Perceptions and Applications of Maker-Centered Pedagogies in K – Grade 12 ADST and STEM Education in BC Public Schools

by

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Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

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Abstract

The researcher surveyed 97 British Columbia ADST or STEM educators concerning their understandings and perceptions of maker-centred pedagogies, and their willingness to apply these approaches. Questions addressed current applications of maker-centred pedagogies in public schools, and the major factors that affect the implementation of maker-centred approaches, including the characteristics of maker-centred pedagogies, the tools and resources used in making activities, and the strategies that support maker-centred approaches.

Findings from qualitative and quantitative analyses suggest that most respondents favored maker-centered pedagogies, and that maker-centred pedagogies are being implemented most often in secondary STEM classrooms, though least in Mathematics. Teachers report using both high-tech digital tools and low-tech and traditional tools in making activities. Concerns raised by respondents, but rarely mentioned in literature on making, are student safety, having sufficient physical space for making, fostering appropriate attitudes toward making, and a need for additional teacher training in this area.

Keywords: maker-centred pedagogies; understanding/perceptions; applications; resource/tools; strategies; public schools

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List of Acronyms

ADST	Applied Design, Skills, and Technologies
BC	British Columbia
DIY	Do it yourself
FSF	Free Software Foundation
HGSE	Harvard Graduate School of Education
IT	Information Technology
K – 12	Kindergarten to Grade 12
ORE	Office of Research Ethics
OST	Out-of-School
PBL	Project-based Learning
RQ	Research Question
SD	School District
SFU	Simon Fraser University
SQ	Survey Question
STEM	Science, Technology, Engineering, and Mathematics
UCLA	University of California, Los Angeles

Glossary

ADST curriculum	Applied Design, Skills, and Technologies. A new curriculum area in British Columbia public schools since 2015. An experiential, hands-on program of learning through design and creation.
Making activities	Activities focused on designing, building, modifying, and/or repurposing material objects.
Maker-centred classrooms	Classrooms in which making-based activities take place.
Maker-centred pedagogies	Pedagogies that employ maker-centred approaches in teaching and learning practices.
Maker movement	A cultural trend that places value on an individual's ability to be a creator of things as well as a consumer of things. Maker culture emphasizes learning-through-doing in a social environment.
STEM subjects	STEM related subjects in public schools, including: Sciences, Technology Education, Engineering, and Mathematics.

Chapter 1.

Introduction

1.1. Background and problem

Teaching in the sciences and mathematics has recently been faulted for overemphasizing structured curriculum and solo, abstract symbol manipulation over practical, in-situ problem solving. A popular alternative, the “maker” approach, emphasizes semi-structured, exploratory, often collaborative problem-solving, using concrete materials and digital tools (Bullock, & Sator, 2015; Clapp, Ross, Ryan, & Tishman, 2016). This approach has become particularly prevalent in summer camps and public and school library programs, but is increasingly found in secondary and elementary schools. The maker approach is closely related to the *maker movement*, *hacking, tinkering* and *modification culture* (Bullock et al., 2015; Clapp et al., 2016), which are credited for many innovative developments in design and technology over the past few decades. Making can be extended to describe a method of instruction, focusing on the activities of the learners, or as an approach to developing curriculum in a responsive and reflective practice – which leads to an emerging pedagogy known as *maker education*, or *maker-centred pedagogy* (Opperman, 2016).

The recent increased emphasis on making has created an impetus for change, especially in science education. Bullock and Sator (2015) present this as an “urgency associated with reform in science education and science teacher education” (p. 60). The authors echo the need for more enrolment in Science, Technology, Engineering and Mathematics (STEM) programs, as well as to have science teachers “make things” as part of their educational experience. They distill the problem this way: “Current science curricula fail to frame the relationship between science and technology as a symbiotic relationship and thus fail to understand that technology education creates a space for science education” (Bullock et al., 2015, p. 71).

There are several dominant motivations for the current trend towards maker-centred teaching and learning. These include an increasing demand for creative, skilled workers in STEM-related careers (also capable of collaborating in teams); a related demand from parents for focus on STEM topics in schools**;** the increasing availability of and funding for technology in schools; and the perception that a maker approach creates a more inclusive, collaborative and open atmosphere, engaging students who would not have traditionally pursued STEM-related activities. Additionally, a focus on design processes and creativity has led to the increasing inclusion of an *arts* focus (STEAM), which also serves to encourage the use of maker-centred approaches.

Considering public education in Canada, the BC Ministry of Education has been working on revising the Kindergarten to Grade 12 curriculum since 2013. The intention of transforming the BC provincial curriculum is to bring applied learning to all areas of the curriculum by revising the individual areas of learning with greater emphasis on curricular competencies – the *doing* part of the curriculum, because “the ability to design and make, acquire skills, and apply technologies is important in the world today and is a key aspect of educating citizens for the future” (BC Ministry of Education, 2016). In BC's new curriculum, there is a newly defined subject, ADST (Applied Design, Skills, and Technologies), which is a totally new curriculum area for the elementary grade-levels (BC Teachers’ Federation, 2015). The competencies associated with this read are closely related to maker-centred teaching and learning.

“Making is a process that people engage in to design, create, and develop things that are of value and use to them personally or for their community” (Bullock et al., 2015, p.61). Maker-centred learning suggested a new kind of hands-on pedagogy—a pedagogy that encourages community and collaboration (a do-it-together mentality), distributed teaching and learning, boundary crossing, and responsive and flexible teacher practices. The underlying potential of a maker-centred pedagogy can cut across genders, classes, ages, and settings (Clapp et al., 2016; Bullock & Sator, 2018). In the book “Maker-centred learning: Empowering young people to shape their worlds”, Clapp et al. (2016) presents two primary benefits of maker-centred learning:

1) Developing students' discipline-specific knowledge and skills (e.g., science, technology, engineering, and math [STEM] skills) and more maker-based knowledge and skills (e.g., learning to code or how to use a drill press).

2) The more dispositional outcomes of developing agency and building character. Maker-centered learning helps students see themselves as people who can effectively take action in the world, mainly—but not only—by making, hacking, or redesigning the objects and systems in their lives (p. 9).

Maker-centred teaching aims to enable self-directed, interest-driven, peer-involved learning. It helps students to develop a sense of personal agency, a sense of self-efficacy, and a sense of community. By applying maker-centred pedagogies, educators tend to facilitating student collaboration, encouraging co-inspiration and co-critique among students, and promoting an ethics of knowledge sharing by redirecting students' quest for authoritative knowledge away from the classroom teacher and toward other sources of inspiration and information (Clapp et al., 2016).

Maker Education is being increasingly adopted in classrooms that range from middle school to community college and from adult basic education to university labs (Opperman, 2016). Because of the variety of subjects and materials encompassed by the maker approach, its actual applications are similarly variable, context to context. This study has focused on maker-centred pedagogy as it is currently being implemented in public school contexts, which is a relatively limited area of study.

Despite many reports of successful implementation of maker pedagogy in various informal contexts (Vossoughi, & Bevan, 2014; Papavlasopoulou, Giannakos, & Jaccheri, 2017), there is currently a shortage of studies relating to the implementation of maker-centred pedagogies which bridge STEM fields in formal educational settings. This is unfortunate, because maker-centred learning experiences have been promoted for their potential to increase young people's proficiency in STEM subjects (Clapp et al., 2016). It is claimed that this approach can develop well-rounded citizens who are informed creators, and foster the development of future problem solvers and innovators.

In spite of a growing body of research focusing on maker education, the researcher has found that there is not a great deal written about the perceptions and understandings of teachers towards maker-centred teaching and learning in schools. While many studies have found positive outcomes when examining specific tools, interventions, and perspectives (in and out of school contexts), there is little research describing the potential of maker-centred teaching and learning in meeting *existing* and *emerging* needs of teachers and students in the school context. Papavlasopoulou et al.

(2017) call for “classrooms as a direction for future research,” including identifying the benefits of a specific tool, and an “analysis of the Maker Movement approach” (p.57). For current maker educators, one challenge is to come to a personal understanding of maker-centred learning and how it could be woven into the curriculum - integrating maker-centred thinking and learning into their daily classrooms (Clapp et al., 2016; Sator & Bullock, 2017).

Given the above, this study has aimed to investigate the general perceptions on the part of teachers of the BC ADST or STEM curricula with regard to maker-centred pedagogies and examine the current status of the application of maker-centred teaching and learning. The study aimed to construct a holistic picture of the applications of maker-centred pedagogies in Kindergarten to Grade 12 schools in British Columbia, with findings that would have implications for the development and implementation of BC’s new curricula in ADST and STEM at the school level, and provide recommendations for school districts integrating maker-centred pedagogies. The research focused on educators' understanding of maker-centred pedagogies, the strategies and resources to support the implementation of maker-centred pedagogies, and the potential of this approach to meet existing and emerging needs in ADST and STEM education in BC public schools.

This research was conducted using a convergent mixed-method approach, in which both quantitative and qualitative data were collected simultaneously from a large group of teachers of ADST or STEM through an online survey. The qualitative and quantitative data were analyzed separately, the results were compared, and findings were combined to form a more generalizable set of conclusions.

1.2. Research questions

The study was designed to address the following four research questions and sub-questions:

Research Question 1: What are current ADST and STEM teachers’ understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favour or doubt maker-centred teaching and learning?

sub-questions:

- What are teacher’s perceptions of the current situation of ADST and STEM education?
- What are teachers’ understandings of maker-centred pedagogies? Do they favour or doubt maker-centred pedagogies?
- What are teacher’s roles in ADST and STEM education?
- What are the major characteristics of maker-centred teaching and learning as understood by practitioners?

Research Question 2: Are there differences in disciplinary areas related to the application of maker-centred pedagogies?

sub-questions:

- In which subject areas have teachers used maker-centred pedagogies?
- What training did teachers receive on maker-centred pedagogies in different subject areas?

Research Question 3: What are the resources and tools that teachers use and need for implementing maker-centred pedagogies?

sub-questions:

1. According to teachers' understanding, are specific resources and supplies necessary in maker-centred teaching and learning?
2. What resources and supplies are reportedly used in maker-centred teaching and learning?

Research Question 4: What are the teaching / learning strategies that teachers adopt in using maker-centred pedagogies?

sub-questions:

- Are maker-centred pedagogies understood to need specific strategies?
- What strategies are understood to support maker-centred teaching and learning?
- Is the sex of the learner understood to have an impact on the outcomes of maker-centred learning?

- What other features/considerations are important in implementing maker-centred pedagogies?

Halverson and Sheridan (2014) suggest educators design classrooms as makerspaces by focusing on student interest, understanding learning as integrated and connected through projects, rather than as an isolated set of skills. To do so, teachers need to understand the characteristics of maker-centred pedagogies. They need to know how making is being implemented, for whom, and under what conditions – and how making can align with the goals and needs of schools (Martin, 2015). Most important, they need to re-frame their own identity as technology educators instead of transmitters of information and understand their roles as makers of curriculum (Bullock et al., 2015).

As there has been very little research concerning teachers' perspectives about making-based approaches, which the researcher think is important for the successful implementation of maker-centred pedagogies in schools, the study addresses teachers' perspectives as one of the research questions (Research Question 1).

Many factors affect the effectiveness of making-based teaching and learning in classrooms, for example the subject areas and topics involved, and the learning contexts. The literature suggests that current interest in making is mainly focused in educational settings centred around STEM concepts. However, there has been a lack of evidence to identify which are the most common subject areas in which maker-centred pedagogy is applied, and there has been little research concerning the directions it is taking, what opportunities it could present for education, and why (Papavlasopoulou et al., 2017). This is another question explored in this study (Research Question 2).

According to Chu, Angello, Saenz & Quek (2017), a common way to motivate students to learn is to make learning fun, and “making is well-positioned to make learning less of a burden for the child, and more of a fun experience” (p. 31). However, in terms of making-based approaches, the literature does not contain verbose theories as to how making makes learning fun (particularly in formal educational settings), as “our understanding of the child’s experiences in a Making-based educational context is deeply lacking” (p. 31).

Garneli, Giannakos, Chorianopoulos & Jaccheri (2013) relate that students strongly prefer making-based activities over practicing on paper, and the motivation to learn STEM skills was increased through participation in making activities. The study suggested teachers engaging the students with activities that is closely connected to the respective curriculum topics to improve the effectiveness. Indeed, to integrate making into the classroom successfully, educators need to consider the specific strategies required to support maker-centred teaching and learning, and feasible conditions for implementation in terms of students, subjects and learning environments. Teachers also need to learn the technologies and tools for implementing making activities (Bullock, 2016). Finding the appropriate activities (Basawapatna, Repenning, & Lewis, 2013) and standardizing or defining "what works" for learning through making (Halverson et al., 2014) are two big challenges to embracing the maker-centred pedagogies in K-12 schools. These questions are also addressed in this study (Research Questions 3 and 4).

1.3. Outline of the thesis

This thesis consists of six chapters. Chapter 2 provides theoretical grounding for the thesis, presents a selective review of relevant literature regarding making and maker-centred pedagogies covering the major themes targeted in this study, and gaps identified through the literature review. It also discusses the alignment of this study with British Columbia's new ADST curriculum, and the way the research will enrich the scholastic literature. Chapter 3 outlines the research methodology employed in this study, including the recruitment of research participants, the design of the survey instrument and the collection of the data. It also describes the procedures employed in the quantitative and qualitative data analysis.

Chapter 4 focuses on the participants’ teaching backgrounds and their general perceptions about maker-centred pedagogies, presenting the statistical results and qualitative analysis findings with regard to Research Question 1. Chapter 5 focuses on respondents’ views of the current applications of maker-centred pedagogies, the resources and technologies used in maker-centred activities, the strategies for effectively applying maker-centred pedagogies, and important considerations that need to be addressed in implementing maker-centred teaching and learning. This Chapter will present the statistical findings and the qualitative data analysis with regard to Research Question 2, Research Question 3 and Research Question 4. Finally, Chapter 6 provides a detailed discussion of the results with regard to each of the four research questions and sub-questions. It will discuss the relationship of the results to existing studies, the significance of the study, and the implications of the findings for implementing maker-centred pedagogies. The limitations of the study and recommendations for future research will also be discussed.

Chapter 2.

Literature Review

This chapter presents a selective review of previous research with regard to maker-centred pedagogies, providing theoretical grounding for and the major themes targeted in this study. It also discusses the alignment of this study with British Columbia's new ADST curriculum (BC Ministry of Education, 2015 ; BC Ministry of Education, 2016), and explains how this study will enrich the scholastic literature.

The review of literature has included 32 articles and 11 books related to maker-centred approaches in education. Two existing literature reviews that were particularly useful were Vossoughi & Bevan (2014) and Papavlasopoulou, Giannakos, & Jaccheri (2017). Most of the articles reviewed highlighted a wide and increasing interest in the maker movement. They focused on one or more technologies, and many focused on out-of-school and library programs. The most common findings include effects on outcomes, self-efficacy, student engagement, and the effects of specific tools.

2.1. Theoretical grounding

The work of the American philosopher of education, John Dewey, emphasized learning by doing – a hands-on or an experiential approach to learning. Dewey viewed knowledge-making as a dynamic process that unfolds through reflective, iterative interaction with the practical demands and challenges of doing things (Dewey, 1902; Dewey, 1916). Building on Dewey's ideas, Jean Piaget's theory of *constructivism* also connects directly to maker-centred learning, with strong emphasis on tinkering and figuring things out (Piaget, 1928), both of which involve starting with one's own ideas and then shaping those ideas based on direct, experiential actions (Clapp, Ross, Ryan, & Tishman, 2016).

Seymour Papert’s *constructionism* situates the maker approach within an evolving pedagogy that emphasizes construction of knowledge through activity. It holds that learning happens best when learners work directly with manipulable media—from

LEGO bricks to computer code—to build things that are sharable with others (Clapp et al., 2016). Papert's theory helps to situate maker-centred pedagogy in a larger developing approach to experiential learning and the construction of understanding. He emphasizes the importance of tactile or conceptual models: "What an individual can learn, and how he learns it, depends on what models he has available" (Papert, 1980). He suggests that the availability of broad and largely unscripted experiences with a broad range of materials and problem-solving situations is crucial to the construction of knowledge. Papert connects this to Piaget's stages of development, asserting that in order to effectively progress, appropriate experiences must be made available. Papert provides several examples of this, before presenting the computer as the best new tool to help students solve problems and think mathematically, providing concrete conceptual models, such as computer programming techniques (e.g. control of the LOGO turtle) (Papert, 1980).

Another related area of educational theory is *peer learning*, because of the social nature of maker-centred learning, and the distributed nature of teaching and learning in the maker-centred classroom. Scholarly understanding of the importance of peer learning can be traced back to the work of Lev Vygotsky, who promoted the idea that all learning is social (Vygotsky, 1980). The benefits of peer learning include increasing student self-esteem, teamwork, and perspective taking. Maker-centred pedagogies embrace all forms of peer learning, including cooperative learning, peer tutoring, project-based learning, and peer critique and evaluation. In maker-centred learning, students explore ideas together and provide one another with instruction; they work together to create something new, and learn from one another by providing each other with informative feedback (Clapp et al., 2016).

Given the growing use of digital technology in making activities, Rode, Weibert, Marshall, Aal, von Rekowski, El Mimouni, & Booker (2015) present a more contemporary approach to the use of computers in maker-centred learning, discussing the benefits of *computational thinking*. They argue that "Making as the act of creating tangible artifacts has ... been described as an activity that is apt to link the digital and the physical" (p. 240). They also extend this argument and state that "computational making provides better ways to attract a diverse range of students to computing fields" (p. 239). Halverson and Sheridan (2014) further define constructionism as "the theory of learning that undergirds the maker movement's focus on problem solving and digital and physical fabrication” (p. 498).

A major cultural phenomenon in which this study is grounded is the *maker movement.* This movement is associated with ideals and objectives that can be compared and sometimes aligned with contemporary pedagogical practice (Vossoughi et al., 2014; Bullock & Sator, 2015). The maker movement has drawn a lot of attention in recent years, supported by rapid advances in technical and infrastructural development (notably *makerspaces*). The maker movement encompasses “activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented toward making a ‘product’ of some sort that can be used, interacted with, or demonstrated” (Martin, 2015). It “emphasizes cross-disciplinary approaches rather than specialization, the process rather than the end product, and a communal effort rather than work in isolation” (Intel, 2014).

Bullock et al. (2015) describe maker culture as the contemporary expansion of the do-it-yourself (DIY) culture into the realms of technology, especially technologies that make use of electric circuits and computer software. “An ethos of the maker movement may be articulated as creating, developing, and playing with technology through ethical principles such as tinkering and hacking (Bullock et al., 2015, p. 70). Maker culture is not necessarily connected to formal education, but shares the objective of self-motivated mastery learning, playful experimentation and iterative design processes. Papavlasopoulou et al. (2017) have provided a good definition:

> The maker culture can be described as a philosophy in which individuals or groups of individuals create artifacts that are recreated and assembled using software and/or physical objects. Typical topics of interest in maker culture include engineering-oriented pursuits such as electronics, robotics, 3D printing, and computer numerical control tools, as well as more traditional activities such as sewing or arts and crafts (p. 56).

In sum, maker-centred learning is deeply grounded in the progressive learning theories of thinkers such as John Dewey, Jean Piaget, Seymour Papert, and Lev Vygotsky. It is also closely connected to educational approaches like peer learning and computational thinking (Clapp et al., 2016; Rode et al., 2015). The researcher found these theories and approaches helpful in identifying factors that might affect teacher perceptions of the maker-centred approach, and major themes that needed to be addressed in the survey questions. The researcher hoped that the survey responses from the participants with regard to the research questions may be able to provide a clearer picture of the factors that influence the application and potential of maker-centred pedagogies in the context of kindergarten to Grade 12 public schools.

2.2. Relevant Literature

This section will review current research on maker pedagogy in relation to the present study. The reader will note that the majority of studies examined below relate to making as pursued in STEM learning contexts. This is a reflection of the state of the literature and the popularity of STEM as a concept in the field of educational practice, though STEM was not an explicit focus in the literature review. Though STEM is not without its critics (Breiner, Harkness, Johnson, & Koehler, 2012), it is not a central concept in the present research; therefore, the researcher will not explore these criticisms in depth.

2.2.1. Benefits of maker-centred teaching and learning

The practice of making has a long history. Many programs in K–12 schools reflect the multiplicity of purposes inherent in making, and the curriculum has been endorsing hands-on and project-based learning for decades. “The resurgence in making that surfaced in the early 2000s brought with it renewed emphasis on the importance of making in schools” (Clapp et al., 2016, p. 155). Existing research has defined many of the advantages of maker-centred teaching and learning in various specific contexts, and highlighted the importance and potential of out-of-school programs. As a representative example, Garneli, Giannakos, Chorianopoulos, & Jaccheri (2013) found that “teaching programming by making an action game is more effective in comparison to the traditional teaching” (p. 83).

Making as an inquiry-based educational practice can inspire interest, foster engagement, develop understanding of processes and concepts, and support students’ identities as thinkers, creators, and producers of knowledge (Vossoughi et al., 2014). Maker-centred teaching and learning provide an extracurricular means for students to engage in more hands-on projects and develop a large range of important but currently underdeveloped skills (Barrett, Pizzico, Levy, Nagel, Linsey, Talley, ... & Newstetter, 2015). Currently, the maker movement has begun to play a role both inside and outside the classroom. Inside the classroom, students may learn through patterns and simulations, while outside activities may occur in summer camps and libraries (Papavlasopoulou et al., 2017). Makerspaces are attracting students and becoming the hub of activity and learning. The processes of making require learners to encounter and work through mistakes and problems (Bullock et al., 2018). Making activities can help students to discover how their creative ideas can lead to new solutions to old problems, empower students and turn them into confident leaders and problem solvers (Smay, & Walker, 2015).

Despite the fact that most making activities have tended to occur outside the classroom, some research has indicated that there are strong connections between making-based approach and the values of formal schooling. Making can align with the curricular demands of schooling (in particular, engineering practices) and can affirm school-based approaches to teaching and learning (Halverson et al., 2014; Martin, 2015). As the school current system has a heavy emphasis on theory, and students do not often have the opportunity to make things in the classroom, the curriculum fails to frame the relationships between the subjects, and schools struggle to connect reflective learning activities to students' personal interests and everyday lives (Kafai, Fields, & Searle, 2014; Bullock et al., 2015).

Making as a pedagogical practice can adapt students to self-directed learning activities and sustain students’ participation by offering new tools, guides, and autonomy. It welcomes learners’ ideas, helps to clarify the nature of the problems, and fosters reflections (Vossoughi et al., 2014). Smay et al. (2015) state several ways that making-based approach can support curricular practices, including: supporting classroom PBL (project based learning) by offering different ways for students to demonstrate their knowledge through different formats and media; helping to find and share curricular ties between subjects; offering ideas for exploration; planning, coordinating, and integrating a design-based approach to help to cover curriculum; and helping teachers to design their own teaching models and tools.

According to Loertscher, Preddy, & Derry (2013), making activities can develop students’ dispositions with regard to their personal expertise, cooperative group work, and collaborative Intelligence. Vossoughi et al.’s (2014) review of literature suggested that, “making can provide a powerful context for integrating the socio-emotional and disciplinary dimensions of learning, and broadening interest and engagement in STEM” (p. 12). In this review, Vossoughi et al. (2014) summarized the major benefits of making as an educative practice in the following three aspects:

1) Position and support young people to participate in science programs and learning activities, including how making programs support opportunities for belonging and mattering; developing interest and identity and expanding experiences and skills in communication, leadership, and the negotiation of differences.

2) Structure and implement program activities to support young people’s learning and development, including providing opportunities for skill building and connections to community and school experiences, the development of conceptual understanding, STEM skills, scientific ways of knowing, understanding of how science is practiced in the world, and critical thinking, reasoning, and innovation.

3) Create a supportive community of learners that can leverage the interests and skills of each member of the group towards shared goals, including opportunities to develop supportive relationships and positive social practices as well as flexibility, initiative, appreciation of diversity, and metacognition (p. 12-13).

Halverson et al. (2014) stress three components of the maker movement, i.e., “making as a set of activities, maker spaces as communities of practice and designed learning environments, and makers as identities of participation that afford new forms of interaction between self and learning” (p. 502-503). In their book, *Maker-Centered Learning: empowering young people to shape their worlds,* Clapp et al. (2016), a research team from Harvard Graduate School of Education (HGSE), emphasize the “biggest aspiration for maker-centered learning” of developing “a sensitivity to the designed dimensions of one's world” (p. 156). The authors argue that, through making activities, students can benefit not only from acquiring making and discipline-specific knowledge and skills, but also from building character, gaining creative confidence, and being resourceful and courageous. Maker-centred learning helps students “to see that world as malleable, and ultimately to believe in one's capacity to shape that world through building, tinkering, re/designing, or hacking” (p. 9).

According to Blikstein (2013), Digital fabrication and making can bring “powerful ideas, literacies, and expressive tools to children” (p. 204), and are “typically associated with the learning and practice of STEM disciplines” (p. 215). Furthermore, “The making of a physical project will always entail some engineering work”. Even though in Blikstein’s study, students were working on a history-themed project, “they ended up having to explore multiple topics in mathematics” or “encountered physics in authentic ways” (p. 217).

Clapp et al. (2016) expound the key characteristics of the educational environments and instructional designs of maker-centred learning, including: 1) In the maker-centred classroom, students are strongly encouraged to teach, and to teach in a variety of ways; 2) Maker-centred teaching presents challenges and opportunities and focuses on facilitating student collaboration, encouraging co-critique and co-inspiration, and promoting an ethics of knowledge sharing; 3) Maker-centred learning is the process of trying to figure things out, in which each one involves choice and ongoing self-direction and exercises agency in support of their own learning; and 4) Maker-centred learning often occurs in special settings such as makerspaces, fablabs, and tinkering studios, and these spaces are usually set up with tools and materials, storage and visibility, and specific and flexible spaces.

In summary, the literature reviewed highlights the following potential benefits of maker-centred learning: 1) it can empower students as self-directed learners and support students’ identities as thinkers, creators, and problem solvers; 2) it can help students to understand processes and concepts, and develop a large range of important skills; 3) it can inspire students’ interest, and therefore improve the engagement in and outcomes of learning activities; 4) it can cultivate students’ collaborative Intelligence, and foster a sense of community; and 5) it can support curricular practices by providing a powerful context for integrating the socio-emotional and disciplinary dimensions of learning.

2.2.2. Applications of making approaches

A second important topic addressed in the literature reviewed for this study is the current applications of making approaches in various contexts.

Some authors present studies focused on one or more technologies used in making activities in school classrooms and examined the effects of specific tools. For instance, Basawapatna, Repenning & Lewis (2013) report an exploration into making programming accessible for G6 students with no programming experience by using the the Simulation Creation Toolkit over 3 days. The results suggest that the learning activities made an analogy between the real world interaction and Computational Thinking Pattern, so that students with minimal prior experience can effectively model real-world interactions.

Employing a mixed-method approach, Chu, Angello, Saenz, & Quek’s (2017) performed one week-long study that examined the student’s learning experience within curriculum-integrated maker activities in which students build electric sifter and mixer with electronic components and tools. The study was conducted in the 3rd, 4th, and 5th grade science classes in the elementary school classroom, and the results showed that making activities had positive impacts on student’s accomplishments and collaborations. Kafai et al. (2014) presented a study investigating the maker activities of high school students' e-textile designs in three workshops over a period of 12 weeks. The findings of this study show that it is important to involve students in creating in two distinct modalities of learning, i.e. the digital and the material.

Many authors reported on maker activities in after school programs, of which makerspace is a frequently mentioned setting where making take place. For example, Smay et al. (2015) discussed the implementation of a makerspace in a school library in a private school (K – 12) and highlighted how making, as a blended model, supports the project-based learning (PBL) and STEM initiatives the teachers were embracing in the context of current educational trends. Loertscher et al. (2013) introduced a makerspace in a school library learning commons. They elaborated the four levels of expertise of what they call the uTEC Maker Model (Using, Tinkering, Experimenting and Creating), and how this model guides learners through the creative and inventive processes. Lamb (2015) stated using online resources to expand makerspaces in the school library, and noted that “makerspaces provide youth with a place to imagine, design, create, construct, and express ideas. Both individual and collaborative products emerge as children tinker and invent” (p. 56).

