Paper Title The Relationship Between Learning Spaces and the Development of Computational Thinking Skill

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Session Title Diverse Learning and Computational Spaces Across STEM Context

Session Type Paper

Presentation Date 4/6/2019

Presentation Location Toronto, Canada

Descriptors Computer Applications, Critical Thinking, Technology

Methodology Qualitative

Unit Division G - Social Context of Education

DOI 10.302/1440741

The Relationship Between Learning Spaces and the Process of Computational Thinking Skill.

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Modern society pressures the educational systems. Technologies transformed industries requiring competencies involving new methods of solving problems. The need to solve today's complex problems gives rise to new types of workspaces, new approaches and new forms of thinking, such as computational thinking. However, in the scientific literature, the relationship between learning spaces and the process of computational thinking is still unclear. Our case study draws on the grounded theory method answering the question: How do learning spaces contribute to the process of computational thinking? We aim to explicit the process of computational thinking in a context of creating a computational thinking challenge and to identify the characteristics of learning spaces that could potentially contribute to this process. Using a qualitative methodology, results show that students applied the computational thinking process model drawing upon concepts and approaches in a multifunctional, comfortable, diversified and engaging environment that constitute the foundations of the 21st century learning.

KEYWORDS: learning process, learning space, computational thinking, technology, competencies, skills, process, flexible learning, personalize learning, innovation

Introduction

Innovative society brings major changes to the world. Journalist and triple Pulitzer Prize laureate, the American author Friedman (2016) indicates that the market place, Mother Nature and Moore's law are reshaping the world at a fast accelerating rate. In fact, he insists that changes are happening not only within technology but also in markets and environment. Lorenz, Rüßmann, Strack, Lasse Lueth and Bolle (2015) attribute this phenomenon to the arrival of a new type of technology called Information and Communication Technology (ICT) during the 1980s. This wave of technological advancement has systematically transformed the operations as well as the processes of industries creating new paradigms of thinking to solve complex problem the global economy. Perhaps this is the reason why the school systems (K-20) around the world are encountering enormous turbulence. In fact, specialists in the education field are asking themselves a lot of questions on how to prepare the next generations for jobs that are not yet created or defined. In this context, the role of new skills such as communication, collaboration and problem solving has significantly increased (Cobo, 2013; Dede, 2010; Toner, 2011). How should education reflect these changes, in respect to the constant evolution of ICT?

The widening gap between the school system and the digital world is well documented in the literature (Cobo, 2013). The International Study Program for the International Assessment of Adult

Competencies (PIAAC) which surveyed respondents aged 16 to 65 on literacy, numeracy, and problem-solving skills revealed that only 10% of Canadians scored the highest level and 41.6 % scored the lowest (Canada, 2010). The Ten-Year Education Plan (2016) reinforces the commitment of the New Brunswick government to: "Increase opportunities that require learners to apply knowledge and skills within and across disciplines to innovate and solve real-world problems." This is why, while addressing the issue of bridging the existing gap between the needs of society and the difficulty for the school system to respond to these needs, we focus on new skills to be acquired in relation to an environment specifically designed for 21st century learners. This environment combines the recent technological advancements, new types of digital tools for the development of computational thinking process, and new types of learner-centered pedagogy.

This paper reports the results of a research where Grades 6 and 7 students designed and create; construct, experiment and validate; and shared robotics challenges using iPads, Apple's coding application "Swift Playgrounds" and "Dash & Dots" robots. The learning space (Figure 1) designed to reflect real-life workspaces where complex problems are addressed in a collaborative approach allows for new problem-solving methods and approaches (Kerch, 2015). Hence, it allows for new problem-solving methods and approaches involving the process of computational thinking, a key 21st century competence, essential yet still under researched. As contribution to the field of research, our study seeks to understand how new learning spaces contribute to new ways of solving complex problems.

Figure 1: **Learning Space**

Objectives:

The importance of setting-up a learning space to anchor active learning such as using the concepts and approaches of the computational thinking process will achieve the main goal of our study, which aims to understand the relationship between learning spaces and the process of computational thinking. In a preliminary work, the framework of CompeTI.CA partnership network conducted an intensive research to gather theoretical concepts indicating possible components of the computational thinking process which still need to be clarified through experimentation (Figure 2).

