., Amabile, T. M. Mueller, J. S. (2011). Consensual Assessment, Elsevier, 253-260.

Hmelo, C.E., Holton, D. L., Kolodner, J.L. (2000). Designing to Learn About Complex Systems, *The Journal of the Learning Sciences, 9 (3),* 247-298.

Howard-Jones, P. A. (2002). A Dual-state Model of Creative Cognition for Supporting Strategies that Foster Creativity in the Classroom, International Journal of *Technology and Design Education, 12(1)*, 215–226.

Howard, Z., Melles, G. (2011). Beyond designing: roles of the designer in complex design projects, *Proceedings of OZCHI '11,* ACM Press, Canberra, Australia, 152-155.

Karnes, M. B., McCoy, G. F., Zehrbach, R. R., Wollersheim, J. P., Clarizio, H. F., Costin, L.,&Stanley, L. S. (1961). *Factors associated with underachievement and overachievement of intellectually gifted children.* Champaign Community Unit Schools, Champaign, IL, USA.

Keefe, J. W. (1987). *Learning Style Theory and Practice,* Reston, VA: National Association of Secondary School Principals.

Klein, D., Phillips, K. (2011). Sustainable Design: An Educational Imperative, *Journal of Technology Studies, 37(2)*, 9-17.

Kolodner, J., Wills, L. (1996). Power of observation in creative design. *Design Studies, 17,* 385-416.

Lau, K. W., Ng, M. C., F. Lee, P. Y. (2009). Rethinking the creativity training in design education: a study of creative thinking tools for facilitating creativity development of design students, *ADCHE 8 (1),* 71-84.

Lee, Y., Bichard, J. A. (2008). Teen-scape': Designing Participations for the Design Excluded, *Proceeding of PDC conference 2008*, ACM Press, 128-137.

Löwgren, J., Stolterman, E. (2004). *Thoughtful Interaction Design: A Design Perspective on Information Technology,* Cambridge, MA: The MIT Press.

Lugmayr, A., Jalonen, M., Zou, Y., Libin, L., and Anzenhofer, S. (2011). Design Thinking in media management education - a practical hands-on approach, *Proceeding of SAME 2011*, Brisbane, Australia, 67-74.

Martin, D. S. (2008). Mixed methods research in documenting creative learning, In A. Craft, T. Cremin, P. Burnard (Ed.), *Creative learning 3-11,* Trentham books Press: 53-62.

Maxwell, J. A. (2005). *Qualitative research design: An interactive approach: An interpretive approach* (2nd ed.). Thousand Oaks, CA, USA: Sage Publications.

McNeill, T., Gero, J., Warren, J. (1998). Understanding conceptual electronic design using protocol analysis. *Research in Engineering Design, 10*, 129-140.

Owen, C. (2007). Design thinking: Notes on its nature and use, *Design Research Quarterly (2),* 16–27.

Pringle, E. (2011). What's with Artist? Researching practice with visual arts practitioners, In P. Thomson, J. Sefton-Green (Ed.), *Research Creative Learning,* Routledge Press: 35-45.

Rauth, I., Ko¨ppen, E., Jobst, B., Meinel, C. (2010). An educational model towards creative confidence. *Proceeding of ICDC,* Kobe, Japan.

Rotherham, A. J., Willingham, D. (2009). To work, the 21st century skills movement will require keen attention to curriculum, teacher quality, and assessment. *Educational Leadership 9 (1)*, 15-20.

Royalty, A., Noelle Oishi, L., Roth, B. (2014). Acting with Creative Confidence: Developing a Creative Agency Assessment Tool, In H. Plattner et al. (eds.), Design Thinking Research, Understanding Innovation, Springer International Publishing Switzerland, 79-96.

Roussou, M., Kavalieratou, E., Doulgeridis, M. (2007). Children Designers in the Museum: Applying Participatory Design for the Development of an Art Education Program, *Proceeding of IDC 2007,* ACM Press, Aalborg, Denmark, 77-80.

Runco, M. A*.,* Chand, I. (1995). Cognition and creativity. *Educational Psychology Review 7 (1),* 243-267.