Some makerspaces have been intentionally designed to address existing inequities in larger communities, as well as to support learning. Grounded in their research and teaching in the Tinkering Afterschool Program, as well as in the insights and questions raised both inside and outside the maker movement, Vossoughi, Hooper, & Escudé (2016) present a framework that treats the following principles as starting points for equity-oriented research and design: critical analyses of educational injustice, historicized approaches to making as cross-cultural activity, explicit attention to pedagogical philosophies and practices, and ongoing inquiry into the sociopolitical values and purposes of making.

Vossoughi et al. (2014) present a review of literature pertaining to three categories in the context of Out-of-School Time (OST) STEM: 1) making as entrepreneurship and community creativity; 2) making as STEM pipeline and workforce development that engage high school and university students as part of an extended STEM curriculum; and 3) making as inquiry-based educative practice may take place in classroom, library, museum, after-school or community settings to "inspire interest, foster engagement, develop understanding of processes/concepts, and support students' identities as thinker, creator, and producers of knowledge" (p. 6). Vossoughi et al.'s (2014) study shows that the majority of peer-reviewed papers pertains to the third category (making as inquiry-based practice) and most of the previous research focused on out-of-school maker spaces, clubs, and museum settings, and were mainly conducted through a qualitative approach.

2.2.3. Use of tools in making

Tools and technologies are important elements mentioned in many publications regarding making activities. For instance, Clapp et al. (2016) stress using tools and techniques for supporting maker-centred thinking and learning.

In the literature reviewed for this study, many researchers mentioned the use of electronic and digital tools in maker-centred learning. For example, Kafai et al.'s (2014) study used electronic textiles as disruptive designs to support making in high school workshops. They found that e-textile maker activities have the potential to diversify students' perspectives on who can and should participate in crafting, computing, and engineering. According to these authors, "creating e-textiles involves knowledge in multiple domains, ... introduces challenges that are particularly needed in schools” (p. 8). In a case study performed by Rode et al. (2015) in a computer club of an elementary school, students used electronic tools (e-textile, LilyPad, Arduino, and electronic kit) in maker activities to practice a wide variety of computational thinking skills.

In their review of 35 university maker spaces (most in libraries), Barrett et al. (2015) mention the use of 3D printers, laser cutters, and electronic tools, and indicate the impact of access to resources on making practices, stating that “as the price of the technology associated with ‘making’, such as the cost of 3D printers, declined, it allowed for greater development of maker spaces” (para. 3). Papavlasopoulou et al.’s review (2017) shows that most studies used digital materials and tools to support making activities. They call for future research on the technologies and tools used in limited studies, but have promising potential, and studies on integrating maker instruction as part of the classroom.

Some researchers mentioned using digital games to improve students’ engagement and learning outcomes. For instance, Garneli et al. (2013) present a study investigating the effects of games on learning performance and attitudes in grade 6 mathematics classes. Their research shows that students “strongly prefer the repetition of this learning process in the future instead of practicing on paper” (p. 82). Additionally, Basawapatna et al.’s (2013) study shows that the use of end-user game programming tools can “increase student motivation in I.T. and computer science” (p. 501), and there is a connection between creating simulations and computational thinking, and the access to these kind of tools. However, “in-class units that involve modelling have not readily been adopted into classrooms nationwide [in the United States].” The biggest obstacle is “time to put together the resources, [and] finding activities that are appropriate” (p. 502). The authors suggest future studies on a large scale and further exploring the extent to which the tools can be used.

Except expensive and high-tech equipments, a few publications stated using other tools and resources in making activities. For example, Clapp et al. (2016) mentioned some of the “most modest tools and materials” (p. 79) used in innovation labs and makerspaces, such as a glue gun and some cardboard. They argue that, “powerful maker-centered learning experiences can take place in much more modestly equipped settings with much simpler tools” (p.79). Lamb (2015) emphasizes using various online resources and tools for expanding makerspaces, including resources to stimulate curiosity; tools for design, planning and creation; multimedia communication resources and simulation resources, etc.

2.2.4. Strategies to support making

The strategies to support and improve the effectiveness of maker-centred learning has not been much explored in the literature. There are ”very few descriptions of collaborative strategies and how they contribute to individual learning.” Papavlasopoulou et al. (2017). However, some publications have launched interesting inquiries.

Chu et al (2017) stress that it is important for future research to study how to support the child’s collaborative maker experience within learning contexts, investigate curriculum-based making on different science topics, and examine the use of different assessment instruments.

Relatedly, Garneli et al. (2013) also suggest that “a fundamental principle of effective learning is that all students learn if the appropriate personalized conditions are given to them” (p. 76). They recommend that to improve student’s learning performance, making activities “should engage the students with code that is closely connected to the respective curriculum topic” (p. 83). On the other hand, Kafai et al. (2014) argue that making need developing “an alternative view of students and teachers” by “viewing students as problem solvers and inquirers and teachers as coaches, guides, and prodders” (p. 13).

2.2.5. Cautions and recommendations

In the publications reviewed for this study, many authors mention the lack of empirical research addressing various aspects of making, and provide suggestions for future studies. As Papavlasopoulou et al. (2017) point out, there has been wide interest in the maker-centred approaches, and the most common subject areas for making are settings centred around STEM concepts. However, “there has been a lack of evidence to identify which are the most commonly used subject areas…[making] could be applied” (p. 58), and “there has been little research concerning the direction it is taking, the opportunities it could present for education, and why" (p. 59).

Maker-centred learning requires more creativity and self motivation compared to most of traditional approaches. Papert (2002) described this kind of challenging learning activity as "hard fun", and emphasized the importance to "harness the passion of the learner to the hard work needed to master difficult material and acquire habits of self-discipline" (para. 1). Vossoughi et al. (2014) state the need for attention to "how making is being implemented or studied as equitable practice, for whom, [and] under what conditions" (p. 34). They summarize some of the cautions and recommendations voiced by other researchers, which include: 1) avoid limiting the openness of maker definitions by tying making more narrowly to STEM outcomes, 2) implement making in school settings with a tripartite focus (tools, community infrastructure, and maker mindsets) rather than fetishizing tools, 3) in maker-centred activities, use everyday materials to extend and deepen student's explorations across contexts, 4) the educational or school focused applications of making tend to focus on middle and high school students, 5) consider longer-term investments in new programs, and 6) be aware of the need for more explicit and detailed analyses of pedagogy in making environments.

Relatedly, Halverson et al. (2014) note that "while school-based makerspaces will likely include the newest technological toys, such as 3-D printers and laser cutters, the focus in design for learning is not on tools but on the process and the product" (p. 499). They state the structural challenges to making, such as "questions of access, scale, and staffing", and assert that "the greatest challenge to embracing the maker movement in K–12 schools, especially in our current accountability environment, is the need to standardize, to define 'what works' for learning through making" (p. 500). Kafai et al. (2014) also state the challenges to integrate e-textile activities in schools and note that "a prescribed curriculum, an extremely limited time period, or students who are unaccustomed to project-based learning are the potential obstacles to implementing a students-as-designers model" (p. 13).

Concerning the application of making in K-12 schools, Martin (2015) highlights four valuable elements of the maker mindset, that is Playful, Asset- and growth-oriented, Failure-positive, and Collaborative. Martin argues that "the potential value of making for K-12 education is perhaps most directly seen in relation to the new Framework for K-12 Science Education" (p. 31), and calls for further studies with regard to "when and how autonomy, and other aspects of the maker mindset are essential for learning" (P. 36), and how making can align with the goals and needs of schools.

Another theme to be further developed, identified by Papavlasopoulou et al. (2017) and Dayton (2017), is the need to analyze the outcomes of making by gender as well as age. Some suggest that maker-centred learning will increase motivation to further pursue STEM education and careers among girls, avoiding what Margolis and Fisher (2003) describe as a "leaky pipeline" affected by many different factors over time (p. 3). These authors suggest that the pedagogy pursued in secondary schooling may influence the self-perception of girls and women as less suited to careers in technology than boys and men, and maker-centred pedagogy may provide more girl-friendly early experiences to reduce the perceived gap. Clapp et al. (2016) reiterated the concerns about equity and access in STEM classrooms, and asked how maker-centred learning can be accessible to a broader and more socially and culturally diverse population. Kafai et al. (2014) and Peppler (2013) present examples of a contemporary success of this approach with e-textiles.

This argument for inclusiveness aligns with a broader and more established claim that maker education can be more open and democratic than pedagogies centred on single disciplines, and the abstract manipulation of symbols in an environment focused on solo performance. Papert describes an ideal bridge between "technical-scientific and humanistic cultures [...] to unite, hopefully without homogenizing, the fragmented subcultures that coexist counterproductively in contemporary society." For Papert, this might also extend to the eventual obsolescence of schools "as we know them today"; this is a provocation to reform that has not disappeared (Papert, 1980, p. 9). Additionally, Resnick (1993) emphasizes the need for a *democratization* of technology through education, characterizing programming specifically "as a medium for expression, not a path toward a career." Martin (2015) describes the maker movement's potential to bring about "the beginning of a much larger social and economic transformation." Vossoughi et al. (2016), however, caution against "uncritical adoption into the educational sphere" of maker values.

2.3. Alignment with BC's new ADST curriculum

According to the "Applied Design, Skills, and Technology Framework" from the

BC Ministry of Education (2015), ADST is “an experiential, hands-on program of learning through design and creation.” “It envisions a K–12 continuum fostering the development of the skills and knowledge that will allow students to create practical and innovative responses to everyday needs and problems” (BC Ministry of Education, 2016).

The BC ADST curriculum features a focus on designing and making, the acquisition of skills, and the application of technologies (BC Ministry of Education, 2016). It aims to build on students' natural curiosity, inventiveness, and desire to create and work in practical ways. It includes skills and concepts from the disciplines of Business Education, Information Technology, and Technology Education, as well as rich opportunities for cross-curricular work and space for new and emerging areas, such as Media Arts (BC Ministry of Education, 2015).

Given these attributes, the researcher considers maker-centred pedagogy to be a promising approach in ADST education, to provide firm foundations for students’ lifelong learning and a diverse range of careers. Applying maker-centred pedagogies in the ADST classroom may be very helpful for reaching the specific goals of the ADST curriculum in students' development – that is, acquiring practical skills and knowledge that bring their ideas from conception to fruition, developing a sense of efficacy and personal agency about their ability to participate as inventors and innovators, and developing a lifelong interest in designing, making, and evaluating products, services, and processes (BC Ministry of Education, 2015).

As ADST is a newly defined subject area in BC, ADST teachers are facing some evident difficulties in implementing the new curriculum effectively. Besides an overall lack of resources, a big challenge that faces teachers in implementing ADST is the lack of a practical framework and guidelines for performing ADST practices in schools, especially in the elementary grade levels (BC Ministry of Education, 2016; BC Teachers’ Federation, 2015). Therefore, ADST teachers have a strong motivation to document and develop strategies and practices to facilitate their teaching and promote students' learning in ADST classrooms.

In view of maker-centred pedagogies being very relevant to both STEM and ADST competencies, and relevant to both STEM and ADST education, the researcher identified STEM and ADST teachers as the target population for this thesis research. The study focused on investigating the current applications of maker-centred pedagogies, exploring their potentials in both ADST and STEM classrooms, in order to provide useful suggestions for implementing the new BC curriculum effectively, and develop some meaningful implications for applying maker-centred pedagogies in Kindergarten to Grade 12 school settings.

2.4. Towards a study of perceptions and applications of maker-centred pedagogies

In reviewing the literature, some shortcomings of the available research were identified. These shortcoming included an overemphasis on non-school contexts, scarce research on general educators' perceptions of maker-centred pedagogy and the learning strategies necessary to implement it, few considerations of the needs of diverse age groups, little emphasis on gender and learner characteristics, and an overemphasis on positive outcomes.

This literature review revealed that despite the large number of publications concerning the maker movement and making activities, most of the studies have focused on activities taking place in after-school programs, or focused on participants' fragmented experiences of making activities in some specific circumstances. This is likely due to the fact that early enthusiasm for making focused around special tools and resources that usually do not exist in school settings. As a result, not much appears to be known in the academic realm about the general situation of the application and implementation of maker approaches in formal school settings. Research that investigates teachers' understanding and perceptions with regard to making approaches has also been scarce. Greater consideration of school contexts is warranted, especially as it relates to making as a part of ADST and STEM education across Kindergarten to Grade 12 grade levels in BC and elsewhere. Further, there is a need for more explicit and detailed analysis of maker-centred pedagogies (Vossoughi et al., 2014; Barrett et al., 2015).

Larry Cuban (1986) provides a historical approach to understanding the adoption of technology in public schools, using examples of such as radio and television. He presents a series of considerations (such as classroom structure, school culture, efficiency, and cost) that affect teachers' willingness to integrate new technologies and teaching methods. Central questions he asks of new technologies include: “Is it simple? Versatile? Reliable? Durable? What is the personal cost in energy versus return in worth for students? Will these new machines help solve problems teachers (and not nonteachers) define?” (Cuban, 1986, p. 66) The researcher feels that Cuban has identified factors that should be systematically examined if we are to understand current practice and extend the study of maker-centred pedagogies.

Maker-centred teaching and learning have shown promise in informal ADST and STEM education. However, few studies have so far focused on curriculum-based making in formal school settings. Prior research focused on informal contexts such as makerspaces and clubs which are located in community settings, libraries and museums. There is an urgent need to explore the resources and tools needed by teachers to implement maker-centred pedagogies in school settings, and the specific strategies that may be effective there.

This thesis attempts to enrich scholarly understanding of the current applications and potential of maker-centred teaching and learning in both ADST and STEM education in Kindergarten – Grade 12 schools.

This review also revealed that the majority of the studies regarding making employed qualitative methods (Bullock et al., 2015; Margolis et al., 2003; Martin, 2015; Kafai et al., 2014). Papavlasopoulou et al. (2017) identified this as a strength, stating that “qualitative measures are more suitable [...], as it has special value for investigating complex issues, such as children’s attitudes to computer science, mathematics, and engineering, topics such as self-efficacy, and general impressions about the process of making activities” (p. 61). However in existing research there is a lack of balance between qualitative and quantitative approaches. While qualitative research does support naturalistic generalization (Stake, 1995; Flyvbjerg, 2001), it is a challenge for readers to compare the findings of various studies that take place in unique settings and gain a larger understanding of how the maker movement is influencing teaching generally, such as teachers’ choice of different tools and approaches to maker-centred teaching and learning. For this reason, this study has employed a convergent mixed methods design, in order to benefit from the unique strengths of both quantitative and qualitative approaches.

Chapter 3.

Methodology

3.1. Research Design

For effective research design and the correct choice of research methods, researchers need to consider their research purpose, research participants, and the balance between strengths and weaknesses associated with different methods (e.g., qualitative vs. quantitative) to ensure that the data collected can address the research questions effectively (Virginia Tech, 2018).

Each research method has different strengths and disadvantages. Qualitative approaches tend to collect richer information, but involve challenges with interpretation, generalization, and replication. Quantitative approaches may support the rapid collection and analysis of data, but can also have substantial blind spots because only the phenomena that are expected to be important are gauged (Caruth, 2013). To combine the features of both research approaches, mixed method research (MMR) had been established. It evolved in response to the observed limitations of both quantitative and qualitative designs, and has become increasingly accepted by researchers (Caruth, 2013).

Creswell (2012) discussed the unique strengths of different methods in educational research in his book *Educational Research: Planning, Conducting and evaluating Quantitative and Qualitative Research*. He argued that quantitative study is strongest for discovering general trends, while qualitative study provides the best way to explore a phenomenon in-depth. Quantitative research is useful in supporting a small team gathering data from a large number of people, and permits the use of statistical tools for generalizing results. On the other hand, qualitative research approaches permit deeper exploration of participants' unique perspectives and experiences, which can be useful for naturalistic generalization (Stake, 1995; Flyvbjerg, 2001). Mixed-methods research attempts to incorporate the strengths of both quantitative and qualitative methods, offering richer insights into the research problem(s) and question(s), and reducing the impact of blind spots which quantitative or qualitative research alone may be subject to. It may also develop questions of interest for future studies (Creswell, 2012; Caruth, 2013).

Caruth (2013) argues that mixed-method research designs possess many potential advantages, including:

a) Handling a wider range of research questions than either a qualitative or quantitative approach by itself.
b) Providing opportunity to use qualitative data (e.g. words, photos, and narratives) to add meaning to quantitative data (numbers), and use of quantitative data to add precision to qualitative data.
c) Possessing advantages in the enhancement of validity through triangulation (ie. cross validation of qualitative and quantitative analyses).
d) Allowing the addition of insight and understanding that might be missed when only a single research design is used.
e) Allowing formulation of more robust conclusions.
f) Having greater capability to generalize the results compared to using only qualitative designs.

As mentioned in previous chapters, earlier research regarding maker-centred pedagogies has primarily been conducted using qualitative approaches. There have been relatively few quantitative studies on this topic, therefore findings have been difficult to compare and generalize. This has made it difficult to identify the full range of resources and strategies that have been used to support maker-centred teaching and learning across different settings. While many studies have reported positive outcomes by examining specific tools, interventions, and perspectives, there has been little research investigating the overall application status of maker-centered pedagogies on a broader scale. There also are not many studies describing the understandings and perceptions of teachers about maker-centred pedagogies.

To address these limitations in prior research, this study examined both educators' understanding of maker-centred pedagogies and the current application status of maker-centred teaching and learning in two school districts.

In order to discover the general understanding of maker-centred teaching and learning in formal ADST (Applied Design, Skills and Technologies) and STEM (Science, Technology, Engineering, and Mathematics) education, as well as to make an in-depth exploration of the key factors of implementing maker-centred pedagogies, this research employed a mixed methods approach, namely a convergent parallel design. The study involved simultaneously collecting both quantitative and qualitative data, analyzing the qualitative and quantitative data separately, and then comparing and merging the results of the two analyses to understand the phenomena under study. The rationale for this design is that the two data types supplied different strengths to offset the weaknesses of each other, and to supplement each other so that a more complete and coherent understanding could be reached (Creswell, 2012). The research design thus allowed the researcher to consider the qualitative data within the context of the quantitative data, and allowed the researcher to take the strengths and advantages of both quantitative and qualitative studies and benefit from using the analysis techniques relevant to both data types.

In order to collect the research data, an online survey was designed, which will be described in the following sections. This online questionnaire consisted of three parts and included both closed-form and open-ended questions. The targeted survey participants were a large group of current ADST and STEM teachers. The quantitative data were compiled from the participants' responses to the closed-form questions, which focused on the general perspectives of educators of ADST or STEM regarding maker-centred pedagogies. Concurrently, the qualitative data were compiled from the responses to the open-ended questions of the same group of participants. These questions elicited teachers' thoughts about the major characteristics of maker-centred teaching and learning, and the strategies, considerations, challenges and needs they were aware of when implementing maker-centred pedagogies.

In the view of the researcher, teachers' thoughts and beliefs about maker-centred pedagogies are worthy of study for at least two reasons. First, if maker-centred pedagogies are to thrive in school settings, it is necessary to provide supports that take account of teachers' beliefs and experiences. For example, professional development efforts are unlikely to be effective if they are viewed by teachers as not providing skills and knowledge that are relevant to the challenges they are conscious of. Furthermore, it is important for researchers promoting maker-centred pedagogies to understand what meaning teachers are making of their innovations. While not everything that teachers think and believe about maker-centred pedagogy is necessarily true, it is nonetheless important to understand.

3.2. Research Sites and Participants

The research sites for this study were public elementary and secondary schools in two districts in the lower mainland of British Columbia (BC), Canada. The researcher elicited survey responses from the public school teachers who were teaching subjects related to ADST (Applied Design, Skills and Technologies) in Kindergarten to Grade 7 classes, as well as the teachers who were teaching science, technology, engineering or math (STEM) subjects in secondary schools at the time of recruiting.

Prior to data collection, the study design and all research instruments and consent forms were submitted for review to the Office of Research Ethics (ORE) of Simon Fraser University, and ethical approval was obtained. Afterwards, the research proposals were submitted to the related school districts (Surrey SD36 and Coquitlam SD43) for permission to conduct the data collection with the teachers. After obtaining the approvals, the recruitment of the research participants was conducted from the population of teachers of ADST or STEM, and the online questionnaire was then distributed to the participating teachers. Potential participants were contacted through their publicly-available district email addresses and by contacting the Principals and Department Chairs of the participating schools, and requesting them to forward the research invitation to teachers internally. This recruiting procedure was undertaken to comply with school district policies, and to ensure that the sample would include teachers with different teaching experiences and backgrounds. In particular, to maximize the representativeness of the sample and to minimize the possibility that the sample would be biased in favour of teachers who were more familiar with maker pedagogies, a participation incentive was offered (as detailed in Section 3.3).

3.3. Instrument and Consent Process

An online survey questionnaire was developed for data collection. Before the link was emailed to the whole cohort of candidates, the online questionnaire was first pilot tested with two volunteers to acquire their feedback on the formulation of the questions, and revisions were made to some of the questions based on the feedback. These two volunteers did not participate in the full study. The finalized online questionnaire consists of both closed-form and open-ended questions, and requires roughly fifteen to twenty minutes to complete. The survey instrument appears in Appendix A.

In the survey, sixteen closed-form questions addressed the participants' teaching backgrounds, their general perceptions of maker-centred teaching and learning, the current status of applying maker-centred approaches, and the needs and challenges with regard to implementing maker-centred pedagogies in formal school settings in BC. These questions had focused on the following five areas: 1) teachers' perceptions on current situations of ADST and STEM education; 2) teachers' understandings of maker-centred pedagogy and their favour for or doubts about maker-centred teaching and learning; 3) the application of maker-centred pedagogies in different disciplinary areas; 4) the roles that teachers should play in ADST and STEM education; and 5) the resources and strategies that can support the application of maker-centred pedagogies.

Twelve closed-form questions asked the participants to indicate their understandings and perceptions of maker-centred pedagogies and their application by responding to the attitudinal question statements in a 5-point scale from "strongly agree" to "strongly disagree." The remaining four closed-form questions required the participants to indicate the grade-levels and the subjects they were teaching or have taught at public schools, from a multiple selection list.

Open-ended questions were also provided on the survey. Each question was framed with the intention of allowing participants to share their views in their own words (Creswell, 2015). These questions allowed participants to provide further details about their backgrounds and perspectives related to maker-centred pedagogies, as well as other important aspects of or challenges with maker-centred pedagogies that had not been covered in the closed-form questions. This part included six open-ended questions that addressed the following topics: 1) the characteristics of maker-centred teaching and learning compared to other approaches; 2) the strategies that can support and facilitate maker-centred teaching and learning; 3) the technologies and tools that are used in maker-centred activities; 4) the important features and considerations that need to be addressed in maker-centred classrooms; and 5) the current situation of teacher training related to maker-centred pedagogies.

Responses to the online survey were anonymous. In the informed consent process, participants were assured that their individual responses would not be shared with school district officials or any third parties. In order to protect participants' personal privacy, their names and other potentially identifying information were removed from their open-ended responses and replaced with pseudonyms (fictitious names) during reporting.

In the survey invitation, participants were assured that their participation in this research was voluntary, and that they were free to withdraw from the study at any time. As compensation for their time and effort participating in the study, all participants were also offered the option to enter a prize draw for a $20 Starbucks gift card, with a chance to win of no less than 1 in 10.

3.4. Data Collection, Data Analysis and Report

3.4.1. Data collection

Quantitative data and qualitative data were collected simultaneously through gathering the participants' responses to the closed-form questions and open-ended questions of the survey. The online survey was developed and implemented on the secure SFU WebSurvey platform. A total of 98 submissions were received, of which 97 submissions contained complete enough responses to the survey questions that they could be used in the subsequent data analysis. One response was substantially incomplete, and was discarded.

3.4.2. Data analysis and report

Analyses for the quantitative data and the qualitative data were carried out separately.

Quantitative analysis

The statistical analysis package GNU PSPP (Free Software Foundation [FSF], 2007, Version 0.8.5) and LibreOffice (The Document Foundation [TDF], 2016, Version

5.1.6.2) were employed for conducting statistical analysis and presenting the results. The process of quantitative data analysis consisted of five steps:

1. Preparation and organization of the quantitative data – the participants' responses to the closed-form questions. This included exporting raw data from the WebSurvey platform, assigning numerical scores from 1 to 5, to the data in corresponding to the 5-point scale data measures, from "strongly disagree" to "strongly agree", and saving the data in the appropriate file formats for using the analysis software.

2. Cleaning up the data and importing the quantitative data into PSPP (FSF, 2007). The data cleanup was required to address two distinct issues. For descriptive analysis, some participants did not provide responses to one or more of the scalar questions, so the corresponding cases were treated as missing data and were removed from the dataset when analyzing the responses to the related questions. In preparation for the inferential analysis, it was found that some teachers taught multiple grade-levels and (or) multiple subjects that crossed groups. These cases (which were not numerous) were treated as invalid and were discarded in the inferential statistical analysis when performing group comparisons.

3. Conducting the descriptive statistical analysis to examine the frequency distributions and the measures of central tendency for each of the variables concerning the research questions.

4. Carrying out inferential analysis to compare the means between groups (e.g. grade level, disciplinary area, and sex). This step included conducting the t-test for two independent samples and calculating the effect size *d* to compare groups of different grade-levels and different sexes, and performing One-Way ANOVA by doing the F-test for three independent samples to compare groups of different disciplinary areas, and performing the post hoc test (Turkey's HSD Test) if a significant F was found (Coladarci et al, 2008).

5. Forming scales from related items and conducting reliability analysis. This involved using GNU PSPP calculating Cronbach's alpha to examine the internal consistency for composite scores of the scales (Creswell, 2015; UCLA).

Quantitative analysis

The qualitative analysis software NVivo 12 Plus (QSR International Pty Ltd [QSR], 2018, Version 12.0) and LibreOffice (TDF, 2016, Version 5.1.6.2) were used to facilitate the qualitative data coding. The analysis of the qualitative data proceeded inductively, pursing the following steps iteratively:

1. Preparing and organizing the data. This included exporting raw data from the survey platform, re-saving it in the required file format for NVivo, and reading through the data to obtain a general sense of the variety among participants' responses.

2. Conducting an initial open coding in NVivo (QSR, 2018) by labelling text segments in as much detail as possible to explore the participants' subtle and in-depth understandings and opinions.

3. Performing a thematic coding by grouping and reducing the list of codes to form themes representing the major ideas in the database with regard to the research questions.

4. Validate the accuracy of the findings through double coding until satisfactory reliability is reached. The online utility ReCal2 (Freelon, 2017) was used to compute intercoder reliability coefficients for qualitative coding results coded by two coders.

5. Building descriptions of the themes and compiling examples and tables to illustrate each theme and present the findings in the research report.

6. Validate the accuracy of the findings through double coding until satisfactory reliability is reached. The online utility ReCal2 (Freelon, 2017) was used to compute intercoder reliability coefficients for qualitative coding results coded by two coders.

Report of findings

The process and results of all data analyses are introduced in the following two chapters. Both chapters contain quantitative and qualitative analyses, to illustrate the research questions under study. Chapter 4 focuses on the participants' teaching backgrounds and their general conceptions about maker-centred pedagogies. Chapter 5 presents data analyses and findings with regard to the applications of maker-centred pedagogies, the resources used in and the strategies support for applying maker-centred pedagogies, and the important considerations that need to be addressed in implementing of maker-centred teaching and learning.

Chapter 4.

Data Analysis (I): Background and Understanding

This chapter focuses on the data analysis and interpretation of the online survey responses to investigate the survey participants' background and to address the first research question of this study, "What are ADST and STEM teachers' current understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favour or doubt maker-centred teaching and learning?"

The analysis process employs both quantitative and qualitative techniques. Quantitative and qualitative analyses will be compared and combined to acquire a comprehensive understanding with regard to the related research questions.

The Chapter consists of four sections. Section 4.1 focuses on participants' backgrounds, and presents a descriptive analysis of the quantitative data with regard to participants' teaching backgrounds and their previous experience related to maker-centred teaching and learning. This section also discusses qualitative data regarding the training that respondents have received on maker-centred pedagogies.

Section 4.2 addresses several sub-questions of Research Question 1 (e.g., the teachers' understandings and perceptions of maker-centred pedagogies), using quantitative approaches to examine the general trends, frequency distributions and measures of central tendency. The variables examined in this section relate to teacher's perceptions of the current situation of ADST and STEM education, their favour (or doubt) about maker-centred pedagogies, and teachers' roles in ADST and STEM education. Both descriptive and inferential analysis are included in this section.