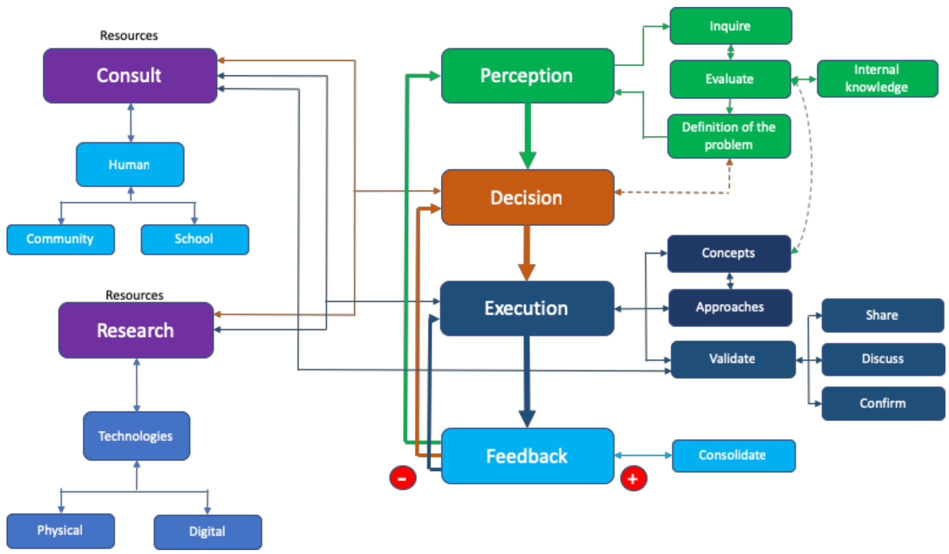

Figure 2: **Theoretical concepts of computational thinking process**

Based on these theoretical concepts, we pursued the investigation analyzing now how students apply the process of computational thinking when creating robotics challenges in a real-life learning space and how the particular characteristics of the learning space can contribute to the process of computational thinking. The following two objectives have guided our investigation: (1) to explicit the student's computational thinking process when solving a complex problem, and (2) to identify the characteristics of learning spaces that could potentially contribute to this process. This ground breaking research will shed some light on learning spaces and the computational thinking skill, not yet clarified, but needed by modern society.

Rationale of the Study and Theoretical Perspective

Few researches explain the relationship between spaces and learning (Zufferey & King, 2016). The French sociologist Lefebvre (1991) was the first to examine the notions of passive learners and the use of space. Kersh (2016) highlights that workplace/learning spaces enhance individual and collective engagement. Moreover, Lye and Koh (2014) indicate that individual engagement and organizational success in a work environment rely on knowledge sharing, peer collaboration, transparency in communications and a culture of "empowerment". In this age of accelerations, employees within a company can no longer afford to work in silos to solve complex problems and are therefore challenged to work together productively and efficiently. Individuals must contribute to local, regional or global development by assessing their capacity and collaborating with partners whose forces (knowledge, abilities and qualities) can complement theirs (Mansilla & Jackson, 2011). In fact, according to Marabito (2014), new collaborative technologies showcase teamwork, learning, problem solving, knowledge development, task completion, and other cognitive achievements. Such a space allows employees to concentrate, collaborate and socialize, learn and innovate. In other words, the need to solve today's more and more complex problems brings new types of workspaces, new approaches and new forms of thinking, including computational thinking (Kersh, 2016; Webster, 2015; Wing 2006). So, what are the characteristics of working-learning spaces? What are the technologies that facilitate productivity?

According to Branigan-Pipe (2016), although teaching and learning strategies have improved, school buildings, classroom organization and classroom design remain the same. The author even suggests that current classroom environments limit student learning and the practice of new learning strategies such as Project Based Learning, Inquiry Based Learning, Challenge Based Learning, Flipped Classroom and Universal Design Learning. Jankowska and Atley (2008) as well as Lye and Koh (2014) agree that learning spaces are one of the systemic components the school system must seriously consider as they are essential to success in a global world.

Numerous studies on engagement link school success to the learning environment. In fact, school environment plays an important role in student engagement and success, and is often associated with individual and collective attitudes and aspirations (Edwards, Gallagher & Whittaker, 2004; Evans, Hodkinson, Rainbird & Unwin, 2006; Hodkinson & Hodkinson, 2004; Kersh, Waite and Evans, 2012; Lye & Koh, 2014; Solomon, Boud & Rooney, 2006). According to King, Joy, Foss, Sinclair and Sitthiworachart (2014), student engagement will be enhanced in spaces that are flexible and that foster the use of multiple learning strategies. Students learn best in environments where they are actively engaged through a learning process where they can prove their learning by actively acquiring knowledge, test knowledge by experiences, convey their finding with peers, collaborate within the network to share their learning and finally reflect by internalizing the knowledge (Chiasson & Frieman, 2017). In addition, to ensure the development of students' full potential, the learning environment must be dynamic and allow for creativity (JISC, 2006; Robinson & Aronica 2015). Kersh (2015) states that learning spaces must be able to motivate, stimulate, engage and promote student learning.

It is essential to provide learning spaces that create conditions that will respond to a diversity of learners by taking into account their learning styles as well as their fields of interest. According to Burns (1972), learning needs to be personalized as there are no two persons who learn in the same way and at the same pace. It is therefore beyond doubt that traditional teaching based on the same approach for all has its limits. Learning spaces thus need to be diversified. As Burns explains, the term "diversified learning space" refers to the learning process of students and relies on learning spaces that offer opportunities to vary, differentiate, adapt and modify the achievement of learning outcomes. In order to provide student-centered learning spaces, as opposed to content-centered teaching approaches, schools must take into account the particularities of students such as their age, culture, level of learning, learning styles, fields of interest, among others (Leroux, Fontaine & Sinclair, 2015). In a diversified space, learning activities allow students to make choices in a learning process, adapted and modified in terms of content, processes, structures and expected outputs (Leroux et al., 2015). According to these authors, the diversification that takes place in the context of learning modifies the skills to be developed, the degrees of complexity and the material to be exploited.