Schön, D.A. (1983). *The Reflective Practitioner: How Professionals Think in Action, New York: Basic Books.*

Schön, D. A. (1991). Designing as reflective conversation with the materials of a design situation. *Proceeding of Artificial Intelligence in Design 1991,* Edinburg, 1-38.

Stake, R. (1995). The Art of Case Research, Thousand Oaks: Sage.

Stempfle, J., Badke-Schaube, P. (2002). Thinking in design teams-an analysis of team communication. *Design Studies, 23,* 473-496.

Stolterman, E. (2008). The nature of design practice and implications for interaction design research. *International Journal of Design, 2(1),* 55-65.

Suwa, M., Purcell, T., Gero, J. (1998). Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions. *Design Studies 19(1),* 455-483.

Thang, B., Sluis-Thiescheffer, W. Vermeeren, A. (2008). Comparing the Creativity of Children's Design Solutions Based on Expert Assessment, *Proceeding of IDC 2008,* ACM Press, Chicago, IL, (8) pages.

Torrance, E.P. (1974). The torrance tests of creative thinking-norms-technical manual research edition-verbal tests, forms A and B- figural tests, forms A and B. Personnel Press, Princeton.

Treffinger, D. J. (1980). *Encouraging creative learning for the gifted and talented*. Ventura, CA: Ventura County Schools/LTI.

Verea, I., Mellesa, G., Kapoorb, A. (2010). Product design engineering; a global education trend in multidisciplinary training for creative product design. European *Journal of Engineering Education 35 (1),* 33-43.

Winters, T. (2011). Facilitating Meta-learning in Art and Design Education, *JADE, 30 (1),* 90-101.

Wormald, P. W. (2011). Positioning industrial design students to operate at the 'fuzzy front end': investigating a new arena of university design education, *Int J Technol Des Educ, 21(1),* 425-447.

Yin, R. K. (2009). *Case study research: Design and methods*. (4th ed.), Thousand Oaks, CA, USA: Sage Publications.

Appendix A.

The Course Curriculum

Week 1: What is Design?
Learning Outcomes

1. Define design as a career discipline
2. Define interaction design
3. Define what makes up an interactive product
4. Examine products and services from an interaction designer's point of view
5. Define audience, goal, purpose, evolution of usage of common objects
6. Determine what skills and interests they possess that will make them successful designers
7. Use storytelling techniques to describe a product's purpose and usage

Breakdown

1. Pre-Questionnaire – Research Specific (5 min)
    a. Have them complete the pre-questionnaire for the research
2. Introduction + Ice-breaker (10 min)
    a. Get to know the students through a 'what is your name' and 'what do you think design is' exercise?
    b. As students announce their thoughts on what design is, write them up on the board.
    c. Review the student-made definition of design and (if necessary) discuss a proper definition for design and interaction design [1, 2]
3. Pull apart an object (20 min)
    a. Provide them with a variety of everyday objects: e.g., door knob, chair, pen, mug, phone, mp3 player, laptop, coins… etc. [4]
    b. In groups of 3-4, have them each discuss: [5]
        i. Who is it for?
        ii. What is it for?
        iii. Why does it exist?
        iv. Are there other types of the same thing?
4. Make an 'interactive product' (20 min)
    a. Discuss what constitutes an 'interactive product' [3]
    b. In groups of 3-4, they are to come up with a concept for an interactive product and will have 30 second presentations in which they are to 'tell a story' of the product, should cover purpose and usage [7]
5. Sketchbook homework (5 min)
    a. Introduce their sketchbooks, its purpose and usage
    b. For next class, they are to fill out at least two pages with sketches visually indicative of what skills or interests might make them successful designers [6]

Week 2: Ideas
Learning Outcomes

1. Use observation skills to reveal details and context clues

2. Quickly determine the value of an idea
3. Gain experience coming up with ideas and throwing some out
4. Identify connections between ideas