Section 4.3 also addresses Research Question 1, but uses a qualitative approach to obtain more detailed information on specific characteristics of maker-centred pedagogies and develop a more in-depth understanding of how the participants view maker-centred pedagogies and why. This qualitative analysis includes an initial open coding of the survey responses as well as a more systematic analysis of derived themes. The results and findings are interpreted and presented in relation to major characteristics of maker-centred pedagogies, to address another sub-question of research question 1.

The last section, 4.4, provides a overall summary of the Chapter. This section summarizes the data analysis results acquired through both quantitative and qualitative approaches, highlights the major findings from each of the sections, and elaborates the conclusions arrived at with regard to the corresponding research questions.

For clarity, the research questions discussed in this Chapter are listed below.

Research Question 1: What are ADST and STEM teachers' current understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favor or doubt maker-centred teaching and learning?

Sub-questions:

- What are teacher's perceptions on current situation of ADST and STEM education?
- What are teacher's understanding of maker-centred pedagogies? Do they favor or doubt maker-centred pedagogies?
- What are the teacher's roles in ADST and STEM education?
- What are the major characteristics of maker-centred teaching and learning?

4.1. Participants backgrounds

This section introduces the data analysis procedures and results regarding the teaching backgrounds and experience of the survey participants. In order to obtain a holistic picture of the current application status of make-centred pedagogies in a wider scope, the sampled population of the study includes teachers from different disciplinary areas (ADST-related classes, mathematics, science subjects, technology, and engineering classes), teaching different grade-levels (from Kindergarten to Grade 12), and with different levels of experience related to maker-centred pedagogies.

Descriptive statistical analysis was performed and findings are presented for seven variables below:

1) the school district that the participant works for,
2) the participant's gender,
3) the grade levels that participant currently teaches,
4) the grade levels that the participant has taught,
5) the subjects that the participant has taught,
6) participant's familiarity with maker-centered pedagogies, and
7) the training that participant had received on maker-centered teaching and learning.

4.1.1. School district and gender

The targeted population of this research was public school teachers from two typical school districts in the lower mainland of British Columbia who were currently teaching ADST related classes and/or STEM courses at the time of the recruitment. The recruiting process had been conducted with an aim to include teachers with a wide range of teaching experiences and demographic backgrounds (e.g. age, and gender) in order to acquire as comprehensive and representative a set of results as possible given limitations of time and budget for the study.

With the cooperation of school district personnel, the invitation letter and online survey questionnaire were widely distributed to potential participants using internal school district e-mail lists. In all, the survey received 98 submissions, among which 97 cases had finished the questionnaire and had valid responses to the survey questions, while one submission (#7) was empty.

Within the 97 valid submissions, 89 cases provided the information for identifying the school district the participants worked for, and 88 submissions provided the information for identifying the participant's gender through publicly accessible resources (e.g., Internet, District websites, Google, etc.). The frequency distribution has been calculated for these two variables, and the results are summarized in Tables 4.1 and 4.2.

Table 4.1. Distribution of participant's school district

School District	Frequency *(f)*	Percentage (%)
School District 1 (Surrey)	46	51.7
School District 2 (Coquitlam)	43	48.3
Total valid case number	n = 89	100

Table 4.2. Distribution of participant's gender

Gender of Participant	Frequency *(f)*	Percentage (%)
Male	38	43.2
Female	50	56.8
Total valid case number	n = 88	100

4.1.2. Grades and subjects

To find out the teaching backgrounds of the participants, two questions were included in part one of the online questionnaire. One question asked the participants to indicate the grade levels they were teaching at the time of data collection, the other question requested the participants to indicate the grade levels and courses that they had taught and the disciplinary categories those courses or grades fell into. Submissions from 97 respondents included answers to both questions. The statistical analysis of these responses shows that this study covered all grade-levels (Kindergarten to Grade 12) of the public schools that the research aimed to investigate.

For the grade levels teachers were teaching at the time, the 97 submissions were categorized into four groups: K- Grade 5, Grades 6-8, Grades 9-12, and Others. The group Grades 9-12 represented the highest proportion of respondents, and accounts for 46.5% of the cases, followed by the group Grades 6-8 with a proportion of 33.1%. Finally, the group K-Grade 5 made up the smallest proportion of respondents, with 18.1% of all cases. The group “Others” consisted of three cases, including two cases where respondents were teaching in the school library, and one case in which the respondent was the vice principal at that time. The frequency distribution and central tendency of the grade level are shown in Table 4.3 and Figure 4.1.

Table 4.3. Grade levels participants currently teach

Grade level	Frequency *(f)*	Percentage (%)
Kindergarten – Grade 5	23	18.1
Grade 6 – Grade 8	42	33.1
Grade 9 – Grade 12	59	46.5
Others	3	2.4
Total sample size	*n* =127	100

Central tendency: n=127, mode=G9-12

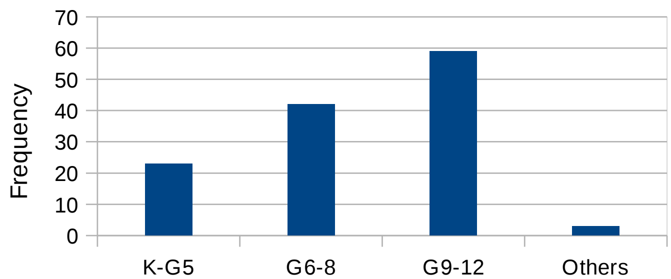

Figure 4.1. Distribution of grade levels teachers were teaching

One point to note is that, because some teachers taught more than one grade level at the same time, 127 references were derived from the 97 submissions. The above descriptive analysis of frequency distributions was performed based on the total reference number of all groups (see Table 4.3). Furthermore, because some teachers taught multiple grade levels that cross the groups, in order to maximize the usage of the data obtained and reduce unnecessary data loss, in the next descriptive analysis in this section and the inferential analysis in later sections, the grade levels are re-divided into two groups, e.g. elementary group (K-Grade 7) and secondary group (Grades 8-12), for the purpose of comparing group means of the grade levels and the disciplinary areas that the participants had taught. Grouping participants in this way produces the smallest number of cross-group cases, and these cross-group cases will be treated as invalid cases and be discarded in the inferential statistical analysis when doing group comparisons.

Considering the fact that elementary teachers teach foundational knowledge and skills across subjects, in this study, the analysis of subjects that teachers had taught focused on secondary level courses. In the quantitative analysis for this section, all subjects were grouped into five disciplinary areas: Sciences, Technologies, Engineering, Mathematics, and Arts. The descriptive analysis results of frequency distribution and central tendency for grade levels and courses that participants had taught are presented in Table 4.4 and Figure 4.2.

Table 4.4. Grade levels and subjects the participants have taught

Grade level	Frequency (f)	Percentage (%)
Elementary Course(s)	41	39.4
Secondary Course(s)	63	60.6
Total	*n*=104	
Disciplinary area	**Frequency (f)**	**Percentage (%)**
Sciences (e.g., Chemistry, Physics ...)	51	34.7
Technologies (e.g., Woodworking, Programming...)	24	16.3
Engineering (e.g., Electronics, Game Design...)	14	9.5
Mathematics	55	37.4
Arts (e.g., Foods, Textiles, Fine Arts ...)	16	10.9
Total case number	*n*=147	
Central tendency	mode=Mathematics	

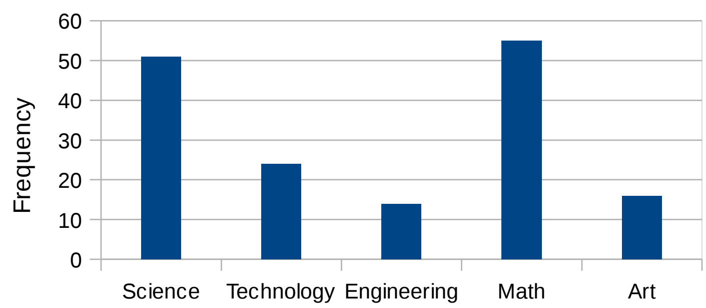

Figure 4.2. Distribution of courses teachers had taught

4.1.3. Familiarity with maker-centered pedagogies

In order to find out how much current public school teachers' know about maker-centred teaching and learning and what opportunities they have to develop and improve the related practices, the online survey included two questions asking about teachers' familiarity with maker-centred approaches and the training they had received on maker-centred teaching and learning.

The descriptive analysis results for the first question are presented in Table 4.5 and Figure 4.3. The frequency distribution of responses to the Familiarity question shows that the majority of the participating teachers are aware of maker-centred teaching and learning, and more than sixty percent of the participants had some experience with using this approach. Sixteen participating teachers were not aware of this approach at all. One might expect an even smaller proportion given the self-selection effect at work in a voluntary survey, as people who are completely unfamiliar with something are unlikely to participate in a survey about it. Having this group represented at all is an advantage for the study.

Table 4.5. Participant's familiarity to maker-centred pedagogies

Familiarity	Frequency *(f)*	Percentage (%)
Never heard of it.	16	16.5
Have heard of it, but never use it	22	22.7
Used maker-centred approaches a few times	36	37.1
Often use maker-centred approaches in teaching	23	23.7
Total case number	*n*=97	100
Central tendency: mode	used a few times	

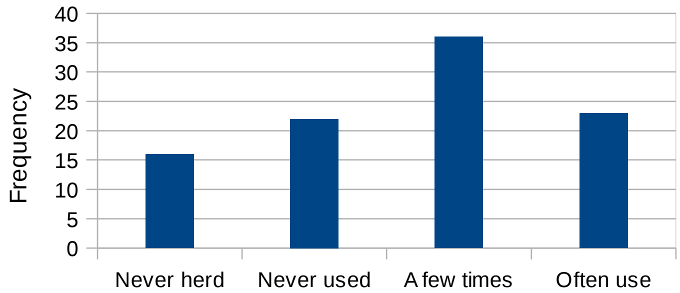

Figure 4.3. Participant's familiarity to maker-centred pedagogies

4.1.4. Training on maker-centered pedagogies

Another set of questions focused on the training that teachers had received on maker-centred pedagogies. In part three of the questionnaire, an open-ended question was also designed to collect information regarding this sub-question.

In all, 94 participants responded to this question. Sixty-four teachers wrote that they had not received any training on maker-centred teaching and learning. The remaining 31 respondents declared that they had received some kind of training. This number included 6 teachers who had received some formal education, 11 who had attended workshops or professional development activities, and 11 who did not identify the kind of training they had received. Overall, though it appears that the ADST and STEM teachers surveyed had not had sufficient formal training on maker-centred teaching and learning, many of the respondents favoured using this approach in their teaching practices and hoped to receive relevant training.

For example, a teacher (P26)[1] responded “I have no training but would love some!”; another teacher (P29) wrote “No (training), at the moment the learning is self directed and I am gaining more knowledge as I find more information, I am a new teacher librarian so that’s why the makerspace has started with limited supplies, direction etc. However, I am open to learning more.” Seven respondents explained that they were self taught on maker-centred teaching. For instance, one respondent wrote:

> A few workshops and my own self directed professional development. The pattern has been: purchase a test kit (e.g. robotics) / learn how to use the technology myself / then design a test learning activity with as many DIFFERENT ABILITY levels to see what works and what doesn't / then try to roll out a unit - usually in pairs since equipment is in short supply / then revise / usually the first roll out NOT successful but the ability of the teacher professional to LEARN and to implement thoughtful changes is key! (P44)

Qualitative analysis techniques and the computer analyzing tool NVivo were adopted to examine participant responses to this open-ended question. The framework of data coding and the coding results are shown in Table 4.6.

Table 4.6. Training on maker-centred pedagogies

Q10. Training on maker-centred pedagogies	**Frequency**	
No training	64	
Received Training	30	
○ Unspecified		13
○ Pro-D activities/workshops		11
○ Formal education		6
Self taught	7	
Total references coded	101	

1. P# indicates the the particular participant with whom the data were generated,

4.2. Understanding and perception of maker-centred pedagogies – Research Question 1

In order to investigate the general understandings and perceptions of ADST and STEM educators in BC public schools, and identify the important factors in connection with the implementation of maker-centred teaching and learning, quantitative analysis approaches were first employed in the survey data analysis. Both descriptive and inferential analysis were carried out to discover general trends, the frequency distributions and the measures of central tendency of the variables related to the research questions.

Twelve selected-response questions included in the second part of the online survey questionnaire were divided into four groups to address each of the four research questions in the subsequent quantitative data analysis sections. These questions requested the survey participants to indicate their understandings and perceptions about maker-centred pedagogy and its applications by rating each of the provided belief statements on a 5-point scale, namely “strongly agree”, “agree”, “neutral”, “disagree”, and “strongly disagree”.

When carrying out quantitative analysis of the survey responses, first numerical scores from 1 to 5, were assigned to participants’ responses corresponding to the 5-point scale from “strongly disagree” to “strongly agree” (Creswell & Clark, 2010). Then the quantitative data analyzing program PSPP was employed to perform the descriptive and inferential statistical analysis.

This section focuses on the quantitative analysis and the interpretation of the responses to the survey questions that are related to Research Question 1. The quantitative data are analyzed and interpreted to answer the following sub-questions:

Research Question 1: What are ADST and STEM teachers’ current understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favour or doubt maker-centred teaching and learning?

Sub-questions:

- What are teacher’s perceptions on the current situation of ADST and STEM education?

- What are teacher’s understanding of maker-centred pedagogies? Do they favour or doubt maker-centred pedagogies?
- What are the teacher's roles in ADST and STEM education?

In the online questionnaire, seven 5-point scale questions addressed the first three sub-questions listed above. Of these questions, two were grouped together forming Scale 1 in connection with the first sub-question, “teachers’ perceptions on the current situation of ADST and STEM education”; four questions constituted Scale 2, which addressed the second sub-question, “teachers’ understanding and favour/doubt about maker-centred approaches”; and the final question was aimed at the third sub-question regarding “teachers’ roles in ADST/STEM education”. This section will introduce the descriptive and inferential statistical data analysis to answer these three sub-questions in four subsections.

4.2.1. Current status of ADST/STEM education – descriptive analysis

Descriptive analysis

In order to discover BC public school teachers’ general perceptions of the current situation with regard to ADST and STEM education, quantitative analysis was conducted based on the participant’s ratings to two 5-point scale survey questions (SQ2.1, SQ2.2):

- SQ2.1. Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice.
- SQ2.2. Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms.

Descriptive analysis was performed for participants’ ratings to each of the question statements. The frequency distribution and measures of central tendency are presented in Table 4.7 and Figures 4.4 and 4.5.

Table 4.7. Teacher's perceptions on current situation of STEM education

Survey Questions	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean	Mode & Median
SQ2.1. Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice.	16	29	20	27	4	n=96 $\bar{x}$=2.7	mode=2 Mdn=3
SQ2.2. Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms.	5	18	11	52	9	n=95 $\bar{x}$=3.4	mode=4 Mdn=4

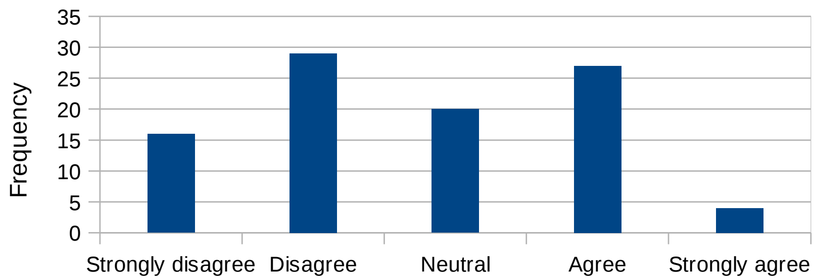

Figure 4.4. Distribution of teachers' rating to SQ2.1

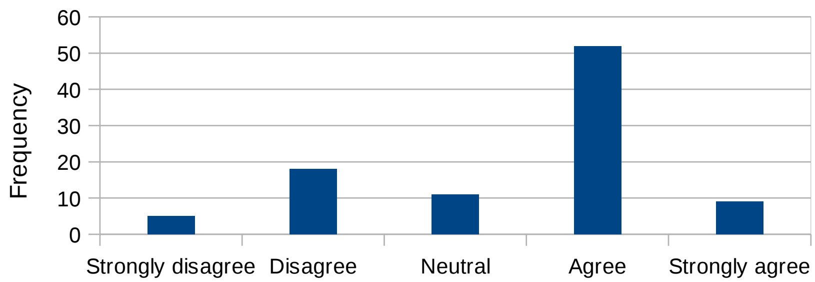

Figure 4.5. Distribution of teachers' rating to SQ2.2

Composite Score and Internal Consistency of Scale 1

Cronbach's alpha is a measure of internal consistency and is traditionally used to address scale reliability. A reliability coefficient of .70 or higher is considered "acceptable" in most social science research situations (UCLA, 2019).

As shown in Table 4.7, survey questions SQ2.1 and SQ2.2 can form a scale (Scale 1) describing teachers' perceptions with regard to making in ADST/STEM education. The composite score was generated by calculating the pooled mean of the two items included in Scale 1. To estimate the reliability of the composite scores, the descriptive analysis was done for Scale 1 with all 95 valid submissions, and the internal consistency was subsequently analyzed by calculating Cronbach's alpha for Scale 1 using the statistical analysis software PSPP. The related results with all valid cases are presented in Tables 4.8 and 4.9. In order to compare the responses of the teachers from different grade-levels, the analysis of internal consistency was also conducted with the elementary group (K-G7) and the secondary group (G8-G12) separately. The results are illustrated in Tables 4.10 and 4.11.

Table 4.8. Descriptive analysis of Scale 1

Scales	Composite Scores	Survey Questions	Case number & Mean
Scale 1. Perceptions of current situation of ADST/STEM education	Case n=95 mean $\bar{x}$=3.08	SQ2.1. Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice.	n=96 $\bar{x}$=2.72
		SQ2.2. Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms.	n=95 $\bar{x}$=3.44

Table 4.9. Reliability statistics of Scale 1 (all responses, N=95)

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's Alpha
SQ2.1	2.72	1.35	0.50	0.66
SQ2.2	3.44	1.14	0.50	

Table 4.10. Reliability statistics of Scale 1 (elementary teachers, N=31)

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's Alpha
SQ2.1	2.13	1.32	0.22	0.36
SQ2.2	3.29	1.41	0.22	

Table 4.11. Reliability statistics of Scale 1 (secondary teachers, N=57)

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's Alpha
SQ2.1	3.04	1.14	0.63	0.77
SQ2.2	3.56	0.96	0.63	

* n=Valid case number

** When the grade-levels were divided into two groups (elementary and secondary), seven cases were dropped because those teachers taught multiple grades that cross the groups.

From the analysis results presented above, several findings emerge which are related to the research question and reflect the current situations of ADST/STEM education in public schools.

For all teachers' responses (Table 4.9), the alpha coefficient of the two items (responses to two survey questions) is 0.66, which is below the acceptable value (usually considered as 0.7) for internal consistency. The low reliability might be caused by the low number of items (i.e. 2) associated with Scale 1 (UCLA, 2019). On the other hand, it might indicate that to some extent the teachers' responses to these two survey questions were not consistent.

When the cases are divided into two different grade groups, the alpha coefficient of the elementary group is 0.36 (Table 4.10), suggesting that at the elementary level, teachers' perceptions on the two items (SQ2.1 “the emphasis on hands-on practice in STEM/ADST teaching" and SQ2.2 “student's opportunities to make things in STEM/ADST classrooms”) are diverse. However, the reliability analysis of the secondary group results in a much higher internal consistency, with an alpha coefficient of 0.77. This means that the secondary STEM teachers' responses to two items are reasonably consistent, and the two survey questions (SQ5.1 and SQ5.2) form a reliable scale to measure the same latent variable – ie. secondary STEM teachers' perceptions with regard to the current situations of the applications of maker-centred pedagogies.

4.2.2. Current status of ADST/STEM education – inferential analysis

The descriptive analysis shows that the participants' responses to survey questions SQ2.1 presents a divergent distribution and the responses to SQ2.2 is highly skewed to the right, indicating that the respondents' perceptions and understanding with regard to these questions have a certain degree of diversity (see Figures 4.4 and 4.5). As discussed in last subsection, the elementary and secondary school teachers' responses had different means and presented different levels of consistency with regard to these two survey questions, implying that the teachers' perceptions regarding making in current ADST/STEM education may be related to their teaching backgrounds. In order to explore the potential factors that caused the difference, the inferential statistical analysis was conducted to compare the means of teachers' responses between different grade levels and different subject areas (Coladarci et al, 2008). For clarity, the two survey questions were:

- SQ2.1. Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice.
- SQ2.2. Students usually do not have enough opportunities to make things in ADST related and STEM subject classrooms.

The statistical analysis was performed by using the statistical analysis software PSPP (FSF, 2007) (a free, open source version of SPSS). The comparison of group means between different grade-levels included conducting the t-test for two independent samples (Elementary and Secondary) and calculating the effect size ***d***. Effect Size ***d*** expresses a mean difference relative to the pooled standard deviation, the rule is *d*=0.20 indicates a small effect, *d*= 0.50 indicates a medium effect, *d*=0.80 indicates a large effect. The comparison of group means between different disciplinary areas consisted of performing one-way ANOVA by performing an F-test for three independent samples, and the post hoc test (Turkey's HSD Test) if a significant F is found (Coladarci et al, 2008). Three points need to be noted here:

1. Because the samples are not representative samples (due to self-selection effects), there is not a meaningful basis for specifying H0, one sample t-test is not applicable here and the interval estimation for each single sample is not meaningful (Coladarci et al, 2008).

2. Some teachers teach multiple grade levels that cross the groups (elementary and secondary). When comparing the means of different grade groups, in order to make the samples independent for the t-test, the inferential analysis will use the grades that the participants are currently teaching, and drop the cases that cross the groups (invalid cases) (Coladarci et al, 2008).

3. Some teachers teach multiple disciplinary areas that cross the groups (science, technology & engineering, and math). When comparing the means of groups, in order to make the samples *independent* for one-Way ANOVA and F-test, the inferential analysis will use the subjects that the participants are currently teaching, and drop the cases that cross the groups (invalid cases) (Coladarci et al, 2008).

Comparing the means of different grade-levels for SQ2.1

This subsection introduces the inferential analysis for the responses to survey question SQ2.1 “Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice”. The analysis includes the frequency distribution, the group statistics for different grade levels, and the comparison of the means of two groups (elementary and secondary) through conducting the t-test and calculating the effect size *d*. The statistical results are presented in Tables 4.12(a), 4.12(b) and 4.12(c).

Table 4.12.(a). Frequency for SQ2.1 (all valid cases) – Grade level

Value Label	Value	Frequency	Percent	Cum Percent
Strongly disagree	1	15	16.85	16.85
Disagree	2	27	30.34	47.19
Neutral	3	18	20.22	67.41
Agree	4	25	28.09	95.50
Strongly Agree	5	4	4.49	100.00
	Total	89	100.0	

Table 4.12.(b). Group Statistics for SQ2.1- Grade level

	Grade	N	Mean	Std. Deviation
SQ2.1	Elementary	31	2.13	1.15
	Secondary	58	3.05	1.07

Table 4.12 (c). Independent Samples t-test for SQ2.1 – Grade level

Effect Size	t-test for Equality of Means						
d	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
0.84	-3.79	87.00	.000	-.92	.24	-1.41	-.44

Because p=0.000, α=0.05, p<α, null hypothesis H0 is rejected, indicating that the mean difference between the two groups is statistically significant. This means that there is a significant difference between elementary and secondary teachers with regard to their self-reported agreement with the statement that "Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice" (SQ2.1). This implies that the elementary teachers emphasize more hands-on practice in classrooms than secondary teachers. The calculated effect size *d* (= 0.84 > 0.8) also indicates a large effect of the elementary (or secondary) teaching role on this variable.

Comparing the means of different grade-levels for SQ2.2

In the same manner as above, inferential analysis was performed for the responses to survey SQ2.2 “Students usually do not have enough opportunities to make things in ADST related and STEM subject classrooms”. The frequency distribution, the group statistics for different grade levels, and the comparison of the means of two grade groups (elementary and secondary) were analyzed by conducting the t-test and calculating the effect size *d*. The analysis results are presented in Tables 4.13(a), 4.13(b) and 4.13(c).

Table 4.13.(a). Frequency for SQ2.2 (all valid cases) – Grade level

Value Label	Value	Frequency	Percent	Cum Percent
Strongly Disagree	1	4	4.55	4.55
Disagree	2	17	19.32	23.86
Neutral	3	10	11.36	35.23
Agree	4	48	54.55	89.77
Strongly Agree	5	9	10.23	100.00
	Total	88	100.0	

Table 4.13.(b). Group Statistics for SQ2.2 – Grade level

	Grade	N	Mean	Std. Deviation
Q2.2	Elementary	31	3.29	1.19
	Secondary	57	3.56	.98

Table 4.13.(c). Independent Samples t-test for SQ2.2 – Grade level

Effect Size	t-test for Equality of Means						
d	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
0.26	-1.15	86.00	.254	-.27	.24	-.74	.20

The t-test shows p=0.254, α=0.05. Because p>α, thus the null hypothesis H0 is retained. This indicates that the mean difference between the two groups is not statistically significant. This means that elementary and secondary teachers did not differ significantly with regard to self-reported agreement with the statement that "Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms". The calculated effect size *d* = 0.26 (< 0.5) also indicates a relatively small effect of the elementary (or secondary) teaching role on this variable. Furthermore, both grade groups have a relative high mean response (3.29 and 3.56), implying that most elementary and secondary teachers agree that currently students do not have enough opportunities to make things in both ADST and STEM classrooms.

Comparing the means of different disciplinary areas for SQ2.1

In order to discover the difference between the teachers who taught different school subjects in terms of their responses to survey question SQ2.1 “Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice”, inferential analysis was conducted to compare three different disciplinary areas (science, technology & engineering, and math) at the secondary level (G8-12). This process included investigating the group statistics, comparing the means of the groups by conducting one-way ANOVA and F-test, and conducting the post hoc test (Turkey’s HSD Test) when a significant F is found. As explained above, the inferential analysis used the subjects that the participants were teaching at the time, and discarded the cases in which teachers taught more than one of these subjects that cross the groups (invalid cases). The analysis results for survey question SQ2.1 are shown below in Table 4.14(a) and Table 4.14(b).

Table 4.14.(a) Group Statistics for SQ2.1 (valid cases) – Disciplinary area

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Science	30	3.00	1.11	.20	2.58	3.42	1	5
TechEng	13	2.62	1.12	.31	1.94	3.29	1	4
Math	18	3.33	.84	.20	2.92	3.75	2	5
Total	61	3.02	1.06	.14	2.75	3.29	1	5

Table 4.14.(b) One-way ANOVA for SQ2.1 – Disciplinary area

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.91	2	1.95	1.80	.175
Within Groups	63.08	58	1.09		
Total	66.98	60			

The F-test shows that the F ratio for one-way ANOVA is 1.80, $F_{.05}$ =3.17, F< $F_{.05}$ (p= 0.175 > α =0.05), the null hypothesis H_0 is retained (Coladarci et al., 2008). This means that no significant difference was found between the science, technology-engineering, and math teachers with regard to their self-reported agreement with the statement that "Much of ADST and STEM teaching has a heavy emphasis on theory and overlooks hands-on practice" (SQ2.1). Furthermore, with all three disciplinary groups, the mean response was above the half-way point of the scale.

Comparing the means of different disciplinary areas for SQ2.2

In a similar fashion, inferential analysis was conducted to compare three different disciplinary areas (science, technology & engineering, and math) at the secondary level (G8-12) with regard to survey question SQ2.2 “Students usually do not have enough opportunities to make things in ADST related and STEM subject classrooms”. The group statistics were analyzed and the means of the groups were compared by one-way ANOVA and F-test. Results are shown below in Tables 4.15(a) and 4.15(b).