A multifunctional learning space, both inside and outside the classroom, refers to a space that contains various resources (Öman, Sofkova & Hashemi, 2015) and that offers a variety of spatial configurations (Webster, 2015) facilitating learning and teaching activities by engaging students in their learnings (Evans et al., 2006; Kersh, 2015; Kersh, Evans & Kontiainen, 2011; Solomon et al., 2006). As today's students are social, multitasking and team-oriented, their learning space must differ from the hierarchical model of formal teaching where students sit and listen. For Fisher (2005), a learning space divided into small sections, each with distinct functions, will provide students opportunities to collaborate, learn and socialize, present, reflect, learn outdoors, experiment and access information and resources. A multifunctional learning space promotes the use of strategies and pedagogical practices placing students in constant reflection and in a mode of production and creation (Jessop, Gubby & Smith, 2012; Robinson & Aronica, 2015). This space facilitates the development of soft skills such as communication, collaboration, creativity and knowledge sharing (Kersh, 2015). In addition, Eraut (2004) and Evans et al. (2006) mention that individuals learn independently or experimentally with peers in a variety of informal learning spaces.

Pedagogy is constantly changing, hence the need to create a learning space enabling all students to learn (Prensky, 2010). New teaching approaches are being implemented in the world of education to allow for varied learning strategies and experiences. Learning spaces that are adaptable facilitates quick transitions between activities, regardless of the configuration of the space (Fisher, 2005; Webster, 2015). As stated by Scott-Webber (2004), these spaces must be reconfigured every twenty minutes to support a variety of activities that meet the different needs and interests of all students. The author adds that the furniture in adaptable spaces must be designed to reconfigure the space with ease and speed to permit individual, group, presentation, communication or collaborative modes (JISC, 2006; Robinson 2009, Robinson & Aronica, 2015). Thus, the front and the back of the class no longer exist (Chamberland, 2016), positioning the teacher in the center of the learning space. Learning spaces must also be flexible, instantly configurable and negotiated by the students themselves (Gruskin & Searson, 2016). In short, the adaptability of learning spaces allows students to organize themselves quickly in their space (chairs, tables, pencils, chalkboard, etc.) favoring various learning formats, such as team, large group or individual to ensure quality learning for all. Based on effective classroom management, the smooth transition between various pedagogical activities maximizes student learning time and minimizes wasteful downtime, hence the importance of easily adaptable resources that promote engaging learning opportunities.

The OECD report (2015) argues that despite the many challenges of integrating new technologies into teaching and learning, digital tools are advancing education especially when technology is focused on quality education and student engagement. According to the report, ICT enable collaborative work spaces, remote and virtual labs as well as digital tools related to solving real-life problems. American studies that have examined the effects of school conditions on student achievement indicate that student's performance is lower in schools with poorer conditions such as lack of access to technologies. In fact, studies in Washington, DC and South Dakota among elementary and secondary schools show considerable performance gaps in the academic performance of students attending lower quality schools (Earthman, 2002). Learning spaces must have ample electrical drops and be equipped with sound amplification systems such as Lightspeed to enhance sound diffusion and numerous wireless access points (Wi-Fi) to support technological tools (Andrews, Wright & Raskin, 2016; D'Amico, Oliver & Chrystal, 2016; Milton, 2008).

Spaces equipped with physical and digital technological tools play an important role in the field of learning (Sheard, Simon, Hamilton & Lönnberg, 2009). In reality, they are the means that help create knowledge while facilitating learning and increasing student engagement. In fact, Jankowska and Atlay (2008) recommend that the walls of the learning space be covered with "Idea Paint" paint to transform them into a dry-erase whiteboards on which students can write, draw, take notes and calculate. These walls promote the sharing of students' work and ideas with their peers and the teacher.

According to the above authors, the use of whiteboards allows students to engage in creative thinking, problem solving, planning and presenting their ideas. Lee (2010) indicates that whiteboards and whitewalls are cognitive tools used not to produce, but rather to learn, and considers them as social tools that support the conceptualization of artifacts. In fact, these tools foster teamwork by providing increased visibility to observers while allowing for collaboration, discussion and brainstorming.

The Barrett, Davies, Zhang and Barrett (2015) study in the United Kingdom shows an increase in students achievement in mathematics, reading and writing in schools with natural light from large windows and with furniture designed appropriately to the age and size of students. The study indicates that student-centered learning spaces with comfortable and ergonomic chairs and desks contributed to these results. In addition, flexible areas, spaces for displaying students productions and minimizing the internal noise caused by the chairs promote learning and a sense of class belonging.

D'Amico et al. (2016) as well as Stewart (2010) mention substantially the same findings regarding school furniture. According to them, movable tables and chairs with wheels allow for a faster reconfiguration of the space. In fact, furniture designed to facilitate kinetic movement (turning and moving) improves students' commitment to the task (Gruskin & Searson, 2016). Steelcase's "Node" chair and "Verb" tables are an example. Rotating chairs help students who have difficulty seeing the teacher or other students from different places within the learning space (Henshaw, Phillip & Bagley, 2011). Low-tech solutions such as mobile and magnetic whiteboards with dry-erase markers can also help students in their learning and teachers in personalizing their teaching

(Gruskin & Searson, 2016). Finally, a space as described above encourages teachers to position themselves closer to the students to give help when needed (Branigan-Pipe, 2016).