Breakdown

1. Sketchbook Recap (10 min)
    a. Discuss what do they think makes for successful designers?
    b. Introduce what is a 'good sketch'
    c. Lead discussion or draw out points on good ideation
2. Problem-Solving Question – Research Specific (10 min)
    a. In groups of 3-4, what would be the 4 first steps to design a new mouse, mobile phone, chair or wheelchair? (list your answers) [1]
3. Human-Centered Question – Research Specific (10 min)
    a. In groups of 3-4, students should select one of the following options and try to list all the problems (on paper): [2]
        i. Issues that people who commute with public transit may face every day in Vancouver?
        ii. Issues that people who commute with their personal vehicle may face every day in Vancouver?
        iii. Issues that people with physical disabilities who commute with public transit may face every day in Vancouver?
        iv. Issues that people with physical disabilities who commute with their personal vehicle may face every day in Vancouver?
4. Collaboration Question – Research Specific (5 min)
    a. Students receive the rubric for self-evaluation, and are to fill it out
5. Brainstorming Challenge (20 min)
    a. Check-in with the students to see who has brainstormed before, what are the rules of brainstorming? No judgment, keep everything, get it all down.
    b. The students have 2 minutes and 100 post-its, in how many ways can they describe 'community' (visually, textually, or otherwise)? Go! [3]
    c. Now the students will go back and map out/organize their ideas into categories [4], discuss a couple of the maps with the larger group.
6. Sketchbook homework (5 min)
    a. Students are to draw a space they are often in, then draw it again paying attention to what they did not draw the first time [1]

Week 3: People and environment

Learning Outcomes

1. Describe how user-centered design is critical to great design
2. Demonstrate techniques for understanding and modeling users
3. Use storytelling techniques to describe an environment

Breakdown

1. Sketchbook Recap (5 min)
    a. Did the students find anything different from the space (start to finish)?
    b. When (or if they did), what helped to make them notice it?
2. Describing an Environment (25 min)

    a. In their teams, students should come up with a description of a common place in the school without going there (8 min), their description should include:
        i. A set of sketches (storyboards) illustrating the space
        ii. A written description of how they experience the space (that they will share with the group) [3]
    b. Each group should share their description of the space with the rest of the class
    c. Try to draw out the differences in their experience of the space; even in such a small group, everyone has their own perception of the space, have them consider:
        i. How would they categorize their descriptions? [2]
3. Understanding an Environment (20 min)
    a. In their teams, the entire class will go and experience that space in silence. Students are to bring their sketchbooks, and make notes (10 min):
        i. What their descriptions missed
        ii. How is the space possibly different this time than in their descriptions?
        iii. What might alter the space?
    b. Back in the classroom, have them post-it their findings on the wall
    c. Discuss how we might categorize this: e.g., senses, experiences, materials… etc.
4. What is User-Centred Design? (5 min)
    a. Using points the students uncovered, discuss how user-centred design becomes important [1]
        i. Ask about how we might understand users?
        ii. Shaping products for people (not the other way)
        i. Creating products that fulfill a need
5. Sketchbook homework (5 min)
    a. Sketch out a map of all the things they use their mobile devices for as compared to their desktop computer

Week 4: On the Move

Learning Outcomes

1. Demonstrate how mobile technology is different from desktop technology
2. Define the benefit and limitations of mobile
3. Define ubiquitous computing and its implications for designers
4. Use storytelling techniques to explain design concepts

Breakdown

1. Sketchbook recap (5 min)
    a. What were the differences that students found in desktop vs. mobile? [1]
2. What is ubiquitous computing (5 min)
    a. You've already defined some mobile differences, let's discuss a scenario: You and your friends want to make pancakes, how would you figure out doing so? [2]
        i. How would your parents have done the same when they were your age?