Table 4.15.(a) Group Statistics for SQ2.2 (valid cases) – Disciplinary area

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Science	30	3.77	.90	.16	3.43	4.10	2	5
TechEng	12	2.58	1.08	.31	1.89	3.27	1	4
Math	18	3.89	.76	.18	3.51	4.27	2	5
Total	60	3.57	1.01	.13	3.30	3.83	1	5

Table 4.15.(b) One-way ANOVA for SQ2.1 – Disciplinary area

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.67	2	7.34	9.08	.000
Within Groups	46.06	57	.81		
Total	60.73	59			

Table 4.15(b) shows that the F ratio for one-way ANOVA is 9.08, $F_{.05}$ =3.17, F> $F_{.05}$ (p= 0.00 < α=0.05), which leads to rejecting the null hypothesis H0 (Coladarci et al., 2008). The mean difference between the three subject groups is statistically significant. In order to find out where the real difference is between these three groups, the post hoc comparison was performed by conducting the Tukey’s HSD Test to make all possible pairwise comparisons among the means of groups (Coladarci et al, 2008). The result of Turkey’s HSD test is described below.

Group1: Science

Group2: Technology-Engineering

Group3: Math

Critical HSD for Turkey's test: HSD = 0.73

Compare HSD with each difference between sample means:

$|\bar{x}1 - \bar{x}2| = |3.77 - 2.58| = 1.19 > 0.73$ (HSD)

$|\bar{x}1 - \bar{x}3| = |3.77 - 3.89| = 0.12 < 0.73$ (HSD)

$|\bar{x}2 - \bar{x}3| = |2.58 - 3.89| = 1.31 > 0.73$ (HSD)

The result shows that Group 2 is significantly different from Group 1 and Group 3; there is not a significant difference between Group 1 and Group 3. Therefore the conclusion is, at the secondary level the technology and engineering teachers' responses to Q5.2 ,"Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms", are statistically different from the responses of the science and math teachers. It implies that students have more opportunities to make things in technology and engineering classrooms than in science and math classrooms, or implies that tech ed teachers value hands-on work more than science and math teachers do, which makes a whole lot of sense given that tech ed teachers have traditionally focused on making in their pedagogy.

4.2.3. Understanding, favour/doubt of maker-centred pedagogies

Descriptive analysis

To answer the second sub-question of Research Question 1, regarding teachers' understanding and favour or doubt about maker-centred pedagogies, the survey participants were asked to provide a rating for each of four questions on a 5-point scale. These questions were:

- SQ2.3. Making-based activity is an important part of ADST-related and STEM classrooms.
- SQ2.4. Maker-centred learning increases student engagement in ADST / STEM classrooms.

- SQ2.5. Maker-centred approaches increase achievement in ADST / STEM subject learning.
- SQ2.11. Developing the ability to design and make, acquire skills, and apply/use technologies is important in education today.

Descriptive analysis was performed for participants' ratings for each of these statements. The distributions of the responses to all of these questions are positively skewed to the right, indicating that the participants have given relatively high ratings to all four questions. The results of frequency distribution and measures of central tendency are presented in Table 4.16. and Figure 4.6. to Figure 4.9.

Table 4.16. Teachers' understanding and favor/doubt about maker-centred pedagogies

Survey Questions	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean	Mode & Median
SQ2.3 Making-based activity is an important part of ADST-related and STEM classrooms.	0	4	3	48	42	n=97 $\bar{x}$=4.32	mode=4 Mdn=4
SQ2.4 Maker-centred learning increases student engagement in ADST/STEM classrooms.	0	1	10	40	46	n=97 $\bar{x}$=4.35	mode=5 Mdn=4
SQ2.5 Maker-centred approaches increase achievement in ADST / STEM subject learning.	0	4	22	41	27	n=94 $\bar{x}$=3.97	mode=4 Mdn=4
SQ2.11 Developing the ability to design and make, acquire skills, and apply/use technologies is important in education today.	1	1	5	31	59	n=97 $\bar{x}$=4.51	mode=5 Mdn=5

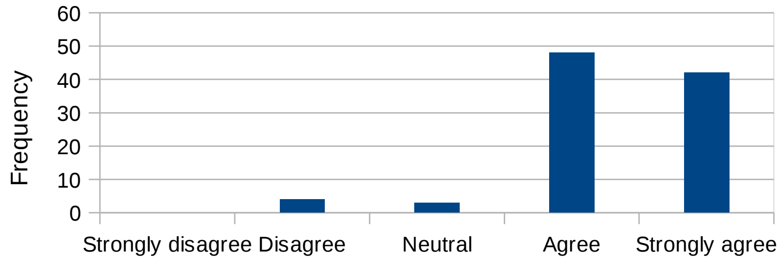

Figure 4.6. Distribution of teachers' rating to SQ2.3

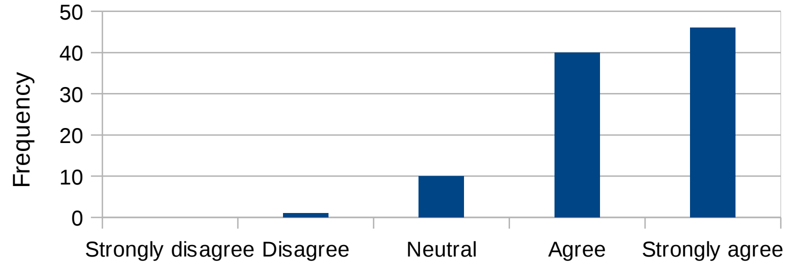

Figure 4.7. Distribution of teachers' rating to SQ2.4

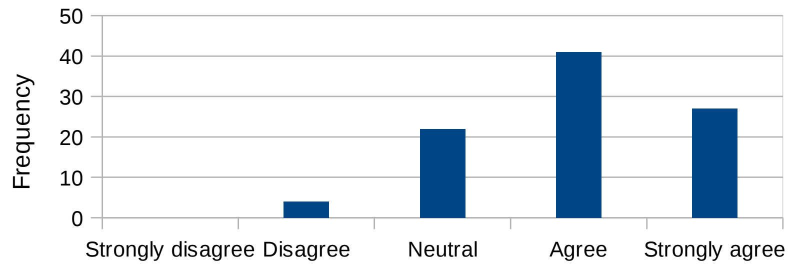

Figure 4.8. Distribution of teachers' rating to SQ2.5

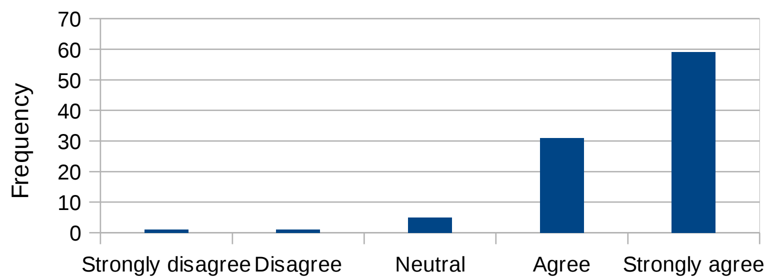

Figure 4.9. Distribution of teachers' rating to SQ2.11

Composite Scores and Internal Consistency of Scale 2

As shown in Table 4.16, participants' responses to the four survey questions SQ2.3, SQ2.4, SQ2.5 and SQ2.11 are quite consistent. Therefore, it appeared that they might form a single scale to capture "teacher's understanding and favour/doubt about maker-centred teaching and learning" (Scale 2). The composite score was generated by calculating the pooled mean of the four items included in Scale 2. In order to verify the reliability of the scale, descriptive analysis was conducted for all 94 valid submissions, and the internal consistency was gauged by calculating Cronbach's alpha. This reliability analysis was done by using the statistical analyzing software PSPP, and the related results are presented below in Tables 4.17 and 4.18.

Table 4.17. Descriptive analysis of Scale 2

Scales	Composite Scores	Survey Questions	Case number & Mean
Scale 2. Understanding, favour/ doubt on maker-centred teaching and learning	Case n=94 mean $\bar{x}$=*4.30*	SQ2.3. Making-based activity is an important part of ADST-related and STEM classrooms.	*n*=97 $\bar{x}$=4.32
		SQ2.4. Maker-centred learning increases student engagement in ADST/STEM classrooms.	*n*=97 $\bar{x}$=4.35
		SQ2.5. Maker-centred approaches increase achievement in ADST / STEM subject learning.	*n*=94 $\bar{x}$=3.97
		SQ2.11. Developing the ability to design and make, acquire skills, and apply/use technologies is important in education today.	*n*=97 $\bar{x}$=4.51

Table 4.18. Reliability statistics of Scale 2 (valid responses, N=94)

Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
SQ5.3	12.86	3.39	.73	.75	0.83
SQ5.4	12.84	3.43	.76	.74	
SQ5.5	13.24	3.33	.57	.83	
SQ5.11	12.69	3.57	.58	.81	

The reliability analysis shows that for all 94 valid submissions, the alpha coefficient of the four items (responses to four survey questions) is 0.83, suggesting that the items within scale 2 have relatively high internal consistency. This means that the four survey questions (Q5.3, Q5.4, Q5.5 and Q5.11) can form a reliable scale to measure the same latent variable, and the values of Scale 2 can reliably express participating teachers' views on this sub-question. Because Scale 2 possesses a quite high mean value (4.3) in the 5-point scale measure, one can justify the conclusion that the majority of respondents had a positive conception with regard to maker-centred pedagogies and favor on implementing maker-centered teaching and learning.

4.2.4. Teacher's roles in ADST and STEM education

In order to address the third sub-question of Research Question 1, regarding respondents’ perceptions concerning the roles that teachers should play in ADST and STEM education, participants were asked to respond to the following *statement on* a 5-point scale:

- SQ2.12. ADST and STEM educators should act as technology-literate facilitators or guides rather than transmitters of information.

There were 96 valid submissions in all for this question. The results of frequency distribution and measures of central tendency are shown in Table 4.19 and Figure 4.10.

Table 4.19. Teacher’s roles in ADST/STEM education

SQ2.12. ADST and STEM educators should act as technology-literate facilitators/guides rather than transmitters of information.	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**	**Mean**	**Mode & Median**
	1	8	13	41	33	n=96 $\bar{x}$=4.01	mode=4 Mdn=4

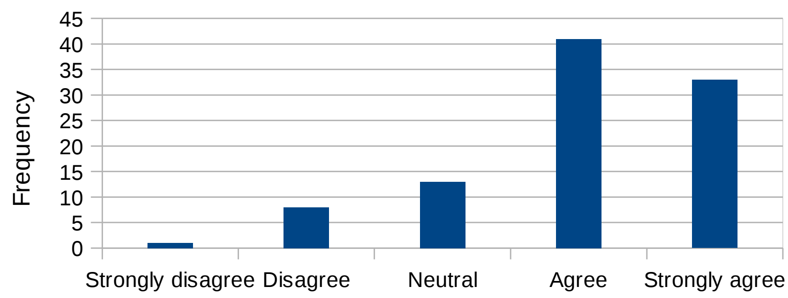

Figure 4.10. Distribution of teachers’ rating to SQ2.12

It is evident that the responses to this item had a positively-skewed distribution. The majority of the participating teachers agreed with the statement that “ADST and STEM educators should act as technology-literate facilitators/guides rather than transmitters of information”.

4.3. Major characteristics of maker-centred pedagogies – Research Question 1

Section 4.2 employed quantitative approaches to examine the general perceptions of both ADST and STEM teachers with regard to maker-centred teaching and learning, and addressed the first four sub-questions of Research Question 1, ie. teacher’s perceptions of the current situation of STEM education, teacher’s understanding and favour/doubt about maker-centred approaches, teachers’ roles in ADST and STEM education, and how interested teachers are in exploring and implementing maker-centred approaches.

In order to develop a holistic picture of the research problem and obtain a more detailed understanding of ADST and STEM teachers’ views on maker-centred pedagogies, the study also employed qualitative analysis techniques to examine teachers’ responses to the open-ended questions on the online survey. These open-ended questions empowered the survey participants to share their stories and their views regarding the research questions, and allowed the researcher to investigate and report the participants’ multiple perspectives and meanings (Creswell and Poth, 2018; Merriam & Tisdell, 2016). This section introduces the qualitative data analysis to address the last sub-question of Research Question 1, i.e, “What are the major characteristics of maker-centred teaching and learning?”

The qualitative data relating to the sub-question were collected through an open-ended question in which the participating teachers were invited to provide their opinions to the question:

- SQ3.1 How do you think maker-centred teaching is different from other teaching approaches?

As Creswell (2012) noted, qualitative analysis is an inductive, simultaneous, iterative, and interpretive process. To make sense of the participants’ responses to the open-ended survey questions, the qualitative data analysis for this study has included several important steps that are commonly used in analyzing qualitative data, including: preparing and organizing the data collected for analysis; exploring the data and conducting an initial open coding; using the codes to develop a more general picture of the data — descriptions and themes; representing the findings through descriptions and visuals (tables and figures); developing an interpretation of the meaning of the results; and carrying out a double coding to establish the trustworthiness of the findings. The analysis process and results are briefly described in the following three sub-sections: 1) Coding framework and open coding results; 2) Double coding and interrater reliability, 3) Thematic analysis of the codes and comparisons between groups for the dominant themes.

4.3.1. Coding framework and open coding

The dataset included all survey participants' responses to open-ended question SQ3.1, "How do you think maker-centred teaching is different from other teaching approaches?" This question received 96 valid submissions in total. Participants' responses to this question varied from very simple expressions, such as "More hands on", and "Students take ownership of their learning", to some long paragraphs which elaborated the comprehensive insights and in-depth views of the respondents. For example, an elementary school teacher responded:

> It [making] allows students to explore, create and design. It encourages independent thinking and allows those who aren't successful in other academic areas to shine. Students have the ability to collaborate and express their ideas, go back and make changes as needed and reflect. It is a "gray" subject area which I feel is a fantastic part of our curriculum. By "gray" I mean that there is no "black or white" answer-there are multiple answers and approaches depending on who's lens you are looking through. Students are highly engaged and the vocabulary that arises throughout our STEM is all tied back into the curriculum. It is my students' favorite subject area by far! (P24)[2]

A secondary school technology-engineering teacher described the characteristics of maker-centred teaching by stating:

> Maker-centered teaching first and foremost allows for hands-on learning experiences. Students must use their creativity and innovative skills to

2.P# indicates the the particular participant with whom the data were generated,

> come up with solutions. Maker-centered teaching can take on a problem-based learning approach. It can also be project based learning. It is different in the strategies to teach the concepts, the classroom management, and level of engagement (P41).

Another secondary school technology-engineering teacher shared his insights and conceptions with regard to the current state of STEM education:

> Most of academia is focused on ideas and their manipulation theoretically. Most teachers and professors are NOT doers in a practical sense. That has not been their life experience not [sic] has their job required much of it. But most people who attend school and are NOT teachers or professors need to USE their knowledge in a practical way: make something, fix something, build or test something etc. So where do these people get these skills from? I have made it my life's work to teach making and doing as an extension to thinking and problem solving. It is part of making whole people to teach the body to do as you teach the mind to think. But academia has lost track off this and in truth has looked down on those of us who have not. Ironic that the pendulum seems to be swinging back. Teaching making and doing is holistic and real. it is about applied knowledge and creative application of concepts. This requires very different skills to be used in both the teacher and the learner (P37).

The early steps of the qualitative data analysis included preparing and organizing the data, making an initial exploration to get the general sense of the data, and conducting an open coding of the data using qualitative data analysis software. The data were organized by case and saved in the formats and syntax required by Excel and NVivo. A coding framework was defined and code labels were assigned following a descriptive method by using phrases to summarize the basic topics of the phrases or sentences in individual responses (Saldaña, 2009; Miles et al., 2014). In the coding process, the codes that emerged from the data analysis were grouped into categories and then consolidated into broader themes (Creswell, 2012; Saldaña, 2009).

The data analysis shows that several themes were frequently reported by participating ADST and STEM teachers as major characteristics of maker-centred teaching and learning. These included: Student agency and Independence, Hands on and experiential, Creativity, Engagement, Flexibility, etc.

The coding framework and initial qualitative data coding results for addressing the question “How is maker-centred approach different from other approaches?” are summarized in Table 4.20. In the table, the frequency of text segments coded under each category and theme are listed in descending order by frequency. Note that not every response was coded, and more than one code could apply to a single response.

Table 4.20. Coding results - Characteristics of maker-centred pedagogies

Survey Question	Description	Reference
SQ3.1. How is the Maker Method Different from Other Approaches?	This node aggregates the responses to the differences between "Making" method and other approaches.	Total=168
Code/Theme	**Definition of Theme**	**Frequency**
Student Agency, Independence	Responses that emphasize the student's leading or independent roles in making activities, including: student expertise, student-centred, student choice, student directed, less teacher-centred, etc.	37
Hands on, Experiential	Responses that emphasize hands on, learning by doing, experiential, applied	32
Creativity	Responses referring to creativity	17
Engagement	Responses referring to (increased) student engagement	13
Flexibility	Responses regarding the flexibility that making requires of teachers/schools in terms of time, arrangement of space.	13
Inquiry based, Problem solving	Responses that define making activities as Inquiry based, problem solving activities.	12
Challenge, Risk taking	Responses related to the challenges of applying making approaches, and the risk taking in making activities.	9
Collaboration	Responses related to collaboration, interaction, community, communication	9
Special roles of teacher	Responses that describe teacher's role is closer to a facilitator or guide than a content expert.	8
Process-oriented	Responses that define making activities as process-oriented rather than content-driven	6
Resources & Tools	Responses regarding special resources needed in making activities.	6
Artifact-centred	Responses regarding the fact that maker pedagogy revolves around students producing and improving tangible artifacts of some kind	3
Strategies	Responses regarding special strategies of maker-centred approaches	3

* Total responses=97; Responses coded to the specified themes=88.

** Cases didn't code to any specified themes=5; Cases with responses as "don't know"=4; Total coded references=168.

4.3.2. Double coding and inter-rater reliability

Throughout the process of data analysis, the researcher needs to ensure that findings and interpretations are defensible (Creswell, 2012). In order to establish the trustworthiness of the qualitative data analysis reported here, the strategy of double-coding by an independent coder was employed. The double-coding procedure included three steps. First, a specifically generated representative sample set was defined based on discussion between the researcher and her supervisor. This sample covered more than 20% of all valid submissions. An independent double coding was carried out for this sample set of responses by the two coders, using a codebook that included an explicit definition and examples of each code. This codebook was developed and refined over four coding trials. After the fourth trial, reliability metrics were calculated, and the researcher used the revised version of the codebook to re-code the entire dataset once again.

To estimate the interrater reliability and determine the accuracy and credibility of the findings, a free online utility ReCal2 (Freelon, 2017) was used to compute the intercoder reliability coefficients for qualitative coding results coded by two coders. The results of the intercoder reliability calculations are shown in Table 4.21.

Table 4.21. Intercoder reliability – Characteristics of maker-centred pedagogies

Code	Percent Agreement	N Agree	N Disagree	N Cases
Student agency, Independence	95%	19	1	20
Challenge, Risk taking	95%	19	1	20
Collaboration, Communication	95%	19	1	20
Creativity	100%	20	0	20
Engagement	95%	19	1	20
Hands-on, Experiential, Applied	90%	18	2	20
Inquiry based, Problem-Solving	95%	19	1	20
Process-oriented	100%	20	0	20
Artifact-centred	100%	20	0	20
Special resources and tools	100%	20	0	20
Flexibility	100%	20	0	20
Special strategies	95%	19	1	20
Special roles of teacher	100%	20	0	20

* Number of codes (variables): 13

** Number of coders per variable: 2

4.3.3. Thematic analysis of the codes

As aforementioned, the initial open coding of participant responses resulted in a large number of codes. In the subsequent analysis steps, the codes were reduced and aggregated. Thirteen themes were ultimately developed to capture a variety of characteristics of maker-centred pedagogies reported by the respondents. These themes represent the major ideas presented in the data, and form a core element in the qualitative data analysis (Creswell, 2012). The themes and the frequencies with which they were mentioned in the data are summarized in Table 4.21.

This section examines the specific themes identified in participants' responses. Descriptions and tables are used to present the findings and major themes derived from the data, and illustrative quotations from participants are added to capture the perspectives of different individuals, or multiple views held by one person. The quotations for each theme of characteristics are labelled with "P#-E/S/C-S/T/M"[3], where the number # between 1 to 97 indicates the particular participant with whom the data were generated, the uppercase letter E/S/C[4] indicates the grade-level that participant was teaching at the time of the data collection (Elementary/Secondary/Cross group), and the uppercase letter S/T/M[5] refers to the subject areas (Science/Technology -Engineering/Mathematics) that a secondary STEM teacher was teaching at the time. In order to maximize the use of all data, although small in number, the cross-group cases were also included in the qualitative analysis, and not excluded as in the quantitative analysis. Tables are used in this part to display the results of group comparisons between different grade-levels and different subject areas in connection with the dominant themes.

Student Agency, Independence

The theme "Student agency, Independence" is most frequently mentioned in the participants' responses to survey question SQ3.1 "How do you think maker-centred teaching is different from other teaching approaches?" Of 88 coded responses, 37 ADST or STEM teachers considered "Student agency, Independence" as an important characteristic of maker-centred teaching and learning. Many teachers emphasized the student's leading role in maker-centered learning processes, saying that maker-centered learning is "student directed" (P22-E) and "student-centered, (it) gives students the opportunity to have choice and ownership over their work" (P3-E) and allows students to "design and create their own learning" (P71S-M). "It gives students the opportunity to use their imaginations, special skills and passions to show their learning in a new way. It gives students the role of expert, where they might be teaching others" (P17-E). From another perspective, maker-centered learning is "less teacher centered" (P45-S-S) and presents "less emphasis on (the) teacher as source of information" (P93-C). In maker-centred teaching, teachers need to have the "ability to let go and let students explore on

3. Number # is between 1 to 97, and is based on the responses coded for the open-ended question.

4. E/S/C: E, S, and C represents elementary, secondary, and cross group respectively.

5. S/T/M: S,T, and M represents science, technology/engineering, and mathematics respectively.

their own” (P2-E). Also, in maker-centered activities “a lot more learning/teaching is put into the hands of the students” (P10-E) and “students collectively are in control and instructors are there to encourage and probe learning” (P65 S-S).

Independence is another common theme in the responses to this question. As some teachers stated, in maker-centered teaching and learning, “autonomy is provided to the student” (P79-S-M), so that learners are “more independent in their learning” (P98-C). The learning activity “relies on student ideas and motivations” (P16-E) and “requires more from students” [than typical teaching] (P83-S-M). “It encourages independent thinking and allows those who aren't successful in other academic areas to shine” (P24-E). During the learning process, “instead of students participating as passive vessels to be filled with knowledge, they actively learn and apply their knowledge while using a growing bank of tools to design and create towards a purpose” (P51-S-S).

Some secondary school teachers responded relating to developing students' sense of responsibility and practical abilities, acknowledging that maker-centered teaching and learning “gives more control, and more responsibility on students” (67-S-S). “It is less stand and deliver, and as such, focuses on building the skills we want to see in our future scientists and graduates” (P33-S-S). It is student-driven learning: “the students are responsible for output” (P40-S-M).

In order to identify the possible influence of the teacher's background on their answers to the questionnaire, comparisons between groups (grade-level and subject area) were performed. The results show that in the responses regarding theme “Student agency, Independence”, the proportion of teachers in elementary and secondary schools is quite close; and at the secondary level, independence is most emphasized by science teachers, followed by mathematics teachers, and finally technology teachers (see Tables 4.22 and 4.23).

Table 4.22. Comparison of grades - Student agency, independence

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	18	48.6
Secondary (G8 – 12)	15	40.5
Cross-group	4	10.8
Total	*n* =37	100

Table 4.23. Comparison of subjects - Student agency, independence

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	17	45.9
Science	8	21.6
Mathematics	6	16.2
Tech & Engineering	4	10.8
Unidentified	2	5.4
Total	*n* =37	100

Hands-on, Experiential

"Hands-on, Experiential" is the second-most frequently mentioned characteristic of maker-centred learning by the survey participants (32 out of 88 responses). This theme was derived from responses such as those described below.

Some teachers wrote that "Maker-centred teaching first and foremost allows for hands-on learning experiences" (P41-S-T). It brings "a more hands-on approach to learning" (P55E), "relies on hands-on practice" (P19-E), and "hands-on exploration" (P30-E). Maker-centred approaches were said to emphasize "hands on learning through doing rather than just hearing" (P74-S-M). "It really has the students and teachers using their hands, body and minds to actually build something tangible" (P62-E). A secondary science teacher stated that, "we have a 'Maker-Space' club where kids can take apart and build things ... maker-centered is 'hands-on' then obviously it gives students an opportunity to manipulate equipment for a variety of outcomes" (P95-S-S). This "hands on experience to apply to theory is much more meaningful" (P86-E) when compared to many traditional ways of teaching and learning.

An elementary ADST teacher described the maker-centred learning process as "applied learning, students discover by doing. They also learn to adapt their creation to achieve the task. They learn to question what they have done, will this work or not. So many kids are more willing to take risks with this kind of teaching and activity" (P28-E). Maker-centred learning "is more engaging and experiential and allows students to test hypothesis" (P59S-M). "It gives students the opportunity to see their learning in action" (P80-S-M). A secondary technology teacher shared his insightful views with regard to the "applying" feature of maker-centred approaches, and wrote that "It allows people [to] 'USE' their knowledge in a practical way: make something, fix something, build or test something etc. ... It is part of making whole people to teach the body to do as you teach the mind to think. ... Teaching making and doing is holistic and real. it is about applied knowledge and creative application of concepts" (P37-S-T).

Group comparisons (grade-level and subject area) for the theme are shown in Tables 4.24 and 4.25. It shows that "Hands-on, Experiential" was stated as an characteristic of maker-centred learning by more secondary school teachers (56%) than elementary school teachers (40.6%); and at the secondary level, this characteristic was more emphasized by science teachers than mathematics and technology teachers.

Table 4.24. Comparison of grade levels – Hands-on, Experiential

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	13	40.6
Secondary (G8 – 12)	18	56.3
Cross-group	1	3.1
Total	*n* =32	100

Table 4.25. Comparison of subjects - Hands-on, Experiential

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	12	37.5
Science	9	28.1
Mathematics	5	15.6
Tech & Engineering	4	12.5
Unidentified	2	6.3
Total	*n* =32	100

Creativity and Engagement

Seventeen teachers noted "Creativity" as a distinct characteristic of maker-centred learning. They expressed that maker-centred learning is "very creative and imaginative" (P9-E), "it not only engages students, but it empowers them to create" (P61-S-M). Creativity is necessarily "required to be successful in a maker-centred approach" (P47-S-T). Teachers stated that maker-centred teaching "allows students to think and create for themselves" (P11-E), "allows for creativity beyond fact acquisition" (P79-S-M), and "get kids talking and thinking outside the box" (P40-S-M). In maker-centred learning, "students must use their creativity and innovative skills to come up with solutions" (P41-S-T). A secondary science teacher wrote that:

> Essentially, the students have the task to create something and improve it. This will be something built or put together by the student and then shared with others. .... In addition, the student can explain how and why they made their project in a particular way..... Making challenges the learner to create something based on their understanding and improve their knowledge and skills as they make it (P73-S-S).

Table 4.26 presents a comparison of code occurrences between different grade-levels (elementary, secondary) with regard to the teacher's responses about “Creativity”, and shows that “Creativity” was mentioned much more by secondary school teachers than by elementary school teachers.

Table 4.26. Comparison of grade levels – Creativity

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	4	23.5
Secondary (G8 – 12)	11	64.7
Cross-group	2	11.8
Total	*n* =17	100

“Engagement” is the theme next most often mentioned in teachers’ responses. Teachers stated that maker-centred learning is “student directed and involves passion and engagement” (P4-E), and that “It engages all types of learners” (P57-S-M). Another explained that “Students are usually more engaged when there are some hands-on activities“ (P76-S-M). Some teachers reflected upon their teaching experience with maker-centred pedagogies and wrote that, maker-centred learning “activates different areas of the brain/different ways of understanding” (P85-S-S); in the learning process, “students are highly engaged and the vocabulary that arises throughout our STEM is all tied back into the curriculum” (P24-E).

Table 4.27 presents the group comparison between different grade-levels (elementary, secondary) with regard to the teachers’ responses about “Engagement”, showing that the secondary school teachers account for the majority of code references. What this may mean is that respondents teaching at the secondary level were more often motivated in their use of making by concerns with student motivation.