This leads us to investigate computational thinking in a new learning space where complex problems are solved in a more efficient way (Barr & Stephenson, 2011).

The term "computational thinking" was originally used by Papert (1980) in the context of the LOGO programming language as he referred to concepts from geometry to form explanatory ideas (Djambong & Freiman, 2016). While the concept of computational thinking in education can be traced back to the work of Seymour Papert (Papert, 1980), Wing's (2006) article has rekindled the interest for promoting computational thinking in K-12. She described computational thinking as thinking skills related to solving complex computational problems. As for Berry (2015), he explains that this form of thinking consists of solving problems by applying a variety of concepts used methodically in diverse approaches as shown in Figure 3.

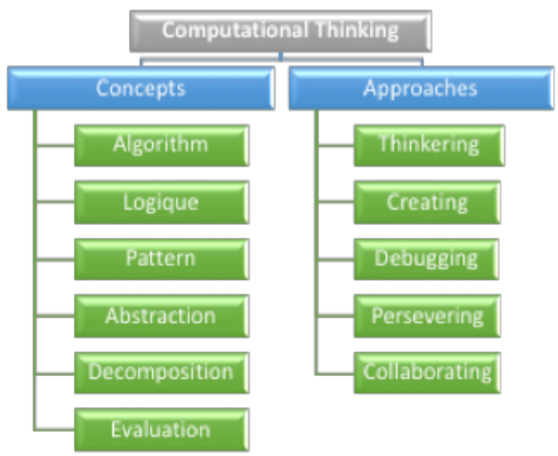

Figure 3: **Concepts and Approaches of Computational Thinking (Chiasson, 2019)**

Buckley (2012) supports Wing by stating that despite the technological tools that help individuals solve problems, it is the human mind that is applied to solve a problem, because the ability to find solutions is related to the knowledge stored in the mind. Being the product of thought, knowledge can vary from simple to more complex thinking (Wing, 2006). It is the nature of the problem that dictates the level of thinking (Buckley, 2012). Thus, that of a lower order is considered as an algorithmic thought requiring a minimum cognitive effort. On the other hand, the higher order thinking, developed as a non-algorithmic and complex way of thinking, often produces multiple solutions involving the interrelation of various criteria, reflection and self-regulation. Many researchers such as Kalelioglu, Gülbahar and Kukul (2016) are trying to further define computational thinking. However, Zhong, Wang, Chen and Lee (2016) associate it with three optics: the problem solving, the form of expression and the three-dimensional framework of Brennan and Resnick (2012).

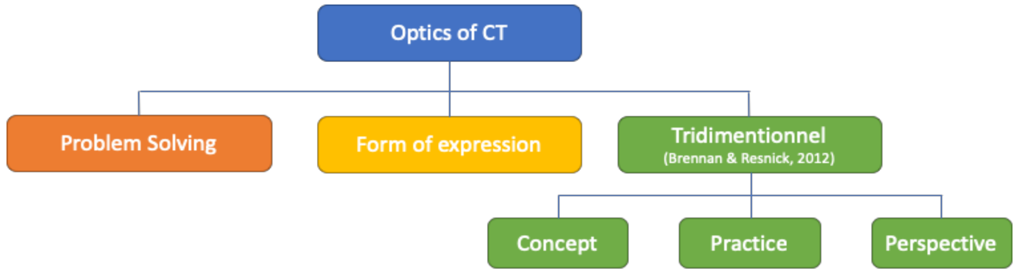

Figure 4: **Optics of Computational Thinking (Chiasson, 2019)**

As shown in Figure 4, the first optic presents computational thinking as a process involving problem solving, systems design and understanding of human behavior while building on the fundamental concepts of computer sciences (Wing, 2006). It is a thought process that solves problems that can be effectively addressed by an information processor (Wing, 2011). According to the "Report of a workshop of pedagogical aspects of computational thinking" (NRC, 2011), computational thinking is an analytical skill that relies on concepts and skills that are needed by all students in all subjects, such as breaking down problems into smaller pieces to deal with, one at a time. While problem solving in other scientific fields focuses on physical objects, computational thinking brings another dimension that relies on abstract phenomena. Finally, problem solving seems to be at the heart of computational thinking in which the main components are: abstraction, algorithm, patterns, decomposition and execution of sequence abstraction results (Zhong et al., 2016) .

The second view of computational thinking involves a form of expression. In fact, programming is a language for expressing ideas, expressions by symbol systems to articulate expressed or implied knowledge. Researchers such as Zhong et al. (2016) and Resnick (2008, cited in NRC, 2010) believe that computational thinking goes beyond problem solving and beyond programming and mathematical concepts and is as fundamental as reading, writing and mathematics.