        ii. How do you think you might do so in 20 years?
    b. Recap a bit on what defines ‘ubiquitous computing’ (ever-present information) [3]
3. Bodystorming (45 min)
    a. Introduce the concept of ‘bodystorming’ (acting out scenarios), students should aim to: (30 min)
        i. Create realistic characters, try to make it believable
        ii. Aim to have us feel for the characters you are portraying
        iii. Have one person in charge of leading the sketch
    b. In their groups, students will be practicing some bodystorming (acting out scenarios) [4]
    c. They will do a short skit (30 seconds) for each ‘year’:
        i. 1970’s – No cell phones, no personal computers, no text messaging
        ii. 2010’s – Cellphones, GPS, PC’s, internet, texting… etc.
        iii. 2050’s – Assume you will have everything we have today, plus whatever they can imagine
    d. Each team will be assigned a different scenario:
        i. You’re meeting your friend at the movies tonight. You’ve already made plans, but how will you find one another when you get there
        ii. You’re late for school. How will you let your parents or guardian and the school know that you won’t get there on time
        iii. You get to your neighbourhood bus stop and see that the bus isn’t running. How will you find an alternate route?
        iv. You are going to take the train to Seattle. You need to purchase your ticket for the train, but the line is really long and the train leaves in 15 minutes. How can you ensure that you can get a ticket for the train?
        v. You just left your friend’s house after hanging out all afternoon and you can’t find your way back to the bus. Assuming you can’t go back to your friend’s house, how will you find your way home?
        vi. You are an intern delivering a package for your boss. When you get to the office, the receptionist tells you that the name of the person that you are supposed to deliver the package to does not work there. How do you get the package to the right person?
        vii. You’re at your favourite shoe store checking out a new pair of sneakers. You want to compare the cost of a pair you see at your favourite store with another pair from a store a number of blocks away, how do you do so?
    e. Students perform the skits (15 min)
4. Sketchbook homework (5 min)
    a. Sketch out three services (physical or digital) that you visit or use on a weekly basis and how you interact with them

Week 5: Services

Learning Outcomes

1. Identify a service and its touchpoints
2. Gain access to practicing designers
3. Use storytelling techniques to explain design concepts

Breakdown

1. Sketchbook recap (5 min)
    a. What were some of the services students identified?
    b. Illustrate what a ‘touchpoint’ is based on their sketches [1]
2. Practicing Designer(s) (10 min)
    a. Have the designer(s) introduce themselves and explain how they became designer(s) (5 min)
    b. Students are to take notes, and have a short period in which to ask questions afterwards (5 min) [2]
3. Improving Services (40 min) [2,3]
    a. Select one of your team’s sketches from the homework last week
        i. As a team identify what is the ‘touchpoint’ where service/people interact (5 minutes)
    b. With the guidance of the instructors and the guest designer, students will step through the design process; develop an improvement on the existing touchpoint through their own exploration (25 minutes)
    c. Students present their improvement (10 minutes)
4. Sketchbook homework (5 min)
    b. Given what we have covered so far, how might you go about solving a big design problem? Sketch out your process.

Week 6: Solving Problems + Project Intro

Learning Outcomes

To look at creative problem-solving methods that designers can use to approach problems of the present and future.

Breakdown

1. Sketchbook recap (5 min)
    a. What were the processes they drew out? Did they miss anything big, or add any other items of their own?
2. Recap the Process (10 min)
    a. Revisit the process and ideas we have covered thus far, including:
        i. Research skills; observing, sketching, capture
        ii. Idea generation; brainstorming, bodystorming, sketching
        iii. Concepts; Ubiquitous computing, user-centred design
        iv. Protyping + presenting ideas
3. Project Introduction (5 min)
    a. Introduce the big project: In their teams, students will choose a problem that they’ve observed or experienced in the city. They will use the process they’ve learned to explore generating solutions to the given idea, and they will work on producing a story and poster that illustrate their problem, their process and their solution
4. Interviewing for Ideas (10 min)
    b. In their groups, students are to ask one another the following questions, and write down one another’s responses:
        i. When do you last remember being frustrated?
        ii. What caused that frustration?
        iii. Did you resolve that frustration? If so, how?

    c. Based on the responses, students should now have a pool of options to work on their final project with
5. Sketching Assignment - Research Specific (10 min)
    a. Draw a visual representation of design-thinking as you understand it
6. Project Work Time (20 min)
    a. Students should aim to have (by the end of this work time):
        i. A topic
        ii. An idea of what they need to research
        iii. A plan for how they will work on their project

Week 7: Project Work Time

Breakdown

Students will be given this entire session to work on their project. By the end of the session, they should have:

1. Completed their narrative (for presenting)
2. Completed their poster, which should include a description of:
    a. The problem
    b. The process
    c. The solution

While they are working on their projects, students will be called over in groups for an interview session - Research Specific.