Table 4.27. Comparison of grade levels – Engagement

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	4	30.8
Secondary (G8 – 12)	9	69.2
Total	*n* =13	100

Flexibility, inquiry-based and problem solving

Thirteen teachers elaborated on the importance of “Flexibility” in implementing maker-centered pedagogies. They viewed maker-centered approaches as “open ended” (P36-S-S) and “more personalized” (P19-E), because it “gives students the opportunity to have choice and ownership over their work” (P3-E), and “explicitly allows the students to demonstrate resiliency” (P-96-E). Maker-centered teaching “allows the students to interpret what is being asked in their own way. All students can come at same problem from different approach[es]” (P-29-E). As a secondary science teacher noted, in maker-centered teaching, “the teacher has to be able to think on their feet and very adaptable because there is not a set lesson. Teachers must differentiate even more than usual because each student is working on something different” (P67-S-S). Another teacher described her maker-centred teaching practices in the school library:

> In the library, I have a lot of freedom when it comes to curricular content and to assessment. This means that my maker-centered teaching can often take unexpected turns. Students often develop or come up with additional criteria to my usually-fairly-freeform activities on their own. I come from a visual arts background, and I treat library as a "studio" class - I demonstrate a skill/technique, then the students have lots of time to work and explore (P13-E).

Relatedly, some teachers viewed maker-centred learning as an “Inquiry based and problem solving” approach, which formed another theme in the data analysis. Teachers mentioned that, maker-centred pedagogy is “student-centered and inquiry based” (P25-E) which “allows students to test hypothesis” (P59-S-U). “Maker-centered teaching can take on a problem-based learning approach” (P41-S-T), it is “more focussed on problem-solving, exploration, and hands-on activities than traditional teacher-centered lectures” (P90-C-T). In maker-centred learning activities, students “learn to question what they have done, will this work or not” (P28-E), and that “allows the student to practice critical thinking and problem solving skills as opposed to rote learning” (P53-S-T).

Collaboration and Challenges

Collaboration was another common theme in the responses. As a respondent expressed, the focus of maker-centred activities is “on the process and the utilization of novel strategies to achieve a specific outcome. Collaboration, testing, reevaluation, novel and creative approaches are all required to be successful in a maker-centered approach” (P47-S-T). Maker-centred activity requires “more communication” and “collaboration” amongst students (P2-E), it “gives students the role of expert, where they might be teaching others” (P17-E). Respondents emphasized that “collaboration is key” in maker-centred activities (P28-E). In maker-centred learning, “the students have the task to create something and improve it...and then share with others” (P73-S-S). It requires “students have the ability to collaborate and express their ideas” (P24-E) through communication and “interaction” (P63-S-S).

In the responses, the participants described teachers’ roles in maker-centered learning as guides and facilitators rather than lecturers and instructors. Maker-centered teaching and learning is “more of a guided, 'coaching' approach” (P7-S-S), “more facilitated than led” (P9-E). It “requires teachers to lecture less and be a facilitator” (P43-S-S). Maker-centered learning “relies on student ideas and motivations” (P16-E), in which “students collectively are in control and instructors are there to encourage and probe learning” (P65-S-S).

Given this, it is not surprising that many responses called attention to the challenges that teachers may face and the risk-taking aspect in maker-centered teaching and learning. One respondent stated that “there is more front-end loading required” (P66-S-S). It “requires teachers to lecture less and be a facilitator which is an uncomfortable feeling for some educators” (P43-S-S). An elementary school teacher wrote, “teachers have to be okay with giving more control to their students than they may be used to. Teachers also have to realize what students are capable of, and recognize the advantages that maker-centered learning provide. Too many teachers are afraid of it” (P84-E). In this vein, another elementary teacher summarized the experience of maker-centred learning as follows: “less control from the teacher - messy, noisy, complex - difficult to assess - exhausting for teachers” (P9-E). One simply stated that maker-centred learning “can involve tools that I'm not comfortable using” (P22-E).

Other Themes

Four other themes appeared with relatively low frequencies compared to those discussed above, but are mentioned here because they represent some important characteristics of maker-centered pedagogies.

Some participants emphasized that maker-centred teaching is more about “Process” than product: “As teachers we have been focused on the end product or assessment. In maker-centered teaching, the focus is the thinking process of the maker whether the end product is successful or fails” (P15-E). As another participant stated, maker-centred learning “is process-driven, rather than ‘correct answer’ driven. (It) develops skills and competencies rather than memorizing facts” (P44-S-S).

Several teachers mentioned the “Resources and tools” that support maker-centered activities. For example, in "maker space", students “play with new tech (robots, programming, green screens, etc)” (P60-S-S), with the resource support they “can take apart and build things, ... manipulate equipment for a variety of outcomes” (95-S-S). Maker-centred learning “involve tools” (P22-E) and needs “space and surface area” (P2-E). Just like a secondary school technology teacher noted, ”Environment (proper facilities, equipment and consumables) plays a big role in the effectiveness of maker-centred activities” (P92-S-T).

Several teachers mentioned the “Tangible“ attribute of maker-centered activities. In maker-centred learning, “students are engaged in doing something. The learning experience is more meaningful since they have an artifact of their learning” (P72-S-S). “It really has the students and teachers using their hands, body and minds to actually build something tangible” (P62-E). The maker-centred approach allows students to “create something and improve it”, and “the learning is presented through a tangible artifact, such as an image or a robot” (P73-S-S).

A few teachers emphasized the “Strategies” that support maker-centred pedagogies. For example, a secondary school technology teacher noted that “The focus of maker-centered activities is on the process and the utilization of novel strategies to achieve an(a) specific outcome” (P47-S-T). “It is different in the strategies to teach the concepts, the classroom management, and level of engagement ” (P41-S-T). Maker-centred teaching and learning require “more planning on the teacher's part to ensure things run smoothly” (P67-S-S).

Finally, several teachers mentioned the “Resources and tools” that support maker-centered activities. For example, in a maker space, students “play with new tech (robots, programming, green screens, etc.)” (P60-S-S), with the resource support they “can take apart and build things, ... manipulate equipment for a variety of outcomes” (95-S-S). Maker-centred learning “involve tools” (P22-E) and needs “space and surface area” (P2-E). As one secondary school technology teacher stressed, ”Environment (proper facilities, equipment and consumables) plays a big role in the effectiveness of maker-centred activities” (P92-S-T).

4.4. Chapter summary

This Chapter employed both quantitative and qualitative analysis techniques to analyze and interpret participant responses to address the first research question of the study, e.g., “What are ADST and STEM teachers’ current understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favour or doubt maker-centred teaching and learning?”

Section 4.1 focused on teachers’ backgrounds, and presented statistical analysis of the participants’ teaching backgrounds and previous experience related to maker-centred pedagogies. This section also included analysis of an open-ended question addressing the training that respondents had received on maker-centred pedagogies. Analysis showed that the survey participants included the public school teachers of ADST or STEM with diverse teaching backgrounds (with regard to both grade-level and disciplinary area).

Of the 97 respondents, the majority had some awareness of maker-centred teaching and learning. More than 60% of the participants had previous relevant experiences of using make-centered approaches, followed by 23% who had heard of it but never used it, and 16% who didn’t know this approach at all. As for training on maker-centered pedagogies, 30 out of 94 submissions indicated that the respondent had received some kind of training, including 6 teachers who had received training through formal education programs, and 11 teachers through workshops or professional development activities. The remaining 64 teachers had not received any training on maker-centered teaching and learning. Results overall indicated a lack of available resources and opportunities for public school teachers to develop their professional competence and expertise in using maker-centered pedagogies.

Section 4.2 presented analysis of teachers' responses with regard to four sub-questions of Research Question 1. There were three main findings:

1. In relation to teachers' perceptions with regard to the current situation of ADST and STEM education, participants' responses indicated that the elementary teachers place greater emphasis on hands-on practice in classrooms than secondary teachers; while at the secondary level, students have more opportunities to make things in technology and engineering classrooms than in science and math classrooms.

2. Regarding perceptions and favour or doubt about maker-centred approaches, the teachers' responses were highly consistent. Statistical analysis result shows that the majority of ADST and STEM educators responding had a positive perception of maker-centred pedagogies, and a favorable view of implementing maker-centered teaching and learning in ADST and STEM education.

3. As for the roles that teachers should play in ADST and STEM education, most teachers agreed with that "ADST and STEM educators should act as technology-literate facilitators and guides rather than transmitters of information."

Section 4.3 presented qualitative analysis of participants' responses to an open-ended question addressing the last sub-question of Research Question 1, "what are the characteristics of maker-centred teaching and learning, and how is the maker-centred approach different from other approaches?" Systematic analysis of the data was carried out, and thirteen themes were derived to capture a variety of distinct characteristics of maker-centred pedagogies described by the respondents. In general, the teachers' responses acknowledged that maker-centered pedagogy possesses specific characteristics that are different from other teaching methods in terms of course planning, course implementation, students' engagement, teacher's roles, classroom management, and the need of learning resources and tools. Of all important characteristics mentioned, student agency and independence, practical ability and creativity were particularly emphasized. The group-wise comparison shows that the secondary school teachers accounted for the majority of code references for theme “Creativity” and “Engagement”; and at the secondary level, “Student agency, Independence” and “Hands-on, Experiential” were mentioned more by science teachers than by other teachers of other subjects.

To summarize the qualitative findings, according to the frequencies mentioned in descending order, the reported characteristics of maker-centred pedagogies are: Student agency and Independence, Hands on and Experiential, Creativity, Engagement, Flexibility, Inquiry based and Problem solving, Challenge and Risk taking, Collaboration, the uniqueness of the Teacher’s role, a focus on Process, unique needs for Resources and Tools, Artifact-centredness, and the need for unique Strategies.

Chapter 5.

Data Analysis (II): Application, Resource, Strategy and Consideration

This chapter focuses on the analysis and interpretation of participants' responses to survey questions that address the last three research questions of the study:

- Are there differences in disciplinary areas related to the application of maker-centred pedagogies?
- What are the resources and tools that teachers use and need for implementing maker-centred pedagogies
- What are the teaching and learning strategies that teachers adopt in using maker-centred pedagogies?

Quantitative and qualitative analysis techniques were adopted to address these research questions and to verify the accuracy and trustworthiness of the findings.

The chapter consists of six sections. Section 5.1 describes the data analysis results and the interpretation of the results to answer research question 2, "Are there differences in disciplinary areas related to the application of maker-centred pedagogies?" Analysis focused on the participants' responses to the open-ended questions that solicited teachers' views and the current application status of maker-centred pedagogies in different disciplinary areas. The qualitative analysis discusses the status of teacher training on maker-centred pedagogies in different subject areas.

Section 5.2 addresses research question 3, "What are the resources and tools that teachers use and need for implementing maker-centred pedagogies?" It includes two subsections. The first discusses the necessity of special resources and tools in implementing maker-centred pedagogies, while the second discusses the specific technologies, tools and supplies that teachers report are used in maker-centred teaching and learning.

Section 5.3 presents data analysis to address Research Question 4 regarding the teaching and learning strategies that can support maker-centred teaching and learning. Two sub-questions are discussed in this section, including whether special strategies are needed when using maker-centred pedagogies, and what specific strategies can support and facilitate maker-centred teaching and learning. Descriptive and inferential statistical analyses were carried out to address the first two sub-questions, and qualitative data analysis was performed to address the third sub-question.

Section 5.4 examines whether gender has an impact on the learning outcomes of maker-centred activities by analyzing the data of the teachers' responses to a closed-form survey question through both descriptive and inferential statistical analysis.

Section 5.5 employs qualitative approaches to examine participants' responses to an open-ended question on the survey regarding other important features and factors to be considered in applying maker-centred pedagogies in ADST or STEM related classrooms.

The last section, 5.6, summarizes the major results presented in the chapter, and attempts to draw some conclusions with regard to each of the research questions addressed. For clarity, the research questions discussed in this chapter are re-stated below.

Research Question 2: Is there a difference in the application of maker-centred pedagogies in different disciplinary areas?

Sub-questions:

- In which subject areas have teachers used maker-centred pedagogies?
- What training did teachers receive on maker-centred pedagogies in different subject areas?

Research Question 3: What are the resources and tools that are used and needed in implementing maker-centred pedagogies?

Sub-questions:

- Are specific resources and supplies necessary in maker-centred teaching and learning?
- What resources and supplies are used in maker-centred teaching and learning?

Research Question 4: What are the teaching and learning strategies that teachers adopt in using maker-centred pedagogies?

Sub-questions:

- Do maker-centred pedagogies need specific strategies?
- What strategies support maker-centred teaching and learning?
- Does gender have an impact on the outcomes of maker-centred learning ?
- What other features/considerations are important in implementing maker-centred pedagogies?

5.1. Current application of maker-centred pedagogies – Research Question 2

This section presents analysis of participants' responses to survey questions related to the question "Is there a difference in the application of maker-centred pedagogies in different disciplinary areas?" It consists of two subsections addressing the following two sub-questions:

- In which subject areas have teachers used maker-centred pedagogies?
- What training did teachers receive on maker-centred pedagogies in different subject areas?

5.1.1. Applications in different disciplinary areas

To address the sub-question "In which subject areas have teachers used maker-centred pedagogies?" descriptive and inferential analyses were conducted on participants' responses to two closed-form questions on the survey.

Subject areas in which teachers used maker-centred pedagogies

Survey Question 1.4 invited teachers who had used maker-centred teaching approaches to list the subject areas and the grade-levels in which they used this method:

- SQ1.4. If you have ever used the maker-centred teaching approach, please list the courses and grades in which you used this method

Of 97 submissions, 64 stated that the participant had used maker-centred teaching approaches. Within these responses, 100 course references and 99 grade references were made. Descriptive statistical analysis was conducted for the responses using the computer program PSPP (FSF, 2007). The frequency distributions of subject areas and grade-levels are tabulated below in Table 5.1(a) and Table 5.1(b), and visualized in Figures 5.1.(a) and 5.1.(b).

Table 5.1.(a) Subject areas teachers used maker-centred pedagogies

Subject Areas	Frequency *(f)*	Percentage (%)
Science (chemistry, physics, biology, etc)	31	31.0
Technology (drafting, programming, wood, etc)	30	30.0
Engineering (electronic, mechanic, electric, etc)	11	11.0
Art (language, fine art, music, etc)	8	8.0
Mathematics	7	7.0
ADST, STEM related	5	5.0
Others (social study, career, club, etc)	5	5.0
Library (including maker place)	3	3.0
Total case number	n = 100	100
Central tendency: Mode	Mode=Science	

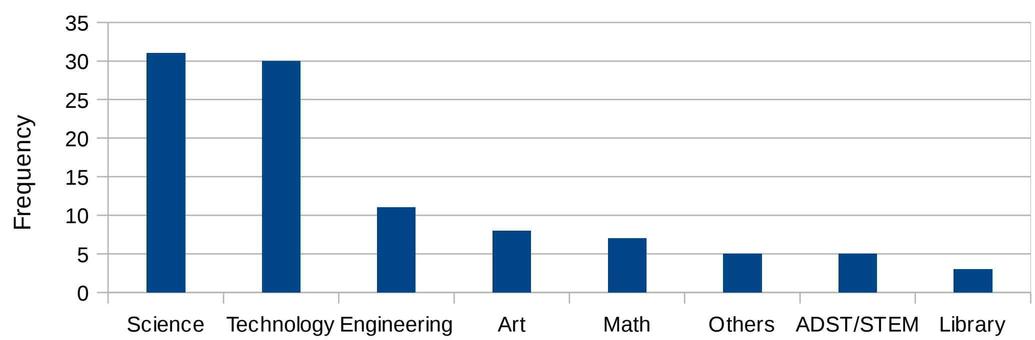

Figure 5.1.(a). Subject areas teachers used maker-centred pedagogies

Table 5.1.(b) Grade-levels teachers used maker-centred pedagogies

Grade-levels	Frequency *(f)*	Percentage (%)
Early Elementary (K-2)	9	9.1
Late Elementary (G3-5)	12	12.1
Middle School (G6-8)	25	25.2
Secondary School (G9-12)	53	53.5
Total case number	n = 99	100
Central tendency: mode	Mode=G9-12	

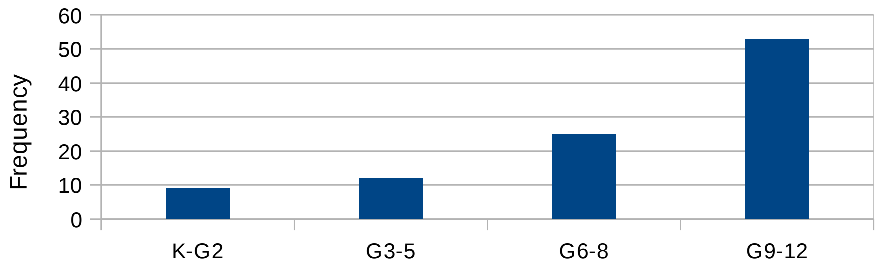

Figure 5.1.(b). Grade levels teachers used maker-centred pedagogies

From these data, some findings can be drawn: 1) Maker-centred pedagogies are used much more in science, technology and engineering classes than other subject areas. 2) Maker-centred pedagogies are used more in the upper grade-levels compared to the lower grade-levels. 3) Maker-centred pedagogies can also be used in non-STEM subject areas, such as art and social studies. This is consistent with the findings of the last subsection. 4) Mathematics accounts for a relatively large proportion (37.4%) of the courses that respondents taught, but a small proportion (6.9%) of the subject areas in which maker-centred pedagogies were applied.

Current situation of ADST and STEM education

In part two of the survey questionnaire, the participants were asked to give a 5-point rating to a statement (SQ2.2):

- SQ2.2. Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms.

Teachers' responses to this question presented a divergent normal distribution (see Table 4.7 and Figure 4.5). The group means on the 5-point scale ratings were: Science=3.77, TechEng=2.58, Mathematics=3.89 (see Table 4.15). To further explore the differences between the responses of teachers from different disciplinary areas, inferential analysis was performed to compare the group means between disciplinary areas (Science, Tech/Eng, Math), by conducting one-way ANOVA (F-test) and post hoc test (Turkey's HSD Test).

At the secondary level the technology and engineering teachers' responses to SQ2.2 ,"Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms", are statistically different from those of the science and math teachers. This suggests that at least according to their teachers, secondary school students have more opportunities to make things in technology and engineering classrooms than in science and mathematics classrooms (refer to Section 4.2.1 and Table 4.15).

5.1.2. Usefulness in non-STEM areas

To understand the respondents' perceptions with regard to the usefulness of maker-centred pedagogies in non-STEM subject areas, the survey invited participants to rate the following statement on a 5-point scale:

- SQ2.6. Maker-centred teaching and learning are useful in subjects not related to ADST and STEM.

A total of 96 participants responded to this question, and descriptive analysis was conducted for the responses. The results of frequency distribution and measures of central tendency are presented in Table 5.2 and Figure 5.2.

Table 5.2. Application of maker-centred pedagogies in non-STEM subject areas

SQ2.6. Maker-centred teaching and learning are useful in subjects not related to ADST and STEM.	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**	**Mean**	**Mode & Median**
	2	2	17	47	28	*n*=96 $\bar{x}$=4.01	Mode=4 Median=4

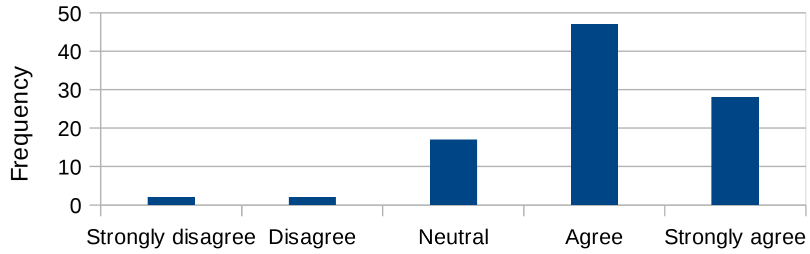

Figure 5.2. Distribution of teachers' rating to SQ2.6

The mean rating is 4.01, and the frequency of the responses has a positively skewed distribution, indicating that most of the teachers agreed with the statement "Maker-centred teaching and learning are useful in subjects not related to ADST and STEM." Of 96 responses, only four teachers (all secondary school STEM teachers) rated the statement "disagree" or "strongly disagree". In order to find out if there was a significant difference between the teachers in different subject areas, the subsequent descriptive analysis by STEM vs. non-STEM teachers was then conducted. The results are shown in Table 5.3.

Table 5.3. Application of maker-centred pedagogies, SETM vs. non-STEM teachers

Survey Question (SQ)	Groups of Teacher	Mean	Case Number
2.6. Maker-centred teaching and learning are useful in subjects not related to ADST and STEM.	STEM	$\bar{x}$=3.93	*n*=74
	Non-STEM	$\bar{x}$=4.27	*n*=22

Note: STEM teachers include all teachers who reported teaching one or more STEM subjects.

5.1.3. Teachers' training in making

Training provides opportunities for teachers to acquire specific teaching skills and improve professional proficiency. In order to understand the training that ADST or STEM teachers had received on maker-centred pedagogies in different subject areas, the survey included an open-ended question as follows:

- SQ3.5. Have you received any training on maker-centred teaching and learning? If yes, in what disciplinary areas?

Of 94 responses to the question, 31 noted that the respondent had received some kind of training on maker-centred pedagogies through formal education programs, workshops, or other professional development activities in different disciplinary areas (refer to Section 4.1.4). In the last chapter, Section 4.1.4 reported on the frequency of training teachers received and answered the first half of the question. This subsection discusses the second half of the question - the subject areas in which the teachers received training with regard to maker-centred pedagogies.

The computer program NVivo 12 (QSR, 2018) was used for the qualitative analysis of participant responses. The data analysis included an initial open coding of the data to categorize the responses and to form major themes. The final coding framework and coding results are summarized below in Table 5.4.

Table 5.4. Disciplinary areas of training on maker-centred pedagogies

Code/Theme	Definition of Theme	Frequency
Science	Responses that indicated the training in science areas	11
Technology / Engineering	Responses that indicated the training in technology and/or engineering areas	11
K- Grade 7	Responses that indicated the training for K-G7 level, but didn't give the specified areas	3
Mathematics	Responses that indicated the related train in math	2
Art	Responses that indicated the training in art	2
ADST	Responses that specified the training in ADST	1
Special Education	Responses that noted that the training in special education	1

Results show that training on maker-centred pedagogies was provided mostly in science, technology and engineering areas. This suggests that teachers who teach these subjects have more opportunities to receive relevant training. This finding is in line with the actual application status of the maker-centred pedagogies discussed previously (sub-section 5.1.1). Below are some representative responses from teachers describing of the training that they had received.

A secondary science teacher "completed a 2 year degree on the new BC curriculum where much of the focus was on this concept (maker-centred teaching)" (P66)[6]. An Industrial/Technology teacher received training at "BCIT in woodwork, metalwork, mechanics, electronics, etc." (P92), and another technology and engineering

6 P# indicates the particular participant with whom the data were generated.

teacher was trained through “a few workshops and my own self-directed professional development” (P47). One secondary school technology teacher emphasized the importance of training and wrote, “during my M.Ed. program there were 2 teachers who exclusively worked in maker spaces. Their insights were invaluable in my understanding of a maker space” (P41).

Beside these, a few teachers received training on maker-centred teaching and learning in other subject areas. For example, a mathematics teacher received training through “workshops” (P10); an elementary teacher “taught visual arts to children and teenagers both in the school system and out of the school system ... There was half of a day of pro-d for teacher librarians on "maker space" activities” (P13); and another mathematics teacher received training on maker-centred teaching in “general middle school application” (P86). There was also one teacher who received training in “ADST” (P68), and one in “special education” (P5).

5.2. Resources, tools and supplies – Research Question 3

In some sense, maker-centred pedagogies evolved from the early maker movement in which the participants were usually high-income people, and the related activities often involved more expensive high-tech tools and materials (Dayton, 2017). In order to investigate the current status and potential of applying maker-centred pedagogies in public schools, and understand the resources needed in teaching and learning activities and the costs of implementing maker-centred pedagogies, the online survey included both closed-form and open-ended questions to address the third research question.

Research Question3: What are the resources and tools that teachers use and need for implementing maker-centred pedagogies?

Sub-questions:

- Are specific resources/tools necessary in maker-centred teaching and learning?
- What resources and supplies are used in maker-centred teaching and learning?

5.2.1. Need for resources and tools

In part two of the survey, teachers were invited to respond to one closed-form question (SQ2.8) using a 5-point scale.

- SQ2.8. Specific resources/tools are necessary for maker-centred teaching and learning

This question received 96 ratings. Descriptive analysis was performed for the data using PSPP (FSF, 2007) to examine the frequency distribution and measures of central tendency of this variable. Analysis shows that the mean value of ratings is 4.08, and the teachers' responses exhibit a positive right skew distribution. This means that the majority of the teachers agreed that maker-centred teaching and learning need to use some special resources and tools. The relevant results are presented in Table 5.5. and Figure 5.3.

Table 5.5. Need of special resources in maker-centred teaching and learning

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean	Mode & Median
SQ2.8. Specific resources/ tools are necessary for maker-centred teaching and learning.	2	5	13	39	37	n=96 $\bar{x}$=4.08	Mode=4 Median=4

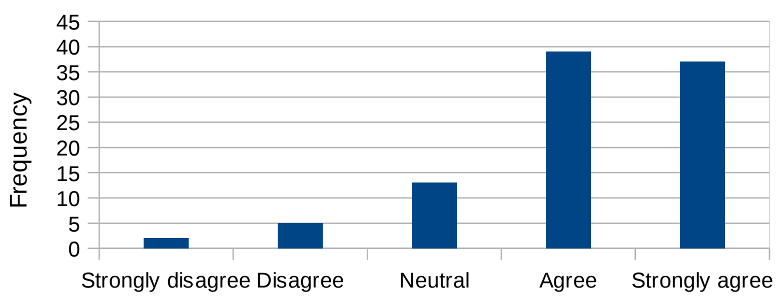

Figure 5.3. Distribution of teachers' rating to SQ2.8

5.2.2. Resources and supplies used

To find out what specific resources are needed in maker-centred teaching and learning, the survey asked the participants to respond to an open-ended question (SQ3.3):

- SQ3.3. What technologies or tools have you used in maker-centred teaching and learning?

Eighty-eight teachers responded to this question, making a total of 257 references to technologies, tools and supplies used in maker-centred teaching and learning. Qualitative data analysis was conducted on teacher responses to this question using NVivo 12 (QSR, 2018). The responses were first explored in detail and classified with attribute labels through an initial open coding of the data. Later, codes were refined, analyzed and grouped to form major themes which represent the main ideas in the data.

This analysis suggests that modern digital technologies were often used by respondents in supporting maker-centred teaching and learning. Many teachers mentioned they had applied one or more high-tech tools or products in applying maker-centred pedagogies, such as iPad, online simulations, 3D printing, etc.

In teachers' responses, 105 references were coded to electronic devices and supplies used in maker-centred teaching and learning. Among those, computers, laptops, and iPads were most often mentioned. Other often-mentioned digital tools, supplies and devices included 3D printers, electronic circuit kits and tools, robotics kits, micro-controllers, digital cameras, etc.

Some teachers used computer programs and apps in their teaching practice with maker-centred pedagogies. These computer programs included some general-purpose software such as the Adobe Suite and Microsoft Word, and many special-purpose computer programs like Photoshop and iMovie for picture and movie editing, Scratch for programming, and TinkerCad for 3D CAD design. One teacher also mentioned the use of science journals.

Beyond these technologies, there were 80 references in which teachers reported using very common and simple materials for maker-centred teaching and learning. These materials included crafting and building materials like cutting boards, clay supplies, straws, paints, and foil; hand tools like hammers, scissors, sewing needles and rulers; kitchen tools; wood and metal work supplies, and so on. The framework of coding themes and the final coding results of the resources and tools teachers used in maker-centred teaching and learning are presented in Table 5.6.