The third optic is proposed by Brennan and Resnick (2012) who present computational thinking as part of a three-dimensional framework related to concepts, practices and perspectives. The first of the three dimensions involves the creation of concepts used by the programmer represented by sequences, loops, events, conditions, operations and data. The second dimension is explained by the practices developed by the programmer as he engages in the creation of concepts, working incrementally and iteratively, while evaluating and debugging, reusing and remixing, as well as abstraction and modulation. The third dimension of computational thinking is related to the perspectives of the programmer based on the links and on his reflections in relation to himself and the world around him. Thus, computational thinking goes beyond the use of interactive technology. The programmer uses technology as a means involving many possibilities in design, expression and creation.

Based on Brennan and Resnick's (2012) three-dimensional framework and the framework of CompeTI.CA partnership network that brought forth theoretical concepts indicating possible components of the computational thinking process that need to be clarified through experimentation (Figure 2), four steps are required to solve a problem during a programming activity: Perception, Decision, Experimentation and Evaluation. At the perception of a problem, a student investigates it through observations, analysis, and evaluation. When the problem is defined, the student makes a decision on how to solve it using concepts in approaches, then implements this decision and receives feedback indicating the outcome of his decision. The success of solving the problem, based on observations, is in itself a feedback validating the acquired learning. However, if the feedback is negative, the student will return to previous steps to further investigate the problem, by consulting other resources or apply other concepts and approaches.

According to Brennan and Resnick (2012), Bundy (2007), Djambong and Freiman (2016) and Wing (2006), there is a lot of interest in computational thinking within the school system for a number of reasons. First, Magana, Marepalli and Clark (2011) indicate that the education system is increasingly looking for activities or pedagogical practices to support students in understanding and solving real-life problems. Indeed, Sanford and Naidu (2016) recommend that school pathways, traditionally focused on reading, writing and mathematics, be revised to include new skills, including computational thinking. Specifically, Czerkawski (2015), NRC (2010) and Wing (2006) argue that the knowledge needed to meet the challenges of the 21st century goes beyond the acquisition of basic knowledge. According to Barr and Stephenson (2011), Fluck et al. (2016) and Wing (2006), computational thinking should be considered as a core competency to be taught through all K-12 programs. As for the ideal time to introduce computational thinking, Magana et al. (2011) suggest presenting it early in the school cycle and this in various contexts involving the solution of complex problems.

Modes of Inquiry, Data Sources, and Methods of Analysis

The methodological approach guiding this case study is rooted in the qualitative research interpretive paradigm (Van Maanen, 1983) allowing conceptual categories to inductively emerge from the collected data during a thematic analysis (Paillé, 1996). This study used two groups of students (24 in Grade 6 and 20 in Grade 7, for a total of 44 students for which we have obtained a parent's consent, in accordance to the University's and School District's ethical norms and regulations) from a middle school in South-East of New Brunswick. To gain better insights into students' experiences with tasks, we created a focus group of 12 randomly selected students (six in grade 6 and six in grade 7). Data collection took place during ten one-hour-sessions in which we conducted semi-structured interviews (after each session), field observations, digital traces and researcher journal. Data analysis was conducted in two stages. First, each of the 10 interviews were transcribed and analyzed, along with video observations, to identify elements of computational thinking process for each phases of the task (creating, experimenting and sharing their challenge with the group). In other words, we observed and described how students worked through their challenge in each of the three phases to identify the elements of the computational thinking process related to the characteristics of the learning space (Paillé & Mucchielli, 2012). Secondly, following a grounded theory perspective (Glaser & Strauss, 1967), a within-case thematic analysis was undertaken using NVivo software to create conceptual categories in order to identify the characteristics of the learning space that contributed to the process of computational thinking thus allowing the conception of the model. The use of various data collection tools such as interviews with students, traces of work, videos, interviews with teachers, research journal gathered from several different sources: students of two class-groups, 3 teams per class, 6 in total was put in place in order to triangulate the data. Interviews with 12 students were repeated several times during the process (Creswell, 1998) and once the new data did not add meaning to what was already understood, the data was saturated (Glaser & Strauss, 1967).

Results

The task of the students was to create a robotics challenge their classmates would solve (Figure 5). In teams of two, they first discussed the required parameters of the task. The challenges they created consisted of programming robots to navigate in a labyrinth. The cards they designed specified the objectives and recommended material for the robotics challenge, including a sketched graph representing the course of the robot.

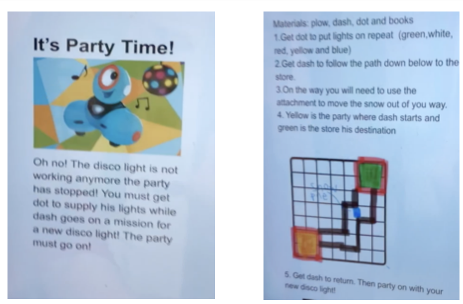

Figure 5: **Challenge Card (Chiasson, 2019)**

After the creating the challenge card, the teams created lines of code referring to the robot's path constructed on the floor (Figure 6a and 6b). Most teams used the step-by-step approach to experiment with their lines of code making changes as the project progressed. All students reported having relied on their observations to notice problems that have arisen during the execution-validation phase. One participant explained it in these words: *"So when it messes up, you see what it does and you change that (line of codes)"*. In fact, their observations prompted questions, engaging them in inquiry in order to identify the source and nature of the problems they encountered. Trial and error was the most popular approach used by the students for problem solving. As one participant states: "*We are doing a lot of testing, yeah*".