Week 8: Final Presentations

Breakdown

1. Final Presentations (20 min)
    a. Have all teams present their work (2-3 minutes per team); thank them for participating and provide some brief feedback or critique on their work
2. Problem Solving Question – Research Specific (12.5 min)
    a. In groups of 3-4, what would be the 4 first steps to design a new mouse, mobile phone, chair or wheelchair? (list your answers)
3. Human-Centered Question – Research Specific (7.5 min)
    a. In groups of 3-4, students should select one of the following options and try to list all the problems (on paper):
        i. Issues that people who commute with public transit may face every day in Vancouver?
        ii. Issues that people who commute with their personal vehicle may face every day in Vancouver?
        iii. Issues that people with physical disabilities who commute with public transit may face every day in Vancouver?
        iv. Issues that people with physical disabilities who commute with their personal vehicle may face every day in Vancouver?
4. Collaboration Question – Research Specific (10 min)
    a. Students receive the rubric for self-evaluation, and are to fill it out
5. Post-Questionnaire – Research Specific (10 min)
    a. Students receive a post-research questionnaire regarding the design process

Appendix B.

An Example of In-depth Interview Transcript

Interview session with a team at Mulgrave school

Me: Hello

Av: We are just waiting for others…

Me: Sure, How are you today? Good. How are you? Good thank you. There are five simple questions for you that basically will help me to understand if in general things worked well or not. So you are helping me to improve the quality of the course.

Me: So, the first question is: tell me about an experience of the course that made an impression on you.

Is: I think the amount of visuals interpreted into solving… like activities worksheets are not project necessary, like something you put huge amount of effort in it. It's more something... It's immediately portraying tough process on paper through visuals…

Av: Like there was not one activity we did that was spelled out for us, It a lot was about ask working to get the solution and you knew what you want it and it kinda let us get there but you guide us through that and it worked pretty well.

Is: the amount of drawing helps you remember things, like I think I remember everything we have been here, so, ya… [Av acknowledge that too]

St: I think that having the guest speaker was pretty cool because it kinda show that you know what we are learning here can actually be put into like a job and I thought that was really cool.

Is: Ya, it's a lot of time you question it when you are sitting in the room, driving yourself in a same and having make it tight (kite) …

St: Ya and you learn that, it's actually actually used pretty good...

Sa: It was different not using a lot of electronics because normally when we are doing the projects, research and everything it's heavily based around using computers, but with this course it was more hands on and collaborative work.

Av: which is a lot better!

Me: great! Good to hear that. So the next question is what worked and what didn't work well for you in the design-thinking course? Well, you kind of covered but if there is anything else you want to share…

Is: oh, I don't know I don't have anything…

Av: I don't know I mean the perfect solution would be in every single class we all take is no homework because I think for us specially we have increased workload every single year and for us … [interrupted by Is]

Is: I think at least if they give us homework to actually look at it more because I feel a lot of people put a huge amount of effort into drawing a picture, which is this big on their sketchbook because they want to but again there is like people like me that maybe that wouldn't work out because

Av: Ya, in a place that half the class is been everyone…

Me: very good comments, so the third question is have you used design thinking for any problem-solving situation in your daily life? And if so can you give me an example?

Is: We use it when we look at the technology…

Av: I am probably have but I am not like realizing it…

Sa: anything even like I don't know even subway finder you still use it but just you don't acknowledge that you gonna use it…

Av: It's all the context and it changes all the time…

Is: I mean giving a problem the first thing you gonna do is analyse the solutions like it's not so much of like I have a problem NOW! What do I do? Like leave the place! No, it's more like you…I am consciously analyse the solutions because no one like conflict and no one likes anyone having a reason to be unhappy… so

St: You also kinda use it in other projects, I mean other subjects as well such as Math and science you can use problem solving [Av: specially math 1] for researching stuff you kinda use the same skills that the course kinda teaches you…

Is: really in a course like socials as well; the first thing you do is, you know you are not given so much problems but analytical situations.

