Thoughtful Thinkers: Secondary Schoolers' Learning about Design Thinking

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Abstract: *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 solve complex problems, and can be best achieved through collaborative and human-cantered 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 paper presents our findings on the successful implementation of an interaction design-thinking curriculum in secondary school education. We have performed qualitative research activities to find out about the success of the curriculum by investigating the abilities of students in transferring knowledge gained from a familiar situation (the course) to an unfamiliar situation (outside the course). Our findings suggested that teaching design thinking to secondary school students was beneficial, enabled students to make thoughtful decisions in solving simple to complex problems in their everyday life situations.*

Keywords*: design education; interaction design thinking; design process; k-12 curriculum.*

Introduction

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 solve 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 explained, '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 & Wyatt, 2010, p. 12).

Design thinking and practices have been implemented into different curricula in design, engineering, and business fields as particular skills help students succeed in the 21st century and prepare them for college or a career (Rotherham & 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 or inquiry-based learning in classroom activities (Dyme et al., 2005).

Design thinking practices are understood by experts to play an important role in different disciplines, such as architecture (Akalin & Sezal, 2009), product design (Verea et al., 2005), media education (Lugmayr, 2005), engineering (Todd & Magleby, 2004). Moreover, studies conducted in the K-12 education indicated 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 & 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 followed 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 design thinking practices, and the evaluation of outcomes after completion of course to estimate the benefits of the practices for students in solving complex problems. However, the implications of teaching such practices on students' ability in making thoughtful decisions to creatively solve problems occur in their daily life have not been studied before.

This research is a collaborative effort between the researchers and school educators. The study is part of a larger one, which explores the design and implementation of a secondary level course on interaction design thinking. We have conducted a qualitative research study to investigate whether the curriculum was beneficial in teaching interaction design thinking practices to students. To answer the research question we observed the student's activities closely, interviewed teachers and students to ask about the results of the course find out whether students were able to connect and transfer their skills from a familiar situation in the course to unfamiliar situations in their everyday life. The result of the study clarified whether students truly learned the materials in the course and whether they were able to apply their skills to new problem solving situations.

Literature Review

Design Thinking Origins and Definitions

The design thinking practices initiated at Stanford University starting in the 1980s, and nowadays continued 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. The term 'Design Thinking' was first introduced by Peter G. Rowe, in his book titled Design Thinking, which was published in 1987. 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, p.7). 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 disciplines. Donald A. Schön's (1983), in his book 'The reflective practitioner', explained how professionals think in action, their thought processes and methods of design practices. Brown and Wyatt emphasized the human-centred nature of design thinking and clarified that in the design thinking not only are 'creating products and services human centred, but the process itself is also deeply human' (Brown & Wyatt, 2010, p.33). Following Brown, Howard and Melles (2011) defined design thinking as a collaborative and human-centred problem-solving process.

Benefits of design-thinking courses in K-12 level

According to several studies, students in all disciplines can benefit from design-thinking practices that encourage creative thinking, communication, and teamwork. 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 tools and practices found beneficial to foster metacognition skills of students, their creativity and confidence through active engagements, risk taking, and expressing ideas. Another study by Dukes and Koch (2012) explored teaching interaction design to teens. The idea behind the study is that design thinking and practice 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, such as storytelling, presenting, researching, and observation. The reflection and discussion encouraged in the course that enabled students to benefit from the variety of ideas proposed in the class. In a study by Lugmayr et al. (2013) the most appreciated benefits that the students gained from the design thinking course was the opportunity to be involved and learn from an interdisciplinary educational team 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, behavioral or functional aspects or components that might be viewed from multiple perspectives. Hence, the course enabled students to gain a deeper and systematic understanding of the complex respiratory system.

While several studies evaluated the benefits and advantages of implementing design thinking in secondary level education, none of them studied the benefits of teaching such course on students' creative problem solving capabilities outside the course and in their everyday life situations.