Figure 6a:

Figure 6b:

Figure 6a and 6b: **Lines of code referring to the robot's path**

When sharing their findings with classmates, all teams admitted to having fun doing this activity. They added they liked challenges and stressed on the importance of putting a lot of effort into solving problems. They learned that problems can be solved with more than one method. While they all acknowledged being worried and frustrated with the problems they faced, everyone shared their determination and perseverance in solving them at which time they admitted to experiencing a sense of relief and pride. Students perceived the robotics challenge as an engaging learning activity they would like to repeat. As one participant puts it: *"Challenges are hard and it is a relief when you done it"*.

In light of our results, the first objective was to explicit the process of computational thinking in a context where students create a robotics challenge. Thus, based on the framework of CompeTI.CA partnership network, a design as a first model explains the computational thinking process which we want to experiment (Figure 7). To better identify the primary components of the computational thinking process (Perception, Decision, Execution and Feedback) and to better track the actions of negative feedbacks, we first, merged the initial actions during the Perception step (observe, analyze and evaluate) into a pseudocode called "Inquire". Second, we added a unidirectional line going from "consolidate" to "previous knowledge". Once students validated their learning with their peers, they anchored this new learning in their previous knowledge (Lin & Xie, 2017). Third, we displaced the resource components on the right-hand side of the diagram thus providing a better visual overview of the computational thinking process model by isolating and making more explicit the actions related to negative feedback.

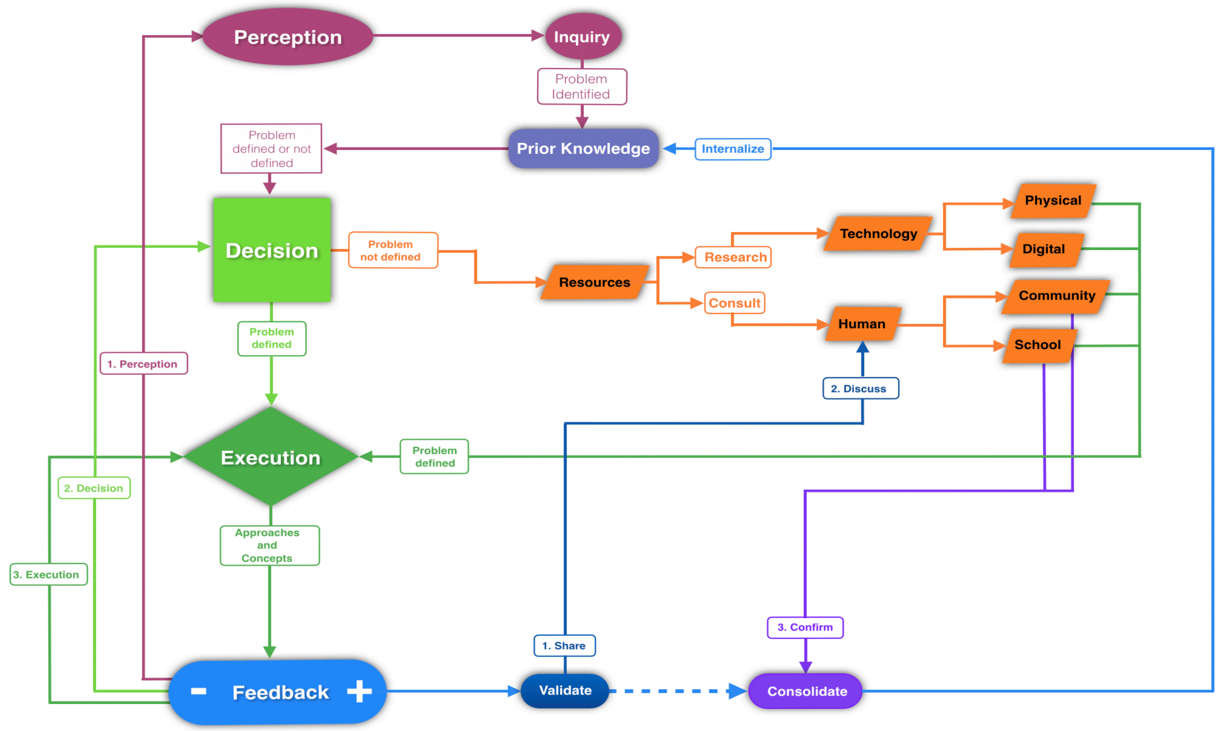

Figure 7: **Computational Thinking Process (Chiasson, 2019)**

For the second objective, which is to identify the characteristics of learning spaces that could potentially contribute to the computational thinking process, among the 20 sub-categories obtained during thematic analysis, we identified four broad characteristics of the learning space which are multifunctional, engaging, comfortable and diversified (Figure 8).