Sa: we go through the same steps: researching, then depending on what it is then you are suppose to like end it or solve it…

Is: I think the DT is more like written there for you but not really at the same time, cause your thought is on paper…

Me: Great ideas, so have you used design thinking for any problem solving situations in your other courses? Can you give me an example?

St: Science…

Av: I haven't sat down, looked at problem, and thought about my like specification what I need to do anything like that, but I think it have been aware of, like it was other ways I could do things versus just going with what I did first…

Me: Ok, so the last question is: is there anything else you want to share with me related to the course?

Av: I like how it was hard it, I like lots of ways we did things,

Is: It wasn't a lot of pressure, it was like you enjoy the classes…

Av: Ya, like it wasn't set in the stones, we had lots of room with everything in it.

Is: and I think Andrew is really a teacher at the same time, because he is like chill but I think gives you a lot of room because a lot of time in course when they give you room almost indecisive person you ever meet…

St: Just like right amount of room that's kinda like makes you…

Av: You can say he has practiced teaching courses for sure…

St: specially for kids in our age that are really easily distracted and…

Sa: specially with the final project that he can't get distracted with it that in sort of the point that you really do whatever you want, and then when you choose something you choose something you like, so ya…

Is: you are more self-motivated compare to project for you and your group whereas getting a grade! So…

Me: great! Thank you so much, lots of great ideas from you!

Appendix C.

An Example of Observation Notes

Observation notes on session 1:

Design thinking activities (problem solving, empathy, collaboration)

In terms of forming their groups, they easily decided to be in team with students who were sitting near them. They formed groups with 2, 3, 4 team members.

In activity 2, the ideas on the definition of design were pretty much random; and they were not sure about the 'functions' clearly.

In activity 4, the ideas that they brought up were quite abstract, and did not seem that they quite considered real problem or people.

Design thinking techniques/tool (brainstorming, storytelling, interview, observation, ideate)

In activity 4, they came up with acceptable stories for the interactive products they made.

Role of students (participation, collaborations on the project, team work)

They started to get into groups quickly with other students sitting near to them.

Sometime only one student took the control of activity and other ones were either silent or share ideas with him. Not much collaboration/sharing ideas were involved. It seemed like they were not sure how to collaborate on the activity. All the students participated in their own way.

In SO group: they did not collaborate on the activity, instead they were looking around… they did not have any idea about time management. When the instructor mentioned how much time is left, they draw something rapidly by the end of the activity. This issue was quite the same in the "JU" group.

Learnability of the activities (How much time did they spend to complete a task, What were the challenges they encountered in each session)

Questionnaire took longer so we did not have enough time for the ice-breaker and first activity so we had to rush through it.

It was a good idea to list the activities on the board to call their attention as they have lost their concentration quickly.

Not open ended material? they started to lose concentration when we ask them to choose their own topic/they started laughing and playing.

Asked them to raise their hands and come to the board is a good strategy to bring their attention back.

When we asked them to write down their homework from the board, one student started to write down/copy all material on the board! So we needed to give them the tasks and materials step by step, and to wipe out the previous info from the board while introducing the new material.

Clarification of the course (what questions come up in each course session and group discussions, what challenges they encounter to complete each task)

One student asked about the clarification of question 3 in the questionnaire.

We needed to repeat describing the tasks that they needed to complete for activity 1 and 2 Andrew walked around their tables to check if they understood what they need to do or not.

Challenge: one group (WO) did not know how to come up with an idea, they kept changing ideas and finally copied from the group next to them!

Concept development (What are the proposed solutions to the design problem, the process to achieve the solution, how applicable and innovative each solution is)

They come up with unique concepts for the activity 2, but the purposes and functions were quite random, abstract, and fanciful. As they did not follow any design process steps, they could not explain why/how they came up with those ideas and the applicability of the concepts were an issue.

Implementation issues (shape of class, materials, timeline, any other unknown problem)

Time was an issue in the first session and everything took longer, for example one student started to chat and talk and did not complete the questionnaire on time.