Table 5.6. Resources and tools used in maker-centred teaching and learning

Code/Theme	Definition of Theme	Frequency (total=257)
Technologies	Technologies that have been applied in maker-centred teaching and learning,	28
Electronic Devices, Equipment, Supplies	Electronic tools, devices and supplies used in maker-centred activities, e.g., computers, digital tools and instrument, electronic kits, robot, electronic component, etc.	105
• Computers	Includes computer, laptop, tablet, mini-computer, etc.	28
• Components, science supplies	Electronic components, supplies and tools for science activities.	18
• Other devices, equipment	Other devices and equipment for making activities.	17
• Kits, digital tools	Includes all kinds of kits and digital tools used in maker-centred learning.	16
• Robots	Robots used in maker-centred learning.	15
• 3D printers	3D printers used in maker-centred learning.	11
Software Tools, Apps, Science Journals	Software tools, apps, and sciences journals used in maker-centred learning.	16
Hand Tools and Materials	The common hand tools and materials (vs. High-tech ones) used in maker-centred teaching and learning.	80
• Art, craft, building materials & tools	Materials, tools, and supplies for art, craft and building activities.	45
• Other hand tools & materials	All sorts of hand tools and materials that are not included in the specified themes	18
• Wood, metal work supplies & tools	Supplies and tools for wood work and metal work.	12
• Sewing supplies and tools	Supplies for sewing	5
Other tools, Materials	Tools and materials that are not included in the specified themes.	4
Learning Activities/Projects	The learning activities and projects using the mentioned technologies and resources	24

From the above results three conclusions can be drawn: 1) Respondents perceived maker-centred pedagogies to require some special resources. 2) Maker-centred pedagogies can involve different kinds of resources and materials. 3) The resources needed for applying maker-centred pedagogies can be simple and inexpensive – supplies don't have to be expensive high-tech products. Below are some representative descriptions of the tools and materials mentioned by teachers.

An elementary school teacher (P24)[7] stated that, "I am a part of our iPad District Pilot project. Essentially this means incorporating 6 iPads into our every day center type activities-through the use of coding, spheros. Our classroom has a STEM area where various supplies are made available to students to build, design and create with." One secondary technology teacher (P47) used "Makebot robitic kits, Microbits, scrap materials for modelling, plasticine for making 3D characters in animation 12 (give students a non-digital tactile experience)".

Many teachers used simple handy materials in maker-centred teaching. For example, an elementary teacher (P13) listed "recycled materials (a lot of cardboard!), tape, cups, popsicle sticks, straws, yarn, fabric scraps, toothpicks, marshmallows, tinfoil, construction paper, etc." A secondary school science teacher (P26) had "done some design challenges where students create a boat to hold pennies and egg drop challenges."

One secondary technology teacher's insightful views regarding the tools needed in maker-centred teaching may make a fitting end to this section:

> I have 30 years of tool use far to varied to list. A tool can be a hammer, a pencil, a laser engraver or a nuclear accelerator (few schools have this last one). The type of tools available dictate the type of work that can be done. But tools are only part of the equation. Teachers must be properly trained to use and teach them, and teachers must invest A LOT of time developing their skills (P37).

5.3. Strategies support maker-centred pedagogies – Research Question 4

As discussed above, compared with other teaching and learning approaches, maker-centred pedagogies have different characteristics in terms of course planning and preparation, teaching methods, classroom management, and students' learning modes. In order to address the ways in which teachers can effectively prepare and deliver the learning content and better support students in learning activities, the online survey

7. P# indicates the particular participant with whom the data were generated.

included several questions to gather both quantitative and qualitative data with regard to the fourth research question:

Research Question 4: What are the teaching and learning strategies that teachers adopt in using maker-centred pedagogies?

Sub-questions:

- Do maker-centred pedagogies need specific strategies?
- What strategies support maker-centred teaching and learning?

5.3.1. Need of specific strategies

To understand respondents' perceptions about developing special strategies to implement maker-centred pedagogies, teachers were asked to rate two closed-form statements on a 5-point scale:

- SQ2.9. Maker-centred teaching requires the development of specific strategies to facilitate students' learning.
- SQ2.10. Collaboration is important in maker-centred learning.

Question 2.9 addressed respondents' general perceptions about adopting special strategies for implementing maker-centred pedagogies, and received 95 ratings. Descriptive analysis of these responses was performed using PSPP (FSF, 2007). and the frequency distribution of the responses and the measures of central tendency were examined. The mean value of all ratings was 4.02, and teachers' responses to this question exhibited a positive right skew distribution. This means that most of the teachers agreed that maker-centred pedagogies require some special strategies to support and facilitate teaching and learning. The statistical analysis results are shown in Table 5.7 and Figure 5.4.

Table 5.7. Need for special strategies in maker-centred teaching and learning

SQ2.9. Maker-centred teaching requires the development of specific strategies to facilitate students' learning.	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**	**Mean**	**Mode & Median**
	0	1	19	52	23	*n*=95 $\bar{x}$=4.02	Mode=4 Median=4

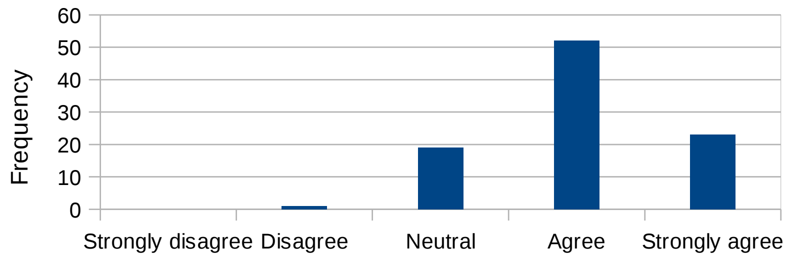

Figure 5.4. Distribution of teachers' rating to SQ2.9

Question 2.10 solicited teachers' specific views about collaboration in maker-centred learning, and received 96 ratings. The frequency distribution of the ratings and the measures of central tendency were examined. The teachers' responses to this question has a highly positive skew with a mean of 4.16, indicating that most of the teachers agreed that collaboration is an important strategy to support student's learning in maker-centred activities. Detailed results are presented in Table 5.8 and Figure 5.5.

Table 5.8. Collaboration in maker-centred learning

SQ2.10. Collaboration is important in maker-centred learning.	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**	**Mean**	**Mode & Median**
	1	2	15	41	37	*n*=96 $\bar{x}$=4.16	Mode=4 Median=4

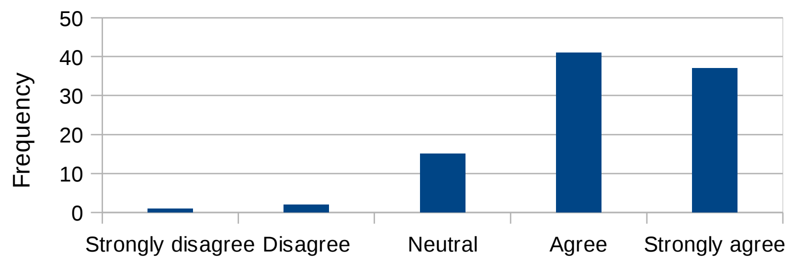

Figure 5.5. Distribution of teachers' rating to SQ 2.10

5.3.2. Strategies to support maker-centred pedagogies

This subsection focuses on specific strategies that support and facilitate maker-centred teaching and learning, through qualitative analysis of participants' responses to an open-ended question in part three of the survey:

- SQ3.2. What strategies support maker-centred teaching and learning?

The qualitative analysis consisted of three major steps: 1) establishing a coding framework and performing open coding, 2) conducting double coding and calculating interrater reliability, and 3) performing thematic analysis of the codes and making group-wise comparisons for dominant themes.

Coding Framework and Open Coding

NVivo 12 (QSR, 2018) was employed to perform an open coding of the responses to SQ3.2 "What strategies support maker-centred teaching and learning?" There were 86 submissions in total, of which 70 teachers provided valid responses with regard to the question asked, nine responded "don't know", and seven provided responses unrelated to the question. Participants' responses included short expressions, like "collaboration, communication", "having resources and time for exploration", as well as some long paragraphs that expressed detailed and comprehensive views. For example, a secondary school technology teacher shared his thoughts on using specific strategies to support students' learning in maker-centred activities:

> Having the right STEM related materials - i.e. robotic kits that are exciting and help students see a practical application of their learning i.e. learning Python to help program robotic commands. Using a exploration approach where multiple outcomes are possible. Reducing teacher directed learning activities. I see the role of teacher as being the one who uses

> their professional judgement to put the best resources in front of students. The final design and outcome of the applied skills task is ultimately left in the hands of the students. This allows students to feel in control of their learning and really helps student engagement. This approach helps students to really understand the value of what is being taught. The place when teaching happens is later in the process when students get stuck or are finding a task difficult (P47)[8].

Another secondary school technology teacher described in detail his views on supporting maker-centred teaching and learning, as well as the current status and challenges of implementing effective strategies:

> First you need to have teachers who are skilled and trained in the safe and successful use of tools needed for making and doing. Tech Ed teachers make this their mission. Few others have even a clue. It simply is not on the radar of most academics nor is it part of their University experience. Next you need curricula created from the stand point of being applied through making. Most STEM curricula is sorely lacking here. ADST is far better on this. Next you need time, resources, tools, materials, money and flexible scheduling to allow the creative application of making and doing. My budgets are 1/5th of what they were 20 years ago and timetabling has never been less flexible. **Huge obstacles. But the biggest obstacle is attitudes** [emphasis in original]**.** I am exceptionally good at what I do and yet year after year and all levels I have experienced prejudice, ignorance and hostility large and small from admin, colleagues, district staff, post secondary instructors and programs and even the community at large. We are an academia centered culture. That means study and tests and grades. NOT making, doing and creating. No time for such things. Leave that to the "trades" people. It is elitist and simply foolish but extremely hard to change (P37-S-T).

Qualitative analysis was carried out on all of the valid responses. This process started from the preparation and organization of the data, followed by an initial exploration for a general sense of the data, and then an open coding using computer programs (Excel, NVivo). The coding framework was defined, and code labels were assigned using phrases to summarize the basic topics of the coded phrases or sentences (Saldaña, 2009; Miles et al., 2014). In the next step, the codes that emerged from the data analysis were consolidated into broader themes (Creswell, 2012; Saldaña, 2009).

The results presented below suggest that many strategies were reported by teachers as being useful in different aspects in applying maker-centred pedagogies. Of

8. P# indicates the particular participant with whom the data were generated.

them, several themes were most frequently mentioned as major strategies to support maker-centred teaching and learning. These include: Collaboration (30), Inquiry and problem-based learning (17), Flexibility (17), Guiding, scaffolding, and facilitation (14), etc. The qualitative coding framework and data coding results are summarized in Table 5.9. Note that only the 70 valid responses were coded, and more than one code could apply to a single response.

Table 5.9. Coding framework and results - Strategies of maker-centred pedagogies

Question	Description	Reference
SQ3.2. What strategies support maker-centred teaching and learning?	This node aggregates the responses about the strategies used with maker-centred pedagogies.	Total=152
Code/Theme	**Definition of Theme**	**Frequency**
Collaboration	Responses relating to collaboration, discussion, and communication.	30
Inquiry, Problem-based learning	Responses related to inquiry, problem-based learning	17
Providing flexibility	Responses related to strategies for providing flexibility in maker-centred teaching, including open-ended questions and timelines, multiple ways of demonstrating learning, multiple options for tools and materials, etc.	17
Guide, scaffold, and facilitate	Responses related to teacher's guide, scaffold, facilitate, and support in maker-centred learning	14
Resources	Responses related to ensuring the necessary resources needed for maker-centred activities, including equipment, technologies, tools, material supplies, and physical spaces.	12
Modelling	Responses related to modelling by teachers	9
Student agency and expertise	Strategies relating to the leading role of student and the development and use of student expertise in the class	9
Clarity of assessment and evaluation	Responses relating to clarity of assessment and evaluation, defining goals and expectations up front	9
Preparation for students	Responses relating to preparation of students for maker-centred learning	8
Teacher & administration support	Responses related to ensuring support for making-centred learning from colleagues and administration	6
Preparation for teachers	Responses related to preparation for teachers to carry out maker-centred teaching successfully	6
Reflection on learning process	Responses relating to student reflection on the learning process	5
Project based learning	Responses related to project-based learning	4
Curriculum innovation	Responses relating to strategies that support maker-centred teaching / learning by improving or innovating the curriculum to provide more opportunities and possibilities for making to happen in classrooms	4
Peer and self evaluation	Responses relating to peer and self evaluation strategies	2

* Total responses=86; Responses coded to the specified themes=70;

* Cases didn't code in any specified themes=7; Cases with responses as"don't know"=9;

* Total coded references=152.

Double Coding and Interrater Reliability

In order to establish the trustworthiness of the qualitative analysis, double coding was conducted for the survey responses. This procedure included four steps: 1) while developing and refining a codebook including an explicit definition and examples of each code over two coding trials; 2) generating a representative sample set that accounted for more than 20% of all valid submissions; 3) conducting an independent double coding for this sample set of responses by two different individuals, comparing results and adjusting code definitions to address discrepancies; and 4) after two iterations, calculating reliability metrics and re-coding the entire dataset using the revised version of the codebook.

The online utility ReCal2 (Freelon, 2017) was used to compute the intercoder reliability coefficients for the qualitative coding carried out by the two independent coders. The calculation derived satisfied results with high Interrater agreement for all fifteen variables (code themes), as shown in Table 5.10.

Table 5.10. Intercoder reliability – SQ3.2. Strategies of maker-centred pedagogies

Code	Percent Agreement	N Agree	N Disagree	N Cases
Collaboration, discussion, communication	90%	18	2	20
Clarity in assessment and evaluation	100%	20	0	20
Preparations for students	95%	19	1	20
Inquiry, Problem based learning	85%	17	3	20
Project based learning	90%	18	2	20
Student agency and expertise	95%	19	1	20
Peer and self evaluation	100%	20	0	20
Reflection on learning process (students)	100%	20	0	20
Modelling	100%	20	0	20
Providing flexibility	90%	18	2	20
Guide, scaffold, facilitate	90%	18	2	20
Curriculum	100%	20	0	20
Teacher & administrator support	95%	19	1	20
Preparations for teachers	95%	19	1	20
Resources	95%	19	1	20

* Number of codes (variable): 15

** Number of coders per variable: 2

Thematic Analysis of the Codes

Through the open coding, fifteen themes were developed to capture a variety of strategies used by the teachers to support maker-centred teaching and learning. This section focuses on the thematic analysis to explore these specific strategies. Some quotations are provided to illuminate the specific perspectives of different individuals. The quotations are labelled with “P#-E/S/C-S/T/M”[9], where the number # indicates the particular participant with whom the data were generated, the letter E/S/C[10] indicates the grade-level that the participant was teaching, and the letter S/T/M[11] refers to the subject areas that the teacher was teaching at the time of data collection. This section also includes group comparisons between different grade-levels and different subject areas for the dominant themes.

Collaboration

The theme “Collaboration” was the most frequently mentioned by the participants in their responses to survey question SQ3.2 “What strategies support maker-centred teaching and learning?” Among 70 coded responses, 30 teachers reported collaboration, discussion or communication as an important strategy to support maker-centred teaching and learning.

Many teachers emphasized the importance of collaboration and communication, and described maker-centred learning as a “cooperative learning (and) collaborative” learning process (P41-S-T) with students “collaborating as a team” (P51-S-S). They noted that in maker-centred learning activities, “forming effective groups is a critical strategy in implementing these kinds of projects” (P75-S-S) and teachers “could assign different roles (and responsibilities) to members in the group or pairs for STEM” activities (P24-E).

Relatedly, some teachers mentioned “cooperative teaching strategies” (P24-E) and the need for “collaboration between teachers“ and “colleagues” (P61-S-M). As a secondary school science teacher responded, “providing opportunities (and time) for

9. Number # is between 1 to 97, and is based on the responses coded for the open-ended question.

10. E/S/C: E, S, and C represents elementary, secondary, and cross group respectively.

11. S/T/M: S,T, and M represents science, technology/engineering, and mathematics respectively.

educators to think, plan and collaborate on maker-centred teaching will help a lot" (P8-S-S).

"Peer support" (P92-S-T), "peer teaching" (P16-E), and "sharing" (P73-S-S) were also reported as effective strategies for maker-centred learning. For example, an elementary school teacher wrote, "I think of myself as a "skill-share-er". I might show the students how to sew, or make origami, or weave, or code a robot, but the students also show each other a lot. Sometimes a student already has developed these skills and is able to share with those around them. Sometimes they make discoveries as they are learning, then share those" (P13-E).

To identify the possible effects of the teachers' backgrounds on their contributions to the responses to this survey question, group comparisons (grade-level and subject area) were made. The results show that the proportion of elementary school teachers is lower than that of the secondary school teachers for theme Collaboration; while at the secondary level, Collaboration was most emphasized by science teachers, followed by technology teachers and finally mathematics teachers, as shown in Tables 5.11(a) and 5.11(b).

Table 5.11(a). Compare grade levels – Collaboration

Grade level	**Frequency *(f)***	**Percentage (%)**
Elementary (K – 7)	12	40.0
Secondary (G8 – 12)	16	53.3
Cross-group	2	6.7
Total	*n* =30	100

Table 5.11(b). Compare subject – Collaboration

Subject Area	**Frequency *(f)***	**Percentage (%)**
Elementary ADST	12	40.0
Science	9	30.0
Mathematics	3	10.0
Technology & Engineering	5	16.7
Unidentified	1	3.3
Total	*n* =30	100

Inquiry, Problem-based Learning

"Inquiry, problem-based learning" is the second most-frequently mentioned theme in the strategies mentioned by the participants (17 out of 70). Below are some representative expressions of the participants.

When using maker-centred pedagogies, teachers provide "teaching regarding questioning" (P21-E), and use "inquiry-based strategies" (73-S-S) to "create inquiry based investigations/explorations" (42-S-S) and "activities" (P67-S-S). Maker-centred activities include "problem-based learning" (P41-S-T) in which students are engaged in open-ended inquiry projects and creative thinking tasks (P35-S-S) that can develop their abilities of real world design, and help them to learn problem solving strategies (P36-S-S).

Group comparisons between grade-levels and subject areas show that the theme "Inquiry, problem-based learning" was mentioned more by secondary school teachers than elementary school teachers; while at the secondary level, Inquiry and problem-based learning were mostly emphasized science teachers, followed by mathematics teachers and finally technology teachers. Results are shown below in Tables 5.12(a) and 5.12(b).

Table 5.12(a). Comparison by grades – Inquiry, problem-based learning

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	7	41.2
Secondary (G8 – 12)	10	58.8
Total	*n* =17	100

Table 5.12(b). Comparison by subjects – Inquiry, problem-based learning

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	7	41.2
Science	5	29.4
Mathematics	3	17.6
Technology & Engineering	2	11.8
Total	*n* =17	100

<u>Providing Flexibility</u>

Seventeen respondents considered "providing flexibility" an important strategy in maker-centred teaching. As some participants noted, in maker-centred teaching and learning, it is important that teachers be flexible (P70-S-S), give students choices (53-S-T), and acknowledge that "'maker-centred' doesn't mean it has to be coding/digital literacy" (P84-E).

According to respondents, flexibility is needed when using maker-centred pedagogies, such as "providing open questions and goals or involving students in goal setting" (P83-S-M), providing open-ended variety in project creation and options within guidelines (P42-S-S), allowing "flexible products" (P96-E) and "using an exploration approach where multiple outcomes are possible" (P47-S-T). Respondents also stressed providing "several different options for materials and tools" (P29-E), providing "flexible scheduling to allow the creative application of making and doing" (P37-S-T), and "giving free-time for students to work" (P3-E).

Tables 5.13 (a) and 5.13 (b) present the results of group comparisons between different grade-levels and different subject areas, showing that the secondary school teachers accounted for a much greater proportion of mentions for the theme "Providing flexibility"; and at the secondary level, providing flexibility was evenly mentioned by teachers of all subject areas.

Table 5.13(a). Comparison of grade levels – Providing flexibility

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	4	23.5
Secondary (G8 – 12)	11	64.7
Cross-group	2	11.8
Total	*n* =17	100

Table 5.13(b). Comparison of subjects – Providing flexibility

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	4	23.5
Science	4	23.5
Mathematics	4	23.5
Technology & Engineering	4	23.5
Unidentified	1	5.9
Total	*n* =17	100

Serving as a guide

Teachers also reported that in maker-centred pedagogy it is important to “guide, scaffold, and facilitate” students’ learning. Some respondents described “facilitation/guiding” as a feature that distinguished maker-centred teaching from other pedagogies that focus on “teacher directed lessons” (P42-S-S). In maker-centred teaching, teachers need to “guide open, curious discussions“ (P18-E), “scaffold the skills needed“ (P51-S-S), and “facilitate learning and encourage the reflecting on the process” (P19-E). In maker-centred learning, students “need to be mentored” and supported (P77-S-S). As one teacher described, maker-centred learning starts the term with a teacher directed project, then a teacher guided project, then student directed/teacher mentored project. Work up to it once basic skills and info are in place (P97-C-T).

Modelling, Student agency, Clarity

Some participants mentioned the importance of “modelling” when using maker-centred pedagogies. In maker-centred learning, teachers need to use examples in the classroom (P2-E) and provide “good modelling on problem solving” (P38-S-S).

“Student agency” is another theme derived from the responses. Some teachers viewed maker-centred learning as “expert learning” (P34-S-S) with the “lessons specifically designed to guide students through their own connections/realizations” (P74-S-M). As one teacher expressed, “I see the role of teacher as being the one who uses their professional judgement to put the best resources in front of students. The final design and outcome of the applied skills task is ultimately left in the hands of the students” (P47-S-T).

Some teachers noted the importance of “Clarity” in assessment and learning goals in maker-centred learning. The learning purpose, goals, and deliverables need to be clearly defined to support student success (P51-S-S). Teachers need to make explicit plans (P96-E), “having criteria generated with students beforehand related to behaviour, equipment use and creation“ (P19-E), giving “students specific roles and responsibilities, and being clear about the assessment and evaluation of their product” (P75-S-S).

Preparation, Support

Some teachers emphasized the preparation of both students and teachers when using maker-centred pedagogies. “Students first need background knowledge” (P77-S-

S) or “some prior experience” (P70-S-S). They also need to be taught the “effective partner and group processes prior to project engagement” (P21-E) and the “problem solving skills to be applied to a variety of projects” (P93-C-T). As one teacher wrote, “you need to teach before you can let them explore. Once they have a solid foundation, then you can let them create” (P89-E).

As for teachers, they “need to have some forethought prior to lessons because trouble shooting is a big part of the learning process” (P66-S-S). As mentioned earlier, maker-centred teaching “need[s] to have teachers who are skilled and trained in the safe and successful use of tools needed for making and doing” (P37-S-T). Teachers need opportunities and time “to think, plan and collaborate on maker-centred teaching” (P8-S-S), and get “familiarity in facilitating projects” (P26-S-S). As a science teacher noted, “having done the project yourself and struggled with finding solutions to problems gives you empathy and a deeper understanding on how to support students” (P72-S-S).

Several teachers pointed out the importance of “teacher/team/admin support, approval, and encouragemen[t]” (P84-E), such as providing “teacher collaboration, more physical resources and teacher training” (P43-S-S), and innovating the curriculum to provide more opportunities and possibilities for making activities (P61-S-M). As mentioned earlier, one secondary technology teacher stressed his concern on this: “**the biggest obstacle is attitudes** [emphasis in original] ... I have experienced prejudice, ignorance and hostility large and small from admin, colleagues, district staff, post secondary instructors and programs and even the community at large. We are an academia centered culture. that means study and tests and grades. NOT making, doing and creating” (P37-S-T).

<u>Other Themes</u>

Besides the themes discussed above, survey respondents also reported a few other strategies for maker-centred teaching and learning. For example, some teachers emphasized “Reflection” on the learning process (P15-E); a few teachers mentioned “Project-based learning” in applying maker-centred pedagogies (P41-S-T). Several teachers noted the strategies that support maker-centred pedagogies by improving or innovating the curriculum, such as providing “time and space in the curriculum” (P26-S-S), and creating the curricula “from the stand point of being applied through making”

(P37-S-T). And last, two secondary teachers mentioned “Peer and self evaluation” in maker-centred learning (P82-S-S).

5.4. Impact of gender – Research Question 4

Existing research suggests that the maker movement’s creative energy, collaborative culture and cross-disciplinary approach appeal to a wide audience, including groups traditionally underrepresented in STEM, such as girls and women. Maker-centred learning can potentially increase motivation to further pursue STEM education and careers among girls (Intel 2014). However, this promise cannot reach its full potential with the current gender imbalance in STEM fields and the disproportionate representation of more highly educated, wealthier males among makers (Dayton, 2017).

In order to address whether gender was perceived by respondents to have an impact on students’ learning outcomes in maker-centred activities, this section examines participants’ responses to a survey question designed to address the third sub-question of research question 4:

Research Question 4: What are the teaching and learning strategies that teachers adopt in using maker-centred pedagogies?

Sub-questions:

- Does gender have an impact on the outcomes of maker-centred learning?

5.4.1. Descriptive analysis

In part two of the survey, the participants were invited to rate the following statement on a 5-point scale:

- SQ2.7. Gender factors have an impact on the outcomes of maker-centred learning.

In total, 96 participants responded to this question. Descriptive analysis was performed for the data using PSPP (FSF, 2007). The analysis shows that the mean value of all ratings is 2.61, and the participant’ responses are skewed toward disagreement. The statistical results of frequency distribution and measures of central tendency are presented in Table 5.14. and Figure 5.6.

Table 5.14. Impact of gender factors in maker-centred learning

SQ2.7 Gender factors have an impact on the outcomes of maker-centred learning activities.	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean	Mode & Median
	17	29	25	24	1	*n*=96 $\bar{x}$=2.61	Mode=2 Median=3

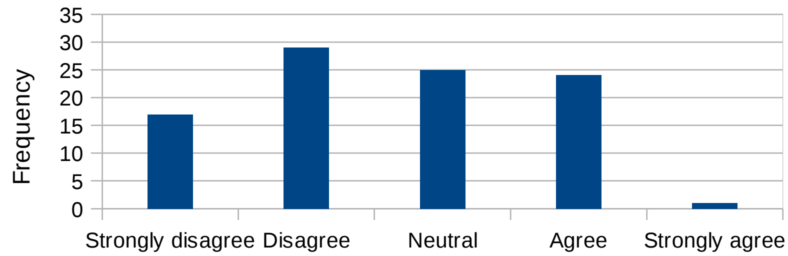

Figure 5.6. Distribution of teachers' rating to SQ 2.7

5.4.2. Inferential analysis:

In view of the divergence of the responses, to investigate possible influences on teachers' responses to this question, inferential analysis was conducted using PSPP (FSF, 2007) to compare the group means of teachers' responses by grade levels, subject areas, and genders (Coladarci et al, 2008).

Comparing different grade-levels

The inferential analysis to compare different grade levels included an examination of the frequency distribution, group statistics, and a comparison of group means (elementary and secondary) by conducting a two sample t-Test and calculating the effect size *d*. The results are shown in Tables 5.15(a), 5.15(b) and 5.15(c).

Table 5.15(a). Frequency distribution for SQ2.7 (valid cases) – Grade

Value Label	Value	Frequency	Percent	Cum Percent
Strongly Disagree	1	15	16.85	16.85
Disagree	2	26	29.21	46.07
Neutral	3	24	26.97	73.03
Agree	4	23	25.84	98.88
Strongly Agree	5	1	1.12	100.00
Total		89	100.0	

Table 5.15(b). Group Statistics for SQ2.7 (valid cases) – Grade

	Grade	N	Mean	Std. Deviation
SQ2.7	Elementary	31	2.61	1.09
	Secondary	58	3.67	1.08

Table 5.15(c). Independent Samples t-Test for SQ2.7 – Grade

Effect Size	t-test for Equality of Means						
d	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
0.06	-0.25	87.00	0.806	-0.06	0.24	-0.54	0.42

The t-Test result shows p=0.806, α=0.05, p>α. The null hypothesis H0 is retained, indicating that the mean difference between the two groups is not statistically significant. This means that elementary and secondary teachers responding to the survey did not differ significantly with regard to their self-reported beliefs that "Gender factors have an impact on the outcomes of maker-centred learning." Also the calculation result of the effect size d (d= 0.06 < 0.5) shows a very small effect, which is consistent with the t-Test result.

Comparing disciplinary areas

To examine the possible difference between teachers who taught different school subjects with regard to their responses, inferential analysis was then conducted to compare three different disciplinary areas (science, technology & engineering, and mathematics) at the secondary level (G8-12). This process included investigating group statistics, comparing the means of the groups using one-way ANOVA (F-test), and post hoc test (Turkey’s HSD test) in case a significant F was found. The inferential analysis was performed based on the subjects the participants were teaching at the time of the survey, and discarded cases in which teachers taught multiple subjects that crossed groups (invalid cases). The analysis results are shown below in Tables 5.16(a) and 5.16(b).