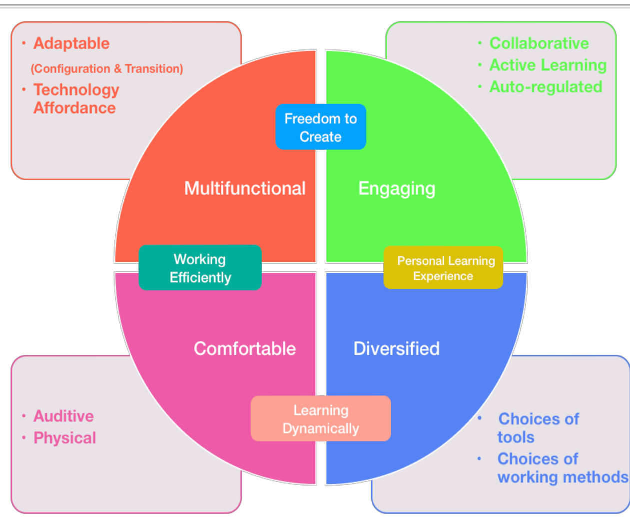

Figure 8: **Characteristics of the Learning Space (Chiasson, 2019)**

Students expressed their appreciation for the learning space as it gave them the opportunity to create, collaborate, meet, experiment, validate and share their learning. First, the multifunctional learning space allowed students to configure and reconfigure the spaces while transitioning rapidly through diverse functions such as from creating to experimenting functions to accomplish their robotics challenge. In fact, the technology affordances (physical and digital) seemed to have contributed to the process during the three phases of the activity. Secondly, the data shows that students participated actively by collaborating with peers in their learning space while receiving instant feedback. Third, the diversified learning space also contributed to the computational thinking process by offering students choices of tools and working methods when carrying out the challenge. Thus, students put into action the various concepts and approaches of computational thinking in a personalized way. Finally, comfortable learning spaces create an environment that facilitate students' concentration. For example, the pivoting of the chairs, according to several students, helps widen their visual field enabling them to follow the movement of the teacher in the classroom: « *the chairs are very good cause you can go and change your position and always look at the teacher when he moves.* » In addition, these swivel chairs help students who need to move to focus and stay on task, thus reducing their stress levels: « *I like the chair because they are comfortable and easier to work and like sometimes you are nervous, you can fidget and help you get more concentrated.* »

Many students expressed their appreciation of this learning space by indicating how engaging, easy and efficient their learning experience is compared to a traditional classroom. One student says it in these words:

> *The class is so engaging and fun. It is not complicated the work. It is not complicated like the other classrooms. Our class is like the future. All classes should be like that because it is a better environment. Having the whiteboards and the chairs on wheels, you can move the tablet that is attached to them.*

In order to narrow the gap between the education system and modern society, this learning space has showed some potential and credibility by bringing these two elements closer together. As the Figure 8 indicates, the interrelation of the four characteristics of this learning space has brought out four great phenomena. First, by having the freedom to create, design, conceptualise, and innovate, students engaged in their learning by being constantly thinking and reflecting while working on their robotics challenge. The second phenomenon refers to helping students work efficiently and effectively. By making use of all resources in the classroom such as physical, digital and human resources, students were more productive in completing their task. Third, the learning space provided for students to learn dynamically. Students were constantly engaged in metacognitive activities such as reflecting, analyzing, communicating, collaborating, constructing, exploring, validating, presenting to name a few. This active learning engaged student while developing social skills by interacting with their peers and members of the community. Finally, this learning space created a personalised learning experience where students were offered choices to be involved in their learning while developing autonomy in an authentic and personalized way. In other words, they have the opportunity to choose how to demonstrate what they have learned.

Through this new learning space, we have also witnessed the emergence of a new configuration of roles. In fact, this space focussed not on teaching but more on student learning. Students took charge of their learning and shared their knowledge gain with their peers. As for the teachers, their role was more that of a facilitator coordinating the assets within the learning space. This phenomenon brought out questions which need more investigation of the role of teachers in this learning space.

Conclusion and Discussion

Our findings indicate that learning spaces can potentially contribute to the computational thinking process. A space that is multifunctional, engaged, comfortable and diversified has the potential to help students perceive and investigate problems in order to test their decisions and resolve them through feedback. In a student-centered framework, students experiment and validate their decisions through feedback giving them the opportunity to conceptualize, create, build, experiment, validate and share their knowledge (Freiman et al., 2016).

Our study reveals some very interesting results that deserve to be highlighted for their contribution to the educational field. In this age of globalization, new skills to solve complex problems are required by the labor market. Many researchers have established links between the generic components of knowledge and the acquisition of skills. In fact, Boudreault (2008) mentions that professional competence is based on the acquisition of specific skills such as Knowledge (comprehension), How to Do (practice, qualities) and How to Be (aptitudes). As a whole, the achievement of the robotics challenge allowed students to mobilize these three important skills in order to develop the computational thinking skill to be better prepared for the professional reality.

In reference to the Figure 9, the integration of the three skills during the three phases of the pedagogical activity allowed the students to gain knowledge through How to Be and How to Do while having access to the resources (human and technological) to create and conceptualize; experiment and validate; produce, present and publish; and finally reflect on their learning (Freiman et al, 2016). This learning experience provides a learning atmosphere where students have freedom to learn and are empowered in dynamic learning as well as being a contributor within the collaborative community.