Material was ok, I have to bring more markers; I shouldn't give them fancy color/highlighter markers as they loved to use them for writing, and they don't care if the text is readable or not. ☺

How/where to put the camera was an issue. May I should hide it somewhere as the schoolteacher suggested. At the end the video recording was ok, and worked well. Students did not paid attention to the existence of the camera.

In terms of table organization, we did not change it but we are planning to do so for the next session as students started to chat across the tables with other groups.

May be I should facilitate/write on the board while Andrew is talking.

What I learned:

1) No open-ended topic for this age as the teacher mentioned, maybe we should give them predefined subjects to work with?; List the tasks for them on the board, they need to continuously overview the upcoming activities; One student came back to take her mobile phone after the class, and mentioned she really liked the course. It was very motivational and pleasing to hear her explanation in the first session.

Appendix D.

An Example of Initial Coding

A: there is one lane is only junior school but senior school is always empty…
A: In the morning junior and senior school come at the same time so there is a lot of junior school coming and later when you get to the intersection when there are lots of park, you can see that the senior school is completely empty so there is no cars going through it and then…
Students started discussing about it while the next group was getting ready for their presentation.

Providing thoughtful answers according to the existing evidences-Q2

Heskey:
Problem is: animal goes to our trash/condo space, so we made a story board of a guy who goes with his garbage outside, but animals ended ripping into it, and rip the garbage all over the place… They discussed who is telling what for couple of seconds.
So the process is: first we research, observe and capture so we see previous solutions to the problem that didn't work and it flows and how we can fix it, and then we brainstorm a bunch of ideas, not the first idea cause it is not normally the best idea following, and we come up with the prototype and invented and think of all aspect we would need, different aspect we need to bring to the solution, and all the details, and we presented and after wards we evaluate and reflect on what went well and what didn't go well…
Solution: the solution is the bear bin TM, so the bin has a lock so animals can't open the lid with their nose, claws, et, and has a wheel on the bottom that can lock so not only is it mobile but you can lock it, so it won't fall down the hill or no one can move it…
So there is also lid attached at the back, it allows for the walk in the front so it also mad out of strong material that animals can't chew or ..

Tangible problem/based on everyday life experience-Q2
Storyboard as a technique, not prepared for presentation-Q3
Research on non-working solutions-Q3
Brainstorming ideas, referring the number of ideas they produced-Q3
Prototyping the idea-Q3
Referring to the evaluation; didn't mention how? Q3

Introducing workable solution/not very innovative bu thoughtful-Q2

Our solution is according to our first storyboard there are lot of problem, now we have proved that the Bear bin can solve every problem you have! So we incorporated very strong material that animal never tear the bin, this material includes a combination of polycarbonate, ABS plastic, Carbone fiber and an aluminum lock.
Next storyboard that shows the solution is the bear bin, putting the bear bin, walking the wheels, going to sleep, and the animals come in and then is rawrrr! we can get in, and then nooo its gotta lock and we can't choose through it!

Providing detailed description researches about the material-Q2

Providing second storyboard fo the proposed solution-Q3

Q: won't this strong material make it very heavy, and what is if they're living in an apartment building with no elevator?
Izic: We found that animal getting into the trash condo space is mainly happening in British properties and lynne valley, and there aren't really many apartment building there so it isn't specifically made for apartments.
Emanuel kept asking questions while the other groups were getting ready to present.
Q: Josh: will the garbage man be able to open it?
Q: Izic: how does it open?

Commenting on their work wel (thoughtful)-Q1

Providing thoughtful answer based on their research-Q1 (Possibly a category?)

Appendix E.

Observation Guide

THE FOLLOWING GUIDELINE HAS BEEN USED TO PILOT THE OBSERVATION SESSIONS WITH THE PARTICIPANTS.

- Design thinking activities (problem solving, empathy, collaboration)
- Design thinking techniques/tool (brainstorming, storytelling, interview, observation, ideate)
- Role of students (participation, collaborations on the project, team work)
- Learnability of the activities (How much time did they spend to complete a task, What was the challenges they encountered in each session)
- Clarification of the course (what questions come up in each course session and group discussions, what challenges do they encounter to complete each task)
- Concept development (What are the proposed solutions to the design problem, the process to achieve the solution, how applicable and innovative each solution is)
- Implementation issues (shape of class, materials, timeline, any other unknown problem)

Appendix F.