Teaching Design Thinking in the Classrooms

This study investigates the design and implementation of a secondary level course on interaction design thinking. We initiate the study by searching for curriculums on design thinking, in general, which have been implemented and tested in secondary level education before. We have contacted several educators and professionals in the field to ask if they can share their curriculum and ideas on the pros and cons of an ideal curriculum. After we collected a couple of curricula examples on design thinking, we started to work with the course instructors to choose the right curriculum to further develop and modify. The modifications were made attentively to match the learning outcomes of each session within 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. Each design thinking session took one hour to complete, and we had 8 sessions in total for each school.

We implemented the design-thinking curriculum in two private secondary schools (Mulgrave and Startford Hall) in greater Vancouver area. Our case selection followed our criteria for the schools to be traditional type and not to be classified under any particular gender, religion, or population. The selected schools are part of the IB (International Baccalaureate) program, a recognized program internationally administered by the International Baccalaureate Organization based in Switzerland, which has authorized 2000 IB schools around the world and 250 in Canada. After finding the right schools, we contacted them through phone or email to ask for permission to run the course. The school's principal and director later contacted us to have a meeting to discuss further our research goals, curriculum material, mutual expectations and limitations. Moreover, we met the schoolteachers to discuss the curriculum and ask for further collaborations on the course. We applied the curriculum in the Middle Years Program, which involved 15-16 years-old students, and focuses on challenging academics and the development of life skills. In total 39 students participated in the course, in grade 9 and 10 from both schools. Either one or two schoolteachers were always attended the course sessions in addition to the researcher and the primary instructor of the course. The primary instructor of the course is a prominent and experienced instructor in both the secondary and post-secondary education.

Interaction Design Thinking Course

After receiving the approval and permission from the university ethics board and school boards, the curriculum was implemented for 8 weeks at each school, from September to December 2014. The course sessions at Mulgrave occurred twice per week and at Stratford Hall once per week were 2 weeks holiday break. The overall curriculum's material and setting for each session is 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; body storming 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 (Project work time): Complete the narrative (for presentation); complete the poster including a description of the problem, process, and solution.
- Week 8 (Final presentation): Final Presentation.

In the design thinking curriculum a variety of materials and activities were applied to encourage both convergent and divergent thinking of students. In contrast to many conventional design thinking curricula that emphasized only problem-solving activities, the curriculum provided open-ended activities that spurred problem finding by allowing students to freely choose the problem that they wanted to explore and solve. The majority of activities in the curriculum were designed and occurred in a collaborative form, and encouraged discussion, reflection, and short presentations to the larger group. Also, students had to present their findings in every activity for 3 minutes in order to learn more about presentation skills and to take the activities more seriously. Overall, bringing a variety of techniques and materials helped students to become fully engaged. Also having little tasks and shorter projects at each session helped them to focus on the tasks and kept them interested in topics. The course materials and techniques were age-appropriate, which is extremely important when working with secondary level students.

Methodology

In context interviews were performed with 39 students (in 12 groups) and 5 teachers after completion of the course, and took 15-20 minutes on average per individual or group to complete. The main intention to conduct these interviews was to understand if the design-thinking course was beneficial for students through investigating whether they were able to apply the problem-solving skills and techniques in their everyday life complex situations. We conducted semi-structured interviews in which we had the flexibility to ask additional questions according to the situation; alternatively, to encourage informal conversations that covered certain questions. The interviews with students occurred in their groups following focus group strategies. However, we acted as interviewers rather than facilitators, and although we encouraged open discussion relevant to the research question, simultaneously, we gave every participant the opportunity to express her/his ideas. The way we conducted the interviews provided a comfortable atmosphere for students to share their thoughts and ideas in their established group. In addition, we recruited participant's observation technique in every session to observe, record, analyse and interpret student's activities, attitudes, and conversations. The interview and observation sessions were recorded using digital audio with the permission of participants, the dialogs transcribed for analysis, and then coded following

grounded theory coding technique. The data analysis for interviews followed open (initial) coding and focused coding of the gathered data.