Table 5.16.(a) Group Statistics for SQ2.7 (valid cases) – Disciplinary area

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
SQ2.7	Science	30	2.77	1.01	.18	2.39	3.14	1	4
	TechEng	13	2.31	1.44	.40	1.44	3.18	1	4
	Math	18	2.50	1.04	.25	1.98	3.02	1	4
	Total	61	2.59	1.12	.14	2.30	2.88	1	4

Table 5.16.(b) One-way ANOVA for SQ2.7 – Disciplinary area

		Sum of Squares	df	Mean Square	F	Sig.
SQ2.7	Between Groups	2.12	2	1.06	.85	.434
	Within Groups	72.64	58	1.25		
	Total	74.75	60			

The F ratio for one-way ANOVA is 0.85, $F_{.05}$ =3.17, $F<F_{.05}$ ($p= 0.434 > \alpha =0.05$), the null hypothesis H0 is retained (Coladarci et al., 2008). Therefore the conclusion is the mean difference between the three subject groups is not statistically significant. This means that no difference was found between the science, technology-engineering, and mathematics teachers with regard to their responses to survey question SQ2.7 "Gender factors have an impact on the outcomes of maker-centred learning."

Comparing different sexes

The inferential analysis of the responses also compared the mean responses of teachers according to sex groups (male and female). Of 88 submissions which provided information sufficient to identify the participant's sex through publicly accessible resources, 87 teachers responded to this question. The inferential analysis examined the frequency distribution of the responses, the group statistics, and the group means comparison between the male and the female teachers. The analysis results of t-Test and the effect size *d* are summarized below in Table 5.17(a), Table 5.17(b), and Table5.17(c).

Table 5.17(a). Frequency for SQ2.7 (valid cases) – Sex

Value Label	Value	Frequency	Percent	Cum Percent
Strongly Disagree	1	16	18.39	18.39
Disagree	2	27	31.03	49.43
Neutral	3	21	24.14	73.56
Agree	4	22	25.29	98.85
Strongly Agree	5	1	1.15	100.00
Total		87	100.0	

Table 5.17(b). Group Statistics for SQ2.7- Sex

	Gender	N	Mean	Std. Deviation	S.E. Mean
SQ2.7	Male	37	2.68	1.18	.19
	Female	50	2.54	1.03	.15

Table 5.17(c). Independent Samples t-Test for SQ2.7 – Sex

Effect Size	t-test for Equality of Means						
d	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
0.12	.57	85.00	.570	.14	.24	-.34	.61

The t-Test result shows p=0.570, α=0.05, p>α. The null hypothesis H0 is retained, indicating the mean difference between the two groups is not statistically significant. This means that the male and the female respondents did not differ significantly with regard to their self-reported belief that "Gender factors have an impact on the outcomes of maker-centred learning". Also the effect size d=0.12 (< 0.5) indicates a very small effect, and is in line with the t-Test result.

5.5. Important factors and considerations – Research Question 4

The previous discussion involved the characteristics and applications of maker-centred pedagogies, the resources required and the strategies needed in maker-centred activities. In order to explore teachers' thoughts regarding other important considerations about maker-centred teaching and learning to address the last sub-question of Research Question 4 “What other features/considerations are important in implementing make-centred pedagogies?", the questionnaire included one other open-ended question as follows:

- SQ3.4. What other features/considerations are important in a classroom in which making-based activities take place?

5.5.1. Coding framework and coding results

In all, 92 participants responded to survey question 3.4. Some teachers provided responses with regard to the themes discussed previously (e.g., resources and tools), while others mentioned new ideas and suggestions, such as class planning and safety issues. There were also teachers who provided deeper responses based on the meaning and purposes of making activities. For example, a secondary technology teacher wrote:

> Making based activities can be very simple. String, paper and glue. But that will not get you where you want to go. I have worked with my school's best and brightest science and math minds in programs like Odyssey of the Mind and Physics Olympics and have had to deal with the academic arrogance of kids who feel like calculating a thing is 95% of building a thing. Far from it. The pretty drawings and fields of numbers mean little when it comes to making a machine that will actually work. They learn that theory is the starting place. But that practical knowledge, skills and decision making are just as important. When they adjust their thinking and come at it from a more open minded viewpoint they succeed and are well pleased. As I said it is a paradigm shift that starts with seeing making and doing on par with literacy and numeracy as valued educational goals for ALL students (P37)[12].

The following discussion is based on all teachers' responses to question 3.4. The data were coded from a specific perspective - the important factors to be considered in applying maker-centred pedagogies.

NVivo 12 (QSR, 2018) was used for open coding of the data, and in total 221 references were coded to 15 themes. Themes most frequently mentioned include: Physical Space (36); Resources, Tools (34); Supplies, Materials (25); Class Planning (16); and Safety, Risk taking (15). The coding framework and data coding results are summarized in Table 5.18. Of 92 submissions, 84 provided valid responses regarding the question asked, six responded "don't know", and two provided responses unrelated

12. P# indicates the the particular participant with whom the data were generated.

to the question. Note that only the 84 valid responses were coded, and more than one code could apply to a single response.

Table 5.18. Coding framework and results – Important considerations

Question	Description	Reference
SQ3.4. What other features/considerations are important in a classroom in which making-based activities take place?	This node aggregates the important features and considerations of maker-centred classrooms.	Total=221
Code/Theme	**Definition of Theme**	**Frequency**
Physical Space	Responses relating to physical spare and storage room for making activities.	36
Resources, Tools	Responses related to resources and tools for maker-centred teaching and learning (including furniture).	34
Supplies, Materials	Considerations regarding consumable supplies and materials.	25
Class Planning	Responses related to class planning and composition, including: learning tasks, topics, objectives, student teams, curricular structures, etc.	16
Safety, Risk taking	Considerations regarding safety and risk.	15
Time	Responses relating to time needed for maker-centred teaching and learning (e.g., flexible schedule)	14
Attitudes toward Making Activities	Responses relating to students' attitudes toward and behaviours in making-centred learning activities, students' and teachers' adaptation to the learning environment and challenges during the exploring process; and teachers' commitments of time and effort to prepare the learning environment.	11
Training for Teachers	Responses relating to teacher training on maker-centred approaches.	11
Classroom Management	Responses related to class management and organization.	10
Room design, Set up, Seating	Responses related to classroom layout, set up, and students' seating in the classroom (including the kinds of furniture, i.e. Movable).	10
Collaboration, Community Connections	Considerations regarding collaboration, communication, and connection with the outside community.	10
Flexibilities	Strategies relating to flexibilities on task, questions, seating, timeline, etc.	9
Support of school, administration, parent	Responses relating to support of school, admin, parents, community, e.g. class size, teacher-student ratio, improve/innovate the curriculum, etc.	8
Funding	Responses related to money, funding, budget.	7
Concerns, Challenges, Difficulties	Responses related to concerns, challenges, difficulties one might encounter in maker-centred teaching and learning.	5

* Total responses=92; Responses coded to the specified themes=84;

* Cases didn't code to any specified themes=2; Cases with responses as "don't know"=6;

* Total coded references=221.

5.5.2. Double coding and interrater reliability

As with the qualitative analyses in previous sections, double coding was conducted for the survey responses to establish trustworthiness. The procedure included: 1) generating a representative sample set that accounted for more than 20% of valid submissions; 2) developing a codebook including definitions and examples of each code over two coding trials; 3) conducting independent double coding for the sample set by two individuals, revising the codebook after examining disagreements between the two independent coders, and 4) calculating the reliability metrics and re-coding the entire dataset once again using the finalized codebook.

The online utility ReCal2 (Freelon, 2017) was used to compute the intercoder reliability coefficients for qualitative coding results by the two coders. Results show satisfactory interrater agreement for all fifteen variables, as shown in Table 5.19.

Table 5.19. Intercoder reliability – SQ3.4. Important factors and considerations

Code	Percent Agreement	N Agree	N Disagree	N Cases
Attitudes toward Making Activities	95%	19	1	20
Concerns, Challenges, Difficulties	95%	19	1	20
Class Planning	100%	20	0	20
Classroom Management	100%	20	0	20
Room design, Set up, Seating	85%	17	3	20
Collaboration, Community Connections	90%	18	2	20
Flexibilities	100%	20	0	20
Safety, Risk taking	100%	20	0	20
Physical Space	100%	20	0	20
Resources, Tools	85%	17	3	20
Supplies, Materials	95%	19	1	20
Time	90%	18	2	20
Funding	100%	20	0	20
Support from School, SD, Parent	100%	20	0	20
Training for Teachers	85%	17	3	20

* Number of codes (variables): 15

* Number of coders per variable: 2

5.5.3. Thematic analysis of the codes

This subsection presents a thematic analysis of the coding results. Elaboration of the themes was shaped by illustrative descriptions and quotations of representative responses. The quotations are labelled with “P#-E/S/C-S/T/M”[13] to indicate the particular participant with whom the data were generated, the grade-level (E/S/C[14]) and the subject

13. Number # is between 1 to 97, and is based on the responses coded for the open-ended question.

14. E/S/C: E, S, and C represents elementary, secondary, and cross group respectively.

area (S/T/M[15]) that the teacher was teaching at the time of the survey. Group comparisons between different grade-levels and subject areas were also carried out for some dominant themes as discussed below.

Physical Space

Of 84 coded responses, 36 participants mentioned "physical space" as an important factor in applying maker-centred pedagogies. As a participant noted, in maker-centred activities, "there needs to be space available in the school to complete activities that require more than a traditional classroom" (P66-S-S). Other participants mentioned that "maker-centred teaching requires space for materials" (P61-S-M), a "place to store things made" (P40-S-M) and to display the "finished projects" (P16-E). Maker-centred classrooms need enough physical space for "teaching, working" (P41-S-T), and "building projects" (P45-S-S). It also needs "space to move around" (P18-E) and "flexible seating spaces" (P24-E).

Group comparisons (grade-level and subject area) show that the elementary and secondary school teachers each accounted for almost half of the mentions of "Physical space"; and at the secondary level physical space was mentioned more by science and mathematics teachers than by technology teachers, as shown in Tables 5.20(a) and 5.20(b). We may speculate that this difference is due to the fact that technology teachers more often teach in workshop environments where the arrangement of space is intended to support work on physical artifacts.

Table 5.20(a). Comparing grade levels – Physical space

Grade level	**Frequency *(f)***	**Percentage (%)**
Elementary (K – 7)	16	44.4
Secondary (G8 – 12)	16	44.4
Cross-group	4	11.1
Total	*n* =36	100

15. S/T/M: S,T, and M represents science, technology/engineering, and mathematics respectively.

Table 5.20(b). Comparing subjects – Physical space

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	16	44.4
Science	8	22.2
Mathematics	7	19.4
Technology & Engineering	2	5.6
Unidentified	3	8.3
Total	*n* =36	100

Resources and Tools

“Resources and tools” was the second-most frequently occurring theme in the responses (34 out of 84). Respondents noted that maker-centred teaching and learning need “access to resources” (P26-S-S), “tools” (P51-S-S) and “technology” (P4-E), such as “computers” (P89-E), “Internet” (P67-S-S), “power sources” (P41-S-T), and “sinks, etc.” (P12-S-S). On the low-tech side, it was also said that “there needs to be ‘real’ tools and equipment to use. More than a 3D printer and a paper-cutter” (P50-S-T). The resources described as useful by respondents also included “suitable tables or benches” (P85-S-S), “moveable furniture” (P13-E), “cabinets for storage, display cases” (P42-S-S), and so forth.

Tables 5.21(a) and 5.21(b) present the comparison results between groups (grade-level and subject area), showing that secondary school teachers made up a much higher proportion of mentions of the theme “Resources and tools”; and at the secondary level, Resources and tools was more emphasized by science teachers than teachers of other subject teachers.

Table 5.21(a). Compare grade levels – Resources, Tools

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	10	29.4
Secondary (G8 – 12)	21	62.8
Cross-group	3	8.8
Total	*n* =34	100

Table 5.21(b). Compare subject – Resources, Tools

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	10	29.4
Science	12	35.3
Math	4	11.8
Tech & Engr	6	17.6
Unidentified	2	5.9
Total	*n* =34	100

Supplies and Materials

The theme "Supplies, Materials" aggregates 25 references to consumable supplies and materials needed in maker-centred activities. Respondents noted that maker-centred teaching and learning require access to "proper supplies" (P40-S-M) and a "variety of materials for choice" (P7-S-S). The supplies might be some specific ones needed for "activities in the wood, auto, electronics, metal" (P57-S-M), or might be simple and basic materials like string, glue, tape, felt pens, and scrap paper (P13-E). One elementary school teacher also mentioned a first aid kit as a necessary supply in making activities (P16-E).

Group comparisons (grade-level and subject area) for the theme "Supplies, Materials" are presented in Table 5.22(a) and Table 5.22(b). The results show that in the responses coded to the theme, the proportions of elementary school and secondary school teachers are very close; also at the secondary level, the proportion of teachers in each subject is not much different.

Table 5.22(a). Compare grade levels – Supplies, Materials

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	12	48.0
Secondary (G8 – 12)	11	44.0
Cross-group	2	8.0
Total	*n* =25	100

Table 5.22(b). Compare subject – Supplies, Materials

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	12	48.0
Science	5	20.0
Math	4	16.0
Tech & Engr	3	12.0
Unidentified	1	4.0
Total	*n* =25	100

Class Planning

"Class planning" is another important factor in maker-centred teaching emphasized by 16 participants in their responses. To implement maker-centred teaching and learning, teachers need to plan, design and compose lessons in a different way than usual. They need to consider the subject topics, learning tasks and objectives, curricular structures, student teams, etc. For example, one participant stated that "[i]t is important that learning tasks are structured in such a way as to encourage ALL learners of ALL ability levels to participate fully. This is accomplished by having very well constructed relevant learning tasks. Ensure that the students can see the relevance of the task." (P47-S-T). Teachers need to consider "time management in covering curriculum and all the topics" (P27-S-S) and figure out "how much choice do you give, what groups of students will work well together, what materials will you have access to" (P28-E). They also need to consider "safety training" for the students (P92-S-T), and "teaching and monitoring students with machinery" (P97-C-T). One secondary school mathematics teacher mentioned the planning of evaluation and noted that "assessment needs to be developed to match the activity" (P71-S-M). An elementary school teacher reflected on the curricular structures and suggested that it was crucial to consider the "connection to other areas of the curriculum. For example, my students designed and built water pipelines as we were learning about earth day, the water cycle and impact on the environment. It makes it meaningful when it transcends across the curriculum" (P24-E).

Group comparisons of different grade-levels and subject areas were done for the theme "Class planning." The results show that class planning was much more mentioned by secondary school teachers than cross-group (middle school) and elementary school teachers; while at the secondary level, the proportion of teachers in each subject is relatively close, as shown in Tables 5.23(a) and 5.23(b).

Table 5.23(a). Comparing grade levels – Class planning

Grade level	Frequency *(f)*	Percentage (%)
Elementary (K – 7)	3	18.8
Secondary (G8 – 12)	10	62.5
Cross-group	3	18.8
Total	*n* =16	100

Table 5.23(b). Comparing subjects – Class planning

Subject Area	Frequency *(f)*	Percentage (%)
Elementary ADST	3	18.8
Science	4	25.0
Mathematics	3	18.8
Technology & Engineering	4	25.0
Unidentified	2	12.5
Total	*n* =16	100

Safety and Risk taking

"Safety and risk taking" was another theme drawn from the participants' responses (15 out of 84). Teachers noted that maker-centred classrooms should have an "atmosphere where risk-taking is safe for students" (P44-S-S). At the same time, maker-centred teaching was described as requiring some "restrictions that eliminate safety hazards" (P93-C-T) and "make sure students are safe at all times" (P61-S-M). To ensure the safety of maker-centred activities, "safety training must be part of the program delivery" (P92-S-T), helping students to understand "proper equipment use and care" (P53-S-T) and "consideration of others" (P16-E). Maker-centred learning needs "qualified/certified teachers for using, teaching and monitoring students with machinery" and dealing with "storage and supplies that are not too dangerous" (P97-C-T).

Time commitment

Fourteen teachers mentioned "Time" as an important factor in applying maker-centred pedagogies, since in maker-centred activities, "students may take longer, or a different approach to learning from the activity" (P38-S-S). Participants stated maker-centred learning needs "more time" (P22-E) and "flexible time frames" (P16-E). Furthermore, maker-centred teaching also needs more time for "teacher collaboration" (P33-S-S).

Attitudes (teacher and student)

Some responses emphasized appropriate "Attitudes" toward maker-centred pedagogies. For example, learners were described as needing to have an "openness to learn from others" (P17-E), "know how to respect the items... the space" (P10-E), and "establish appropriate behaviours in the makerspace" (P73-S-S). Maker-centred teaching was also described as requiring "teacher commitment" (P62-E). Maker-centred teaching was said to demand "a teacher who agrees with the philosophy and has the technological means to help when needed" (P20-S-T). Teachers need to have "a willingness for messiness" (P13-E), be at "comfort with a loud, unstructured classroom environment" (P26-S-S), and "be able to fail" (P23-E). One elementary school teacher stated that, "people need to realize that classroom management will look different. It will look chaotic and messy and it will be noisy, and teachers have to be okay with this and letting the kids learn. They also have to be okay with (and get their students to be okay with) failing" (P84-E).

Teacher training

In the participants' responses, "Teacher training" (P1-E, P43-S-S) also emerged as a very important theme. In maker-centred learning, students were said to need "an expert who can guide kids to make different projects" (P82-S-S). Maker-centred teaching needs "qualified/certified teachers" (P97-C-T) who "must know how to use the equipment/ tools" (P50-S-T) and have "the technological means to help when needed" (P20-S-T). It is important to provide "training for teachers on what maker-based activities are, how to structure them and how to deliver them to have a purpose/tie into the lesson and not just a filler project" (P98-C). Through training, teachers can obtain skills on "assessing projects and process" (P26-S-S), "time management in covering curriculum and all the topics" (P27-S-S), and ensuring the "safety" of learning activities (P92-S-T).

Classroom Management and Room Design

Ten teachers mentioned "Classroom management" as an important factor in the success of maker-centred teaching. As the participants noted, maker-centred teaching and learning require excellent classroom management (P63-S-S) on "organization, tool and student management, safety ... teaching and monitoring students with machinery" (P97-C-T). This management includes "keeping students accountable/on task" (P3-E), encouraging "student engagement" (P28-E), establishing a "productive work environment" (P72-S-S) with a "collaborative feel" (P44-S-S), and establishing appropriate behaviours in the makerspace, such as good cleanup and safety procedures, (P73-S-S), etc.

Relatedly, the theme "room design" (P62-E) was derived from ten responses related to classroom layout, set up, and students' seating in the classroom. For example, teachers noted that maker-centred classrooms need to have "suitable tables or benches, no carpet on floor" (P85-S-S). There should be "space to move around" (P18-E), and the "ability to move seating & tables" (P52-S-T). The room set up should be "barrier free so all students can access the material and tech without need for assistance constantly" (P32-C-M), and that the layout needs to consider "teaching space vs. working space" (P41-S-T).

Collaboration, Flexibility

Although it has been discussed earlier as a strategy of maker-centred learning, collaboration was emphasized again by some teachers with regard to the important considerations in applying maker-centred pedagogies. As they noted, "communication and group work are important" (P38 -S-S) in maker-centred learning activities. Teachers need to "form collaborative groups" and create a "collaborative feel" (P44-S-S, P75-S-S). Students need to be open "to learn from others" (P17-E), and "be prepared and comfortable working with others, understanding the perspectives of others and managing interactions" (P79-S-M). Maker-centred teaching needs "teacher collaboration" as well (33-S-S).

Relatedly, teachers also mentioned the importance of "Flexibility" in a number of aspects in maker-centred learning, such as "flexible time frame" (P16-E), "flexible seating" (P18-E, P24-E), allowing students to "take longer, or a different approach to learning from the activity" (P38-S-S), etc.

School community support

Some participants' responses drew attention to the support required from school administrators, parents, and the school community to sustain maker-centred pedagogies. One elementary school teacher mentioned the "participation of parents in each activity" (P94-E), while another teacher stated, "I asked for parent donations to assist with STEM and it helped immensely" (P24-E). Teachers pointed out the necessity of “support by admin” (P15-E) in several aspects related to maker-centred pedagogies, including “time built into the school's schedule for making based activities” (P82-S-S) and “adequate teacher - student ratio” (P98-C), because the “class sizes must be smaller in order to facilitate [this] successfully” (P66-S-S).

Relatedly, funding was also mentioned in some responses as necessary for applying maker-centred pedagogies. As some teachers stated, maker-centred teaching and learning need to have adequate financial support from the school for tools and expendable supplies (P67-S-S, P25-E). “There must be enough committed money to support the programs, which can be expensive” (P92-S-T).

Concerns

Several teachers also mentioned concerns about potential challenges and difficulties that may occur in maker-centred teaching and learning. For example, teachers may face the “safety concerns of using tools ... (and) unfamiliarity with assessing projects and process skills” (P26-S-S). The “classroom dynamics is a big concern, [with regard to] managing students at stations, student engagement” etc. (P28-E). Also the “classroom management will look different. It will look chaotic and messy and it will be noisy, and teachers have to be okay with this and letting the kids learn. They also have to be okay with (and get their students to be okay with) failing” (P84-E). Maker-centred teaching requires a lot of input and effort from the teachers, as one secondary school science teacher described, “I have tried to bring this concept alive in my classrooms, but it requires a lot of work and creativity” (P43-S-S).

5.6. Chapter Summary

This chapter presented an examination of participants’ responses to survey questions designed to address Research Question 2, “Are there differences in disciplinary areas related to the application of maker-centred pedagogies?”; Research Question 3, “What are the resources and tools that teachers use and need for implementing maker-centred pedagogies?”, and Research Question 4, ”What are the teaching/learning strategies that teachers adopt in using maker-centred pedagogies?”

Section 5.1 focused on the current application of maker-centred pedagogies in different disciplinary areas to address Research Question 2. Analysis of the survey data suggested the following:

1) Maker-centred pedagogies are used much more in science, technology and engineering classes than other subject areas;

2) Maker-centred pedagogies are used more in upper grade-levels than lower grade-levels;

3) Mathematics accounted for a relatively large proportion of the courses the participating teachers taught, but a smaller proportion of the courses in which maker-centred pedagogies were applied;

4) At the secondary level, students have more opportunities to make things in technology and engineering classrooms than in science and mathematics classrooms;

5) Teachers generally believe that maker-centred pedagogies can be useful in non-STEM subject areas; however

6) The training teachers received on maker-centred pedagogies were mostly in science, technology and engineering areas.

Section 5.2 addressed Research Question 3 by presenting analysis of data about the resources, tools and supplies needed in maker-centred teaching and learning. Results suggested that:

1) Teachers tend to believe that maker-centred teaching and learning require some special resources and tools, such as computers, electronic devices, etc., however

2) Maker-centred pedagogies can involve different kinds of resources and supplies. The tools and materials don't have to be expensive high-tech products, but can also be inexpensive and low-tech ones. Commonly available materials and hand tools can also be used in maker-centred teaching and learning.

Section 5.3 addressed the first two sub-questions of Research Question 4, “Do maker-centred pedagogies need specific strategies?” and “What strategies support maker-centred teaching and learning?” Descriptive analysis showed that most of the respondents agreed maker-centred pedagogies require some special strategies to support and facilitate teaching and learning, and most considered collaboration as an effective strategy in maker-centred learning activities.

In analysis of teachers’ open-ended responses to a related survey question, fifteen themes were derived. The themes captured a variety of specific strategies for maker-centred teaching and learning reported by the teachers, and of all strategies mentioned, Collaboration, Providing flexibility, Inquiry and problem-based learning were those most emphasized. Group-wise comparison shows that “Collaboration” and “Inquiry, Problem-based learning” were mentioned more by secondary school teachers than elementary school teachers, and the secondary school teachers accounted for a much greater proportion of mentions for “Providing flexibility”; while at the secondary level, “Collaboration” and “Inquiry, Problem-based learning” were mostly emphasized by science teachers. The other themes included: Guiding, scaffolding, and facilitation; Resources; Modelling; Student agency and expertise; Clarity of assessment and evaluation; Preparations for students; Teacher and administrative support; Preparations for teachers; Reflection on the learning process; Project based learning; Curriculum innovation; and Peer and self-evaluation.

Section 5.4 discussed the teachers’ responses to a survey question regarding the impact of gender on learning outcomes in maker-centred learning. Respondents’ reported agreement with the statement “Gender factors have an impact on the outcomes of maker-centred learning” had a mean of 2.6 on a 5-point scale (neutral), and were skewed toward disagreement. The Group mean comparisons showed no significant difference on this question between the teachers of different grade-levels, sexes, or different disciplinary areas with regard to their responses.

Section 5.5 presented analysis of participants’ responses to an open-ended question relevant to the last sub-question of Research Question 4, “What other features/considerations are important in implementing maker-centred pedagogies?” Open coding and systematic analysis of the responses were carried out, and fifteen themes were derived to capture the teachers' perspectives on the important factors and considerations in applying maker-centred pedagogies. Findings provide detailed, specific, and comprehensive considerations with regard to applying maker-centred teaching and learning. Of the considerations reported by participants, Physical space, Resources and Tools, Supplies and Materials, and Class Planning were most frequently mentioned. The group-wise comparison shows that the secondary school teachers accounted for a much greater proportion of mentions of this theme than elementary school teachers for “Resources, Tools” and “Class planning”; and at the secondary level, “Physical space”, “Resources, Tools” and “Supplies, Materials” were more frequently mentioned by science teachers than other teachers of other subjects. Other themes included: Safety, Risk taking; Time; Attitudes toward making activities; Training for teachers; Classroom management; Room design, set up, and seating; Collaboration, community connections; Flexibility; Support from school, administration, parents; Funding; and Concerns, challenges, and difficulties.

Chapter 6.

Summary and Discussion

This study adopted a convergent mixed-method design to investigate the current applications and the potential of maker-centred teaching and learning in ADST (Applied Design, Skills, and Technologies) and STEM (Science, Technology, Engineering and Mathematics) education in public K–12 schools in British Columbia, using practicing teachers from two districts as informants. Four research questions were pursued, relating to teachers' understanding of maker-centred pedagogies; the current application status of maker-centred pedagogies; the resources and tools that teachers use and feel that they need for implementing maker-centred pedagogies; and the strategies needed to support maker-centred pedagogies.

This Chapter will summarize the significant results of this study and examine how these findings enrich the related scholastic literature, then discuss the implications of the findings for applying maker-centred pedagogies in ADST and STEM education in BC public schools. The limitations of this study will be discussed, and recommendations for future research will be offered.

6.1. Summary of major findings

6.1.1. Research Question 1 – teachers' understandings of maker-centred pedagogies

In order to answer Research Question 1 "What are current ADST and STEM teachers' understandings of maker-centred pedagogies? To what extent do ADST and STEM teachers favour or doubt maker-centred teaching and learning?" the study analyzed the participants' responses to four sub-questions: 1) What are teacher's perceptions of the current situation of ADST and STEM education? 2) What are teachers' understandings of maker-centred pedagogies? Do they favour or doubt maker-centred pedagogies? 3) What are teacher's roles in ADST and STEM education? And 4)

What are the major characteristics of maker-centred teaching and learning as understood by practitioners? (Sections 4.2 and 4.3)

In relation to teachers' perceptions of the current situation of ADST and STEM education, the data analysis showed that according to the participants, elementary teachers generally place greater emphasis on hands-on practice in classrooms than secondary teachers do; while at the secondary level, students have more opportunities to make things in technology and engineering classrooms than in science and math classrooms. Regarding the perceptions and favour or doubt about maker-centred approaches, the statistical analysis showed that teachers' responses were highly consistent. The majority of participating teachers responded positively to maker-centred pedagogies, and had a favorable view of implementing maker-centered teaching and learning in ADST and STEM classrooms.

As for the roles that teachers should play in ADST and STEM education, most teachers agreed with the statement that "ADST and STEM educators should act as technology-literate facilitators and guides rather than transmitters of information."