Interview and Focus Group Guide

Focus Group Session (Students)

1. Tell me about an experience of the course that made an impression on you.
2. What worked and what did not work well for you in the design-thinking course?
3. Have you used design thinking for any problem-solving situations in your daily life? Can you give me an example?
4. Have you used design thinking for any problem-solving situations in your other courses? Can you give me an example?
5. Anything else you want to tell me related to the course?

Participant Interview Session (Course Instructors)

After each course session:

1. Do you have any general comment about the course session today?
2. Do you have any comments on techniques and materials we used in today's session?
3. Do you have any thoughts on individual students that come to your mind in regards to being a design thinker?

By the end of the course:

1. Do you have any general comment about the course?
2. Do you have any comments on techniques and materials that we used in the course?
3. Do you have any thoughts on individual students that come to your mind in regards to being a design thinker?
4. What was the most challenging part in teaching D-thinking course?
5. What worked and what did not work in your opinion?
6. What can be enhanced in the future design-thinking course?
7. How successful was the course to help students become design thinkers?

Participant Interview Session (School Instructors)

1. Do you see any benefit in using the curriculum or part of it in your course?
2. Did you have any experience that showed that students may have applied design thinking rules in the (…) course?

Appendix G.

Open-ended Questions

Problem Solving Question

In groups of 3-4, what would be the 4 first steps to design a new digital mouse, mobile phone, chair or wheelchair? (List your answers)

Human-Centered Question

In group of 3-4, read the following paragraph first:

The traffic situation in many big cities is becoming a big problem. According to a European GPS manufacturer, Vancouver is the worst city in Canada for traffic congestion and the second worst after Los Angeles for relative slowness in North America. When people are driving on the Vancouver road network, their travel time will be 30 per cent longer than it would be when there was no traffic on the road…

With your group members, please choose one of the following question, and try to list the problems that:

a) People who commute with public transit may face every day in Vancouver?
b) People who commute with their personal vehicle may face every day in Vancouver?
c) People with physical disability who commute with public transit may face every day in Vancouver?
d) People with physical disability who commute with their personal vehicle may face every day in Vancouver?

Collaboration Question

Please answer the following questions individually:

1. How did you support the team in this session?
2. What have you done well or not well?
3. How other team members helped the team?

Appendix H.

Questionnaire

Student's name: .....

1) How confident are you that you could find sources of creative inspiration not obviously related to a given problem?

   (1) Not at all confident
   (2) A little confident
   (3) Moderately confident
   (4) Very confident
   (5) Completely confident

2) How confident are you that you could effectively work on a problem that does not have an obvious solution?

   (1) Not at all confident
   (2) A little confident
   (3) Moderately confident
   (4) Very confident
   (5) Completely confident

3) How confident are you that you could identify and apply ways to enhance your own creativity?

   (1) Not at all confident
   (2) A little confident
   (3) Moderately confident
   (4) Very confident
   (5) Completely confident

4) How confident are you that you could explicitly define or describe your creative process?

   (1) Not at all confident
   (2) A little confident
   (3) Moderately confident
   (4) Very confident
   (5) Completely confident

5) How confident are you that you could use the space or material around you to help you be more creative?

   (1) Not at all confident
   (2) A little confident
   (3) Moderately confident
   (4) Very confident
   (5) Completely confident

6) How confidence are you that you could learn from non-traditional resources (such as museums, student clubs, people, etc.) rather than textbooks?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident

7) How confident are you that you could share your work with others before you consider it to be perfect?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident

8) How confident are you when you try/explore an approach to a problem may not produce the final or best solution?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident

9) How confident are you that you could continue work on a problem after experiencing a significant failure?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident

10) How confident are you that you could solve problems in ways that others would consider creative?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident

11) How confident are you that you could help others be more creative?

(1) Not at all confident
(2) A little confident
(3) Moderately confident
(4) Very confident
(5) Completely confident