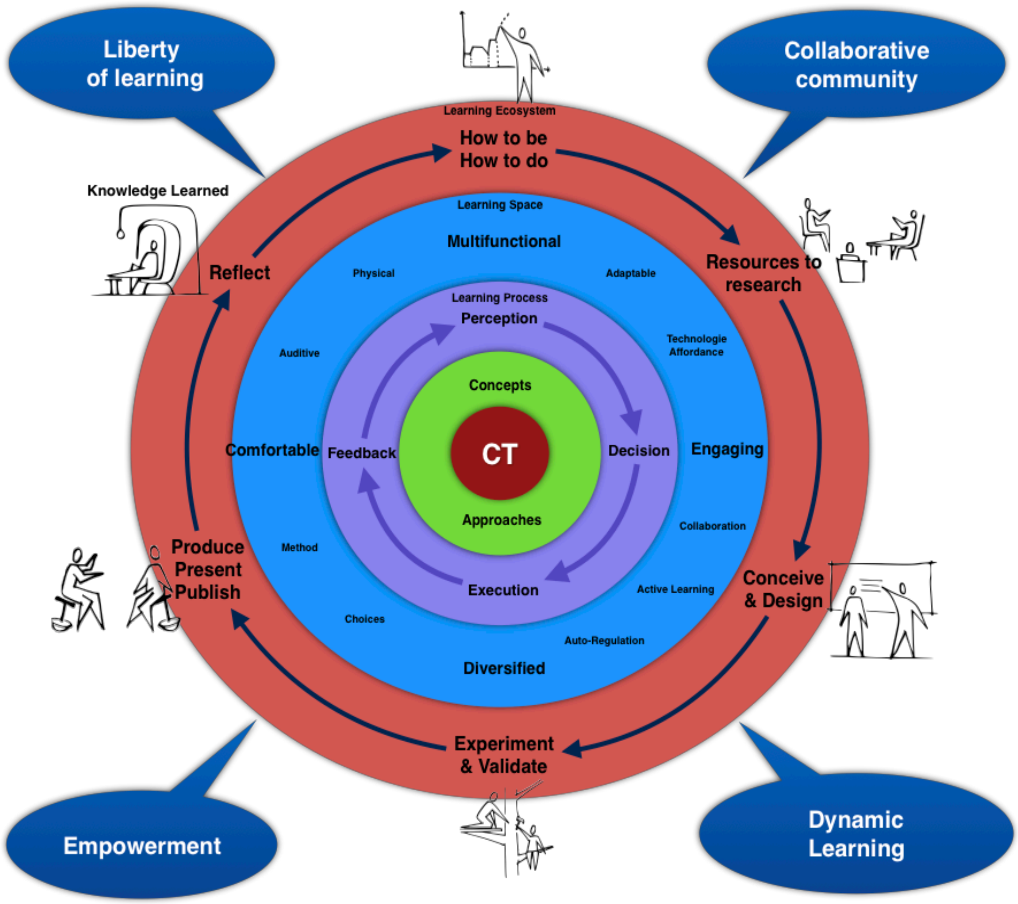

Figure 9: **Modern Learning Ecosystem (Chiasson, 2019)**

The explicit process of computational thinking, as defined by the model (Figure 7), will benefit students in all aspects of their life as they engage in problem solving situations and in various subject courses (Barr & Stephenson, 2011; Brennan & Resnick, 2012). Moreover, the four identified characteristics of learning spaces (multifunctional, diverse, engage and comfortable) favoring the computational thinking process is a solid advice for the education system. In modern society, schools can no longer learn and teach in traditional classrooms, thus the urgency to take into account the features that facilitate the process of computational thinking. Besides bridging the gap between schools and the real world, this study will guide the education system on how to create learning environments aiming to enhance the development of competencies. While some studies have explored learning spaces or computational thinking, none has studied the relationship between the two for the purpose of skill development. To our knowledge, this pioneer research is the first to focus on specific features of learning spaces that contribute to the development of competencies such as computational thinking in a complex problem-solving context.

Although the results were obtained on a small scale, we are confident a larger scale would yield similar conclusions. This research shows promising and new results in the education field. Through this study, some questions have emerged in areas that need further exploration: When will schools implement a learning space with the characteristics stated above in order to develop competencies such as computational thinking. How can current schools transform into environments that respond to an innovative society? What are the return effects of investing in this new learning space? How can learning be measured in these new learning spaces?

Scholarly Significance

Our study investigated the complex relationship between learning spaces and the novel process of computational thinking skill. In an innovative setting including new technologies, students created a challenge, solved it in teams of two and shared with their peers. Although the results were obtained on a small scale, they provide new insights in the field of educational innovations forging paradigmatic changes in the 21st century learning perspective. Through this study, new direction has emerged in areas needing further exploration: How to expand novel models of schools to wider school settings and what accompaniment is needed from school leadership perspective, teaching and learning perspective, as well as research to ensure effective implementation of new learning spaces with the characteristics stated above in connection to the development of essential competencies such as computational thinking, thus closing the gap between the needs of society and its school system.

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