Applying design process in everyday life situations

Here, we explain our 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 practice such as sketching, critical thinking, and refining the ideas as they learned in the course. They started applying their skills in making physical artifacts or spaces at home or outside the home, such as a den, a table, a pound, and an aquarium. As Samuel 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 artifacts such as building games or digital arts. As Mason explained: 'at home when I am playing games and stuff life stream and life streaming is pretty much like making a video that's live and people can watch it while you are doing those certain things and 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 life stream channel, for my video stuff that I do so that's nice!' To complete these projects, they applied the techniques or materials they found useful, but they did not follow the design steps as they learned in the course. Each student found his/her own process to creating the artefacts. For example, to answer the question whether he applied the whole process Alex 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!' All and all, students could identify and bring interesting examples relevant to the application of design thinking in making DIY artifacts at home.

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 Avery, a student in grade 9 mentioned, the problem situation is 'a conflict and a reason to be unhappy' so she consciously analyse the solutions to the situation, whereas solving those everyday problems occur mostly in their head. She says: 'giving 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 physical materials or tools, but they prefer to directly reflect on the problem instead. As William 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.' Daniel, another student in grad 9 identified the application of design thinking in every project he has done, and further explained: 'basically for any projects we really do researching but we don't really think about doing it, we just do it.' Students brought up some other examples of applying design thinking in everyday life including: getting on the roof of the garage, building a puzzle, playing a video game, and bringing a jacket on a rainy day.

Applying design process in other courses

In addition to the home, student identified and provided appropriate examples on the application of design-thinking process 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 to the design thinking course. Students explained that they used the similar process in English, math, humanity, science, socials, personal projects, and theater but in different ways. As an example Avery 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 brought up by a student as an example. In other courses such as English, they applied the critical thinking to reflect on a passage. As Sofia clarified and explained: 'in English you have to read a book, like this year we are reading and we answer 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 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 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 descripting something like that.'

As one of the schoolteachers identified, students voluntarily applied some of the ideation techniques that they learned in his class '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, 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.

Further to our investigation in finding the benefits of design thinking in other contexts, we found that design thinking techniques in other courses such as literature or history might parallel one another in terms of the skill sets needed and learning outcomes. For instance, the storytelling purpose in a design-course is to describe a product's functions and utilizations. However, in a History course the technique can be used to analyze literature and to engage peers in discussion of historical events.

DT in a familiar situation

Design thinking process

As we talked to the schoolteachers we found that jumping to final solution without spending enough time on the process might be an issue in secondary level education. So we developed the interaction design thinking curriculum that employed research and ideation activities, as well as creations and evaluations to encourage both divergent and convergent thinking of students. By emphasizing the ideation tasks students followed the process of design step by step, without jumping to the final solution immediately. Also, throughout the course we encouraged them to apply the design thinking process; i.e. in their final project, we asked them to cover the problem they found, the process and techniques they applied to solve the problem, and their proposed solution. We found the evidence of applying design thinking techniques in most of the projects. Some of the most frequently used techniques were researching, brainstorming, storyboarding, and sketching.

Inquiry based activities

One of the issues that educators encounter while teaching courses at the K-12 level is the choice of topics and whether they should limit or leave the activities open-ended. As we talked

to the schoolteacher at the beginning of the course, we found that giving broad topics to students at this age may cause distraction and lack of focus in completing a project. However, we did not want to force students or restrict their choices, as one of the main objectives of the course was to encourage creative thinking of students.

In regards to our study with secondary school students, we observed and acknowledge that it is important that students take the responsibility to find the right topic (in this case to identify the right problem) as well as to choose appropriate ideation and creation techniques to use in their design processed. By the end of course the schoolteacher also acknowledged and further expressed: 'I think that's great the activities were open ended and it was allowed 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.' Furthermore, several students indicated that they liked and preferred to freely choose and explore their own topic rather than being assigned to certain tasks. Some of the selected phrases from students include: 'the course wasn't set in the stones'; 'the course was self-motivated', and 'the teacher gave right amount of room'.

In addition, giving students options to choose a realistic problem rather than a pre-defined one is important. 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 finding and problem solving activities, so students had the chance to conduct research to find a real-world issue as well. As Daniel, a student in grade 10 explained: '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.' Also, schoolteacher acknowledged that: '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!'

The course instructions

We found that a coordinated combination of verbal and visual instructions was beneficial for students to learn effectively. Having visual activities enabled students to represent their thought processes on paper immediately, helped them to remember things quicker, gave them variety to explore more areas and to literally see the ideas. This is quite different than how they accomplished their tasks in other courses, helped them to explore and express their ideas differently. As Avery 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 brought up the same though on sketching processes: 'its 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.'

The combination of verbal and visual instructions incorporated into teaching materials as well. Throughout the course, the instructor used his tablet to write or draw the list of activities or task instructions and showed them through an interactive board. This helped students to better concentrate on their tasks and to quickly get what we asked them to complete. The tool worked greatly in terms of solving the problem of distraction and lack of concentration with this age group. Also, using the tablet to sketch some ideas in real-time while explaining the techniques such as storyboarding, helped students to get the idea through a step-by-step process. As Henry, 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!' Another

student clarified the course helped him to 'actually do the things instead of just being told about them.' As is clear in his statement, students liked and preferred to have hands-on activities during the course. To acknowledge that Alex mentioned that 'they learned the same skills in a different way; more practical way!' Finally, the course helped with students' engagement by providing them the opportunity to present their ideas in a different format. As the schoolteacher noticed and expressed: 'there are four students in this class that is 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.'

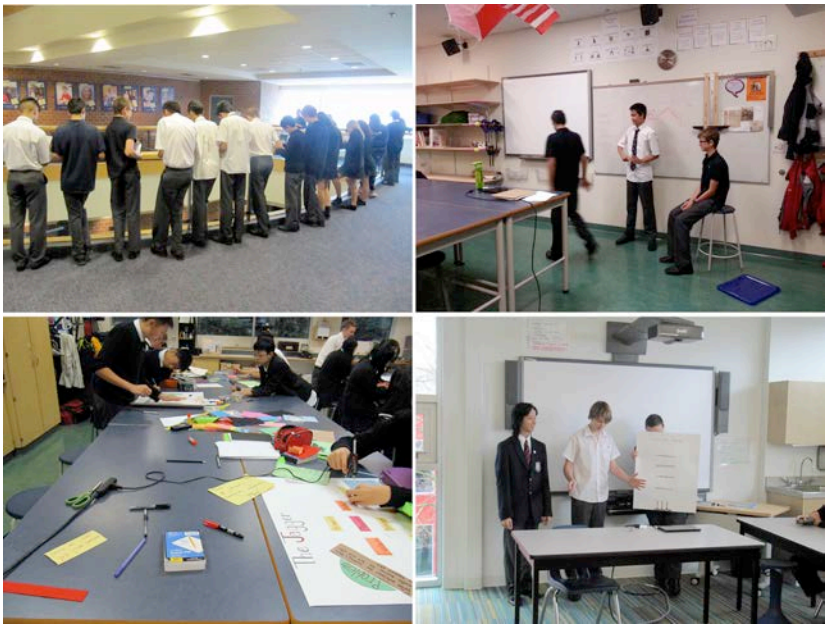

Figure 1 A variety of design techniques and activities were employed in the course. From left to right: observation, body storming, prototyping, and presentation.

Knowledge gained

The real benefits of any design thinking process or activity depends on how educators apply it in their curriculum. In this study, we synthetized students' and teachers' experiences of attending an interaction design thinking course to present our findings about the benefits of implementing such pedagogy for secondary school students. Our knowledge gained and suggestions for implementation are summarized in the sections bellow.

From design-in-school to design-in-life

Our findings indicate that a design-based instruction that involves the whole design process can offer distinctive benefits in transferring knowledge gained in an educational context to everyday life situations. Such pedagogy helps students to develop their own design-based meta cognitive strategies that enable them to solve unknown problems. According to Lowgren and Stolterman (2004), design thinkers can make much more deliberate and

thoughtful decisions to solve complex design problems. We found that students tended to apply and transfer design thinking techniques and strategies in everyday life situations and other courses voluntarily, as an important evidence that represents whether students learned the skills and abled to to use the skills in future problem-solving situations. In addition, having involved in open-ended and research-based activities such as interview and observation enabled students to identify and solve the real life-centred subject matters, understand and empathize real issues, and connect and transfer their knowledge and experiences to other contexts. Students learned that the process of solving a problem is applicable to a wide range of subject areas in everyday life situations. Hence, having such experience motivated students to engage and learn even better in the course, because they had a forward-looking expectation that the knowledge gained in the course will enable them to make more deliberate decisions in any complex situations that they may encounter in everyday life situations.

From verbal to visual instructions

Our findings reveal that having an interactive and visual-based teaching style together with explaining things verbally would help students to grasp the demanded tasks immediately and effectively. Furthermore, the wide range of design activities from brainstorming to body storming to formal presentations, enabled students with different cognitive learning types to succeed in certain design activities. This helped students to gain self-confidence, improved their self-image and motivation to perform better in individual and collective activities throughout the course. While we found this teaching strategy beneficial for this age group, creating an environment that enables students to perform and organize their procedural thought and knowledge freely is critical. This can be achieved only through open-ended activities that allow students to choose their preferred subject area to work on and as a consequence make the tasks more meaningful for them. During in-class activities, we recommend educators to involve in the activities and guide students in their design processes, while leaving them to explore freely.

From creative to critical thinking

Teaching the whole design process (but not only certain design activities) is substantial, which enhance students' creative and critical-thinking skills through activities that encourage both divergent and convergent thinking. Some design techniques and strategies such as ideation and problem finding enabled students to explore different directions and develop creative abilities through divergent thinking. According to a study by Runco & Chand's study (1995), motivation found to be an important aspect of creative thinking, which can be facilitated through problem finding activities. While we acknowledge the importance of problem finding activities, we found open-ended activities beneficial and motivational in the creative problem solving process. Besides, finding out a realistic problem is critical due to the fact that an individual not only would solve a problem but also would find the right problem that keep him/her motivated and responsible throughout a design process. On the other hand, design techniques and strategies such as defining a problem, creating and discussing a solution encouraged student's convergent thinking and enabled them to become critical-thinker and decision maker. Finally, the whole design process enabled students to effectively coordinate their thoughts and actions, in order to improve their understanding of problem area and to

propose a workable solution. Spending adequate amount of time on design process and activities before rushing into a solution is essential. Hence, we recommend teaching the whole design process, including both problem finding and problem solving activities to empower students to organize their procedural thoughts and knowledge, dig down to the root problems, and propose an appropriate solution to the defined problem.

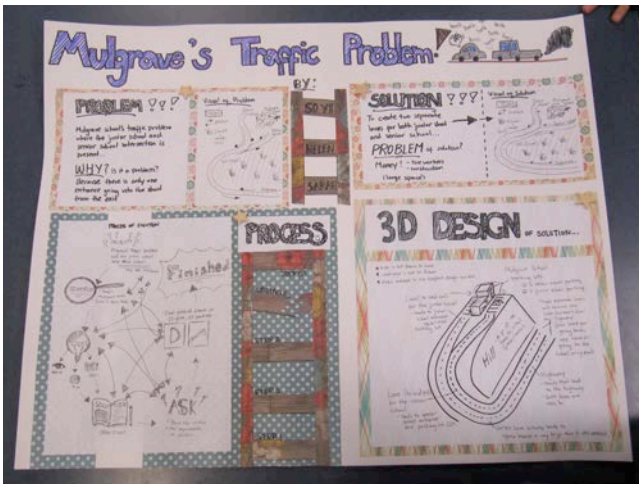

Figure 2 A visual representation of problem solving process in the final project.

Conclusion

Many high-school students in Canada have limited exposure to design thinking and creative problem solving that enable them to become a creative thinker. In this study, we present our findings about the implementation of an interaction design thinking course in secondary-level education, to emphasize and clarify the benefits of having such pedagogy for pre-university students. Our findings revealed that a design-based instruction that involves whole design process could offer distinctive benefits for students to transfer their knowledge from familiar to unfamiliar contexts. Such pedagogy enabled students to develop their own design-based meta-cognitive strategies in solving unknown problems. Furthermore, a range of activities and tasks were employed to empower and motivate students with different cognitive learning types to perform better in the course. We found motivation as an important factor in creative problem solving, which can be encouraged through problem finding and open-ended activities. Our proposed curriculum is going to be employed in both secondary schools as mentioned by schoolteachers, which represents the success of pedagogy. This also illustrates the importance of teaching design thinking and problem solving strategies in secondary education as recognized by school educators.

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