Participants' responses with regard to what they viewed as the major characteristics of maker-centred teaching and learning were qualitatively coded. In all, thirteen themes were developed to capture the variety of characteristics of maker-centred pedagogies mentioned by teachers. These characteristics are: Student agency and Independence, Hands on and Experiential, Creativity, Engagement, Flexibility, Inquiry based and Problem solving, Challenge and Risk taking, Collaboration, the uniqueness of the Teacher's role, a focus on Process, unique needs for Resources and Tools, Artifact-centredness, and the need for unique Strategies.

In general, teachers' responses acknowledged that maker-centered pedagogy possesses specific characteristics that are different from other teaching methods in terms of course planning, course implementation, students' engagement, teacher's roles, classroom management, and the need of learning resources and tools. Of all important characteristics reported by the teachers, student agency and independence, practical ability and creativity were particularly emphasized. The group-wise comparison shows that secondary school teachers accounted for the majority of code references for the themes "Creativity" and "Engagement"; and within the secondary level, "Student agency, Independence" and "Hands-on, Experiential" were mentioned more by science teachers than by teachers of other subjects.

6.1.2. Research Question 2 – current application of maker-centred pedagogies

To address Research Question 2 "Are there differences in disciplinary areas related to the application of maker-centred pedagogies?" the participants' responses were analyzed concerning two sub-questions: 1) In which subject areas have teachers used maker-centred pedagogies? And 2) What training did teachers receive about maker-centred pedagogies in different subject areas? (Section 5.1)

In relation to the current application of maker-centred teaching and learning, the data analysis showed that within the sample, maker-centred pedagogies are used more in upper grade-levels than lower grade-levels. At the secondary level, the analysis maker-centred pedagogies were reported to be used much more in science, technology and engineering classes than other subject areas. According to the survey respondents, secondary school students have more opportunities to make things in technology and engineering classrooms than in science and mathematics classrooms. As for the usefulness of maker-centred pedagogies in other subject areas, despite the vast majority of participants being ADST or STEM teachers, the respondents generally believed that maker-centred pedagogies can also be useful in non-STEM subjects (e.g., languages, fine arts, and social studies).

Concerning the training teachers received, the analysis results showed that 31 out of 94 respondents had received some kind of training related to maker-centred teaching, and six of them had received some formal education. According to respondents, training on maker-centred pedagogies had been provided mostly in science, technology and engineering disciplinary areas, suggesting that teachers who teach these subjects have more opportunities to receive relevant training. This finding is consistent with the reported application status of the maker-centred pedagogies discussed above. On the other hand, it was found that although the participating ADST and STEM teachers had not had sufficient formal training on maker-centred teaching and learning, many of the respondents favored using this approach in their teaching practices and hoped to receive relevant training in the future.

Mathematics accounted for a relatively large proportion (37.4%) of the courses that the respondents had taught, but a small proportion (6.9%) of the subject areas in which maker-centred pedagogies were reportedly applied. Considering that mathematics is a more conceptual and abstract discipline, this result may not be considered surprising. The following response of a mathematics teacher may provide an explanation for this finding: maker-center teaching and learning “gives students the opportunity to see their learning in action. However, Math is included in this list and as an applied subject it makes sense but with just pure math, it isn't always the best. It’s hard to put math in the same category as STEM when seen from a pure math perspective” (P 80)[16].

6.1.3. Research Question 3 – resources and tools needed in maker-centred activities

Research Question 3 was “What are the resources and tools that teachers use and need for implementing maker-centred pedagogies?” To address this question, the study investigated the participating teacher’s views with regard to two sub-questions: 1) According to teachers' understanding, are specific resources and supplies necessary in maker-centred teaching and learning? And 2) What resources and supplies are reportedly used in maker-centred teaching and learning? (Section 5.2)

Regarding the necessity of unique tools in maker-centred activities, the statistical results indicated that respondents tended to believe maker-centred teaching and learning require some resources and tools that are not always readily available, such as computers, electronic devices, access the Internet, etc.

Qualitative coding of the specific tools and materials that the respondents had used in their teaching practices showed that according to respondents, maker-centred pedagogies can involve many different kinds of resources and supplies, both high-tech and low-tech. The mentioned tools and materials were grouped into several categories, including: high-tech tools or products (e.g., iPads, online simulations, and 3D printing), electronic devices and supplies (e.g., circuit kits and tools, robotics kits, and electronic components), computer programs and apps (e.g., Photoshop, iMovie, Scratch, and TinkerCad), and simple materials and hand tools (e.g., cutting boards, clay, foil, hammers and scissors).

16. P# indicates the the particular participant with whom the data were generated.

One surprising finding worth emphasizing here was that the teachers who reported using the most common materials for maker-centred activity accounted for a significant percentage of all responses received (80 out of 257 references). This result indicated that the resources and tools required for maker-centred pedagogies are diverse, and can be simple and readily available. The tools and materials don't have to be expensive high-tech products, but can also be inexpensive and low-tech ones.

6.1.4. Research Question 4 – strategies and considerations of using maker-centred pedagogies

Research Question 4 asked, "What are the teaching / learning strategies that teachers adopt in using maker-centred pedagogies?" The data analysis explored four sub-questions: 1) Are maker-centred pedagogies understood to need specific strategies? 2) What strategies are understood to support maker-centred teaching and learning? 3) Is the sex of the learner understood to have an impact on the outcomes of maker-centred learning? And 4) What other features/considerations are important in implementing maker-centred pedagogies? (Sections 5.3, 5.4, and 5.5)

Regarding the educators' understanding of using specific strategies in maker-centred activities, the statistical results showed that most of the respondents agreed that in implementing maker-centred pedagogies, it is necessary to develop some special strategies that can help to support teachers' teaching practice and help to facilitate students' learning activities. Particularly, most of these teachers agreed that collaboration is an important strategy for maker-centred learning.

Fifteen themes were developed using the strategies reported by the participating teachers as being useful in many aspects of maker-centred teaching and learning. These themes include: Collaboration; Providing flexibility; Inquiry and problem-based learning; Guiding, scaffolding, and facilitation; Resources; Modeling; Student agency and expertise; Clarity of assessment and evaluation; Preparations for students; Teacher and administrative support; Preparations for teachers; Reflection on the learning process; Project based learning; Curriculum innovation; and Peer and self-evaluation.

Among all strategies mentioned, Collaboration, Providing flexibility, Inquiry and problem-based learning were most frequently mentioned by respondents. Group-wise comparison showed that "Collaboration" and "Inquiry, Problem-based learning" were mentioned more often by secondary school teachers than elementary school teachers, and “Providing flexibility” was mentioned much more by the secondary school teachers as well. While at the secondary level, “Collaboration” and “Inquiry, Problem-based learning” were mostly emphasized by science teachers. These results indicated the important associations between the adoption of effective strategies and the grade levels and disciplinary areas in which maker-centred pedagogies are implemented.

Participating teachers appeared to perceive no necessary link between learning performance and learners’ sex in maker-centred learning. Respondents’ reported agreement with the statement “Gender factors have an impact on the outcomes of maker-centred learning” had a mean of 2.6 on a 5-point scale (neutral), and were skewed toward disagreement. The group mean comparisons also showed no significant difference between the teachers of different grade-levels, sexes, or different disciplinary areas with regard to their responses to this survey question.

The survey included an open-ended question that elicited ADST and STEM teachers’ thoughts regarding important considerations for implementing maker-centred teaching and learning. Qualitative analysis of participants’ responses resulted in fifteen themes being developed to capture the teachers' perspectives. These themes are: Physical space; Resources and tools; Supplies and materials; Class planning; Safety, risk taking; Time; Attitudes toward making activities; Training for teachers; Classroom management; Room design, set up, and seating; Collaboration, community connections; Flexibility; Support from school, administration, parents; Funding; and Concerns, challenges, and difficulties.

Of all considerations reported by the participants, physical space, resources and tools, supplies and materials, and class planning were most frequently mentioned. Through group-wise comparison, it was found that “resources and tools” and “class planning” were mentioned much more by secondary school teachers than by elementary school teachers. This indicates that there are differences between elementary and secondary schools in terms of the tools and materials they believe are needed in maker-centred learning activities, and the organization of learning processes. When applying maker-centred approaches, teachers may feel the need for learning activities in secondary classes to use more high-tech tools and materials. Secondary school teachers may also feel the need to organize the teaching and learning more effectively to achieve expected outcomes. The results also showed that at the secondary level, “physical space”, “resources and tools” and “supplies and materials” were more emphasized by science teachers than teachers of other subjects.

6.2. Findings related to existing studies

This research has revealed how current teachers of ADST or STEM in two BC public school districts understand maker-centred pedagogies and the applications of these approaches from their own points of view. Many of the findings corroborate and support what researchers have previously reported; though this study has also provided empirical evidence of teaching practices that can contribute to the scholarly discourse on maker-centred learning. This section will connect the major findings and compare them to previous research findings presented in the literature review.

6.2.1. Teachers’ perceptions of maker-centred pedagogies

Findings addressing Research Question 1 indicated that the majority of ADST or STEM educators felt positively about maker-centred pedagogies, and had a favorable view of implementing it. This was an important finding, as general ADST or STEM teachers’ perceptions with regard to maker-centred approaches had not been explored in literature reviewed for this study. Analysis also indicated that elementary teachers generally place greater emphasis on hands-on practice than secondary teachers, while at the secondary level, students have more opportunities to make things in technology and engineering classrooms than other classes.

Regarding the special roles that teachers should play in ADST and STEM education, the statistical results showed that most teachers agreed with this view that educators should act as technology-literate facilitators and guides rather than transmitters of information. This finding resonates with Kafai et al.’s (2014) suggesting that making requires developing “an alternative view of students and teachers” by “viewing students as problem solvers and inquirers and teachers as coaches, guides, and prodders.”

The study showed that the participating teachers perceived maker-centered pedagogies to possess unique characteristics in comparison with other approaches, and reported many distinct characteristics of maker-centred pedagogies. These were captured in thirteen themes. Among these themes, many characteristics reported are consist with what scholars emphasized in the literature. For instance, “Student agency and Independence” was supported by (Vossoughi et al., 2014) who state that making welcomes learners’ ideas, helps to clarify the nature of the problems, and fosters reflections. Bullock et al. (2015) describe maker culture as the contemporary expansion of the do-it-yourself culture.

The themes “Hands on and Experiential” and “Creativity, Engagement” were in line with Dewey (1902) and Piaget’s (1928) theories which both emphasize tinkering and figuring things out, starting with one's own ideas and then shaping those ideas through experiential actions. Seymour Papert’s (1980) *constructionism* situates the maker approach within an evolving pedagogy that emphasizes construction of knowledge through activity and learners work directly with manipulable media to build things to share with others. More important, these important features of making were highlighted in BC’s new K-12 ADST curriculum (British Columbia Ministry of Education, 2015) which defines ADST as an experiential, hands-on program of learning through design and creation, featuring a focus on designing and making, the acquisition of skills, and the application of technologies.

The reported characteristic “Inquiry based and Problem solving” is coherent with Vossoughi et al.’s (2014) study, which showed that the majority of peer-reviewed papers pertain to making as inquiry-based practice. “Collaboration” was another characteristic of maker-centred learning that was emphasized by respondents in this study, and presented in literature as well. Vossoughi et al. (2014) stated a major benefit of making as creating a supportive community of learners that can leverage the interests and skills of each member of the group towards shared goals. Loertscher et al. (2013) argued that making activities can develop students’ dispositions with regard to collaborative intelligence.

Most of the characteristics reported by participants in the present study are consistent with the features of the *maker movement* elaborated by the authors of research reviewed (Martin, 2015; Intel, 2014) or support the scholars’ arguments about maker-centred approaches. For example, Intel (2014) argued that making emphasizes the process rather than the end product, and a communal effort rather than work in isolation. Halverson et al. (2014) also emphasized “a focus on Process” in making activities. Smay et al. (2015) advocated “Flexibility” to support classroom PBL (project based learning) by offering different ways for students to demonstrate their knowledge through different formats and media. Martin (2015) highlighted Failure-positive as a valuable element of the maker mindset, which echoes the “Challenge and Risk taking” characteristic of making activities mentioned by participants in the present study. Clapp et al. (2016) summarized the key characteristics of maker-centred learning which included student agency, facilitation, collaboration, and flexibility.

Group-wise comparisons were used to examine the associations between some major characteristics and grade levels or disciplinary areas. “Creativity” and “Engagement” tend to be more frequently mentioned by secondary teachers than elementary teachers, and “Student agency, Independence” and “Hands-on, Experiential” were more emphasized by science teachers than those of other disciplines . As no similar group comparisons have been found in previous studies reviewed, the researcher believes this finding can provide some useful perspective.

6.2.2. Applications and training on maker-centred pedagogies

Research Question 2 addressed the current application of maker-centred teaching and learning in formal school settings. The results showed that maker-centred pedagogies are used more in upper grade-levels than lower grade-levels in BC public schools, indicating that making activities are integrated into the secondary STEM classes more than the elementary school or lower grade level curriculum. This finding may be explained by the fact that ADST is a new curriculum area for the elementary grade-levels in BC public schools, and confirms the importance of developing making skills emphasized in the new BC ADST curriculum (BC Ministry of Education, 2016). It is also consistent with the results of Vossoughi et al.’ (2014) review of literature, i.e., the educational or school focused applications of making tend to focus on middle and high school students.

Though some publications reviewed presented studies focused on one or more technologies used in making activities in school classrooms (Basawapatna et al., 2013; Chu et al., 2017; Kafai et al., 2014), most of previous research has focused on maker activities in after school programs and in informal educational contexts, such as makerspaces, libraries, museums or community settings (Vossoughi et al., 2014). The present research findings on the application of maker-centred pedagogies in formal educational contexts can enrich the relevant academic literature.

In relation to applying maker-centred approaches in different disciplinary areas, the study results showed that maker-centred pedagogies are used much more in science, technology and engineering classes than other subject areas. This finding is consistent with the the application of making presented in many studies (Clapp et al., 2016; Dayton, 2017; Vossoughi et al., 2014; Papavlasopoulou et al., 2017), and supports Martin's (2015) argument that "the potential value of making for K-12 education is perhaps most directly seen in relation to the new Framework for K-12 Science Education" (p. 31).

It was also found that though the vast majority of participants of this study were teachers of ADST or STEM, the statistics showed that these teachers generally believed maker-centred pedagogies can be useful in non-STEM subjects as well. This finding echos Vossoughi et al.'s (2014) statement calling for making to be considered as equitable practice, avoiding limiting the openness of maker definitions by tying them narrowly to STEM areas.

Not much is said in the existing literature regarding teachers' training on making. Data from this study showed that among 94 respondents, 31 had received some kind of training related to maker-centred teaching, and only six of them had received some formal education. Although most of the participants in this study favored using making in their teaching practice and hoped to receive relevant training, most had not received what they considered sufficient formal training on maker-centred teaching and learning.

A surprising finding was that mathematics accounts for a relatively large proportion (37.4%) of the courses the respondents had taught, but a small proportion (6.9%) of the subject areas in which maker-centred pedagogies were reportedly applied. This suggests that mathematics is thought of as different from other subjects in terms of the opportunity to apply maker-centred pedagogies. However, Garneli et al.'s (2013) study provided a successful example of examining the Effect of math Gem Game on learning performance and attitudes in grade 6 math classes, and showed that making activities can improve learning outcomes in comparison to the more traditional ways.

6.2.3. Resources and tools used in maker-centred activities

This research provided an overall view of the use of resources and tools in applying maker-centred pedagogies. Consistent with other research, one of the findings was that most teachers believe special resources and tools are important for maker-centred teaching and learning (Clapp et al., 2016; Vossoughi et al., 2014; Smay et al., 2015).

The qualitative analysis showed that the respondents had used several kinds of resources and tools in their teaching practice, including: high-tech tools and products (e.g., iPads, online simulations, and 3D printing), electronic devices and supplies (e.g., circuit kits and tools, robotics kits, and electronic components), computer programs and apps (e.g., Photoshop, iMovie, Scratch, and TinkerCad), and simple materials and hand tools (e.g., cutting boards, clay, foil, hammers, and scissors).

The high frequency of use of high-tech electronic tools such as iPads, robotics kits, and 3D printing is not surprising, and fits with the concept of the maker movement presented in many publications reviewed (Kafai et al.'s, 2014; Rode et al., 2015; Barrett et al., 2015; Papavlasopoulou et al., 2017). The use of high-tech tools reflects Rode et al's (2015) argument, which describes making as the activity of creating a tangible artifact "that is apt to link the digital and the physical" (p. 240), and supports Halverson et al's (2014) description of maker activities which "focus on problem solving and digital and physical fabrication" (p. 498).

Computer programs and apps were also commonly used by the research participants, and were reported in some of the research reviewed. For example, Basawapatna et al. (2013) discussed making through programmng using the Simulation Creation Toolkit; Garneli et al. (2013) investigated the effects of math computer games on learning performance and attitudes; and Lamb (2015) emphasized using various online resources and tools for expanding makerspaces.

In contrast to the frequent mention of digital tools in the literature, is may be considered surprising that a significant percentage of the respondents in the present study reported they had used simple common materials for maker-centred teaching (80 out of 257 references), indicating that the resources and tools required for maker-centred pedagogies do not have to be expensive high-tech products. This echoes the view that making pedagogy can be democratic, inclusive and accessible (Clapp et al., 2016), and provides meaningful evidence for Papavlasopoulou et al.'s (2017) definition of typical topics of interest in maker culture, which involve electronic digital tools, as well as more traditional tools and materials. It also supports Vossoughi et al.'s (2014) recommendation of using everyday materials to extend and deepen students' explorations across contexts in maker-centred activities.

6.2.4. Strategies of maker-centred teaching and learning

The majority of the survey respondents agreed that when using maker-centred pedagogies, it is necessary to employ some special strategies. The specific strategies necessary to support and improve the effectiveness of maker-centred teaching and learning were not much explored in the literature reviewed. However, Chu et al (2017) called for studies on how to support learners' collaborative maker experience within learning contexts, investigations on curriculum-based making on different science topics, and examinations of the use of different assessment instruments. The present study responded to these calls.

The qualitative analysis yielded 15 themes that categorized the strategies reported by participating teachers. Presumably due to the social nature of making activities and the distributed nature of teaching and learning in maker-centred classrooms, Of those strategies, "Collaboration" was most frequently mentioned by the ADST or STEM teachers as necessary to support maker-centred learning. Relatedly, teachers noted "Peer and self-evaluation" as a strategy to improve learning. These results were coherent with Vygotsky's (1980) conception that all learning is social, and supported Clapp et al. (2016) who emphasized that facilitating student collaboration, encouraging co-critique and co-inspiration, and promoting knowledge sharing are the key characteristics of maker-centred learning.

In accordance with the discussion of the characteristics of making approaches in Section 6.2.1, "Providing flexibility", "Inquiry and problem-based learning", "Student agency and expertise", and teachers' "Guiding, scaffolding, and facilitation" were frequently mentioned by participants as helpful strategies for implementing maker-centred pedagogies. Some teachers considered "Clarity of assessment and evaluation" and "Reflection on the learning process" to be important factors affecting the outcomes of maker-centred learning, while “Modeling” was mentioned by teachers as an effective teaching strategy. This last finding is consistent with Papert (1980), who emphasized the importance of tactile or conceptual models.

Survey respondents noted the importance of adequate preparation for students before pursuing maker-centred activities. This strategy is in line with Piaget’s stages of development (Piaget, 1928), and is coherent with Papert (1980) who asserted that in order to effectively progress, appropriate experiences must be made available. Papert provides several examples illustrating this, such as providing concrete conceptual models and computer programming techniques to students before presenting the computer as a problem-solving tool (Papert, 1980).

Group-wise comparisons of survey responses showed some relationship between recommended teaching and learning strategies and the grades or subjects taught by respondents. “Collaboration”, “Inquiry, Problem-based learning”, and “Providing flexibility” were mentioned more frequently by secondary school teachers than elementary school teachers; while “Collaboration” and “Inquiry, Problem-based learning” were mostly emphasized by science teachers than teachers of other subjects.

In relation to the impact of learners’ sexes on the potential outcomes of maker-centred learning, analysis showed the respondents’ views were diverse, and there was no significant difference between the responses from teachers of different grade-levels, sexes, or subject areas. This indicated no necessary link (at least in teachers’ minds) between learning performance and learners’ sex in maker-centred learning. This result resonates with the argument that maker education can be more open and democratic (Papavlasopoulou et al., 2017; Dayton; 2017) and confirms Clapp et al.’s description of maker-centred pedagogy as an educational approach which can cut across genders, classes, ages, and settings (2016). It also supports the principles presented by Vossoughi et al. (2016) for their framework of equity-oriented research and design.

6.2.5. Other considerations for using maker-centred pedagogies

In order to obtain a more complete and comprehensive understanding of the overall situation relating to the implementation of maker-centred pedagogies, the survey also inquired about other factors and considerations that teachers thought important for implementing maker-centred pedagogies. The data from this question provided new ideas and suggestions with regard to some crucial factors that were rarely discussed in the literature reviewed, such as physical space, class planning and safety issues.

"Physical space" was mentioned by a large proportion of teachers (36 out of 84) as a necessary condition for maker-centred activities in both elementary and secondary classes. "Effective room design and set up" was also mentioned as indispensable. The appropriate "Resources and tools", "Supplies and materials" are very important as well according to the teachers. These considerations were in line with Clapp et al.'s (2016) elaboration of the educational environments and instructional designs of maker-centred learning, which emphasized the special settings with tools and materials, storage and visibility, and flexible spaces.

Study results suggested that "Class planning" is an important factor for the effectiveness of maker-centred teaching. As discussed by respondents, this includes considering the subject topics, learning tasks and objectives, curricular structures, student teams, etc. Relatedly, Garneli et al. (2013) suggested engaging students with making activities that were closely connected to the respective curriculum topic to improve students' learning performance. Vossoughi et al. (2014) also suggested considering longer-term investments in new programs, and being aware of the need for explicit and detailed analyses of pedagogy in making environments.

The participating teacher suggested that "Safety and risk taking" needs to be given special attention in maker-centred learning. They noted that making activities require qualified teachers who are adequately trained on the equipment provided, and have mastered the necessary technical skills to provide help to students when needed. Teachers also suggested other important factors that may influence the success of implementing maker-centred pedagogies but are not discussed in the literature, including "Time", "Attitudes toward making", "Classroom management", "Flexibility", and "Support of administration." Among these, the attitude of school authorities and other teachers towards maker-centred pedagogies was considered a great obstacle, that was not mentioned in any of the literature reviewed.

The survey responses also indicated specific "Concerns, challenges, and difficulties" that teachers perceived with regard to safety, tools and skills, classroom dynamics, and time and effort demands. These findings provide useful suggestions for teachers in preparing their work, and important information for school authorities in supporting and assisting teachers effectively. In the relevant literature, Halverson et al. (2014) discussed the structural challenges to making approaches, and asserted that the greatest challenge to using making in K–12 schools was the need to standardize and define "'what works' for learning through making" (p. 500). Sator et al. (2017) mentioned some barriers to carrying out maker projects such as costs, reusability of materials, and time management. Relatedly, Kafai et al. (2014) asserted that "a prescribed curriculum, an extremely limited time period, or students who are unaccustomed to project-based learning are the potential obstacles to implementing a students-as-designers model" (p. 13). However, neither of these researchers mentioned the safety concerns or space concerns raised by participants in the present study. Selwyn (2011) articulated the concern that research on educational technology is inherently framed as progressive and positive. Technology enthusiasts' tendency to the accentuate promise and potential of new technologies at the expense of realistically examining challenges is a longstanding problem in the Educational Technology literature (Selwyn, 2010).

Finally, it was found that resources, tools, and class planning were mentioned much more often by secondary school teachers than elementary school teachers, indicating that in learning activities, secondary classes may need to use more high-tech tools and materials, and teachers may be more intensely aware of the need to organize teaching and learning effectively to achieve the expected outcomes. The results also showed that at the secondary level, "physical space", "resources and tools" and "supplies and materials" tend to be more critical for science classes as compared to those of other subjects.

6.3. Significance and implications of the study

6.3.1. Overall significance of the study

Significance with regard to teaching and leaning practices

This study systematically examined both ADST and STEM educators' understandings and perceptions of maker-centred pedagogies and their willingness to apply these approaches, presented their reports with regard to the current applications of maker-centred teaching and learning in BC public schools, and investigated the major factors that educators understand to affect the implementation of maker-centred approaches, including the characteristics of maker-centred pedagogies, the tools and resources used in making activities, and the strategies that can help to support and integrate these promising teaching and learning methods.

The results of the study revealed detailed, specific, and valuable information in relation to the implementation and application of maker-centred teaching and learning. The study suggests many feasible and practical suggestions to support maker-centred teaching and learning practices. These findings have important reference value for guiding or helping applying maker-centred pedagogies in K-12 public schools.

The data analysis furnished some surprising findings that future studies can investigate further, such as use of maker-centred approaches in disciplinary areas other than STEM subjects, and the effectiveness of particular strategies to support maker-centred practices in different disciplinary areas. As compared to previous studies that focused on specific innovations carried out in settings shaped intensively by researchers, the author hopes that the results of this study may lead to a more representative view concerning the perceived promise of maker-centred pedagogies in formal education, and the strategies and resources that may be necessary to ensure success.

Scholarly significance

Academically, this thesis attempts to enrich scholarly understanding of the current applications and potential of maker-centred pedagogies in ADST and STEM education in K-12 schools, and may contribute to the scholarly literature in several ways, including the scope of participants involved, the contexts focused on, and the methods employed.

This research was conducted on a large scale compared to most of the prior studies, which have focused on individual examples of application or specific occasions. Thus, the results obtained can hopefully provide a somewhat more representative picture of the applications of maker-centred teaching and learning in public schools.

Instead of investigating activities taking place in after-school programs, this study adopted a broader perspective by giving voice to both ADST and STEM educators' understandings and experiences of maker-centred teaching and learning in formal school contexts. The research data were collected from teachers of all grade levels (K-12) and several different subject areas (ADST, science, technology, engineering, and mathematics). This alone affords a valuable contribution to the literature, in which research on making in formal school settings is relatively scarce.

The study employed a mixed-methods design, which incorporated the strengths of both quantitative and qualitative approaches, presenting a comprehensive analysis with regard to the problems under study and offering both a general overview of and the rich insights into the research questions. This approach enriches and supplements the current literature, which is dominated by qualitative research and is relatively lacking of in broad-based quantitative studies.

6.3.2. Implications for implementing maker-centred pedagogies in BC public schools

As ADST is a new subject area in the BC curriculum, there is a lack of practical frameworks and guidelines to implement ADST in schools. The results of this study may have meaningful implications for the development and implementation of ADST and STEM curricula in Kindergarten to Grade 12 classrooms, and provide suggestions for ADST educators, especially in the elementary levels.

The results of this study give a sense of the characteristics of maker-centred approaches as perceived by practicing teachers, and presented many practical suggestions for applying maker-centred pedagogies in public school settings. On the other hand, the findings of this study indicated the important issues and considerations that teachers believe need to be addressed in applying maker-centred pedagogies, and the challenges and obstacles that this approach faces, some of which have not been discussed previously in the literature.

Overall, the findings reflect the perceived benefits and potential of maker-centred teaching and learning, which may inspire general attention to these approaches. More important, the results of this study provided some suggestions to school authorities and administrations to promote and support the implementation of maker-centred pedagogies, including: 1) Provide time commitment for maker-centred pedagogies by integrating making activities into curriculum and syllabus; 2) Provide resources needed in maker-centred teaching and learning, such as technologies, tools, materials, physical space, etc.; and 3) Provide training on making for both ADST and STEM teachers, including the philosophy of maker-centred approaches, the technologies and skills, the strategies to deliver the course content and structure the learning process, and the strategies to guide and support students' learning.

6.4. Limitations and recommendations

6.4.1. Limitations of the study

All research studies have inherent limitations, because no research design can serve all purposes. Nonetheless, it is important to delineate the limitations of the present study.

One limitation of this study is that the sampling method favoured teachers of ADST and STEM curricula. Therefore the results obtained regarding the research questions only reflected the understandings and perceptions of this segment of public school teachers. Also though the survey-based design of this study is effective to obtain a general overview of related issues, it is not well suited to collecting detailed information about the physical environments and contexts in which teachers work that may affect how making activity happens.

Another limitation is that the recruitment of survey participants was conducted based on voluntary principles. The respondents to the survey were therefore primarily teachers who were interested in maker-centred pedagogies and already had some experience of using this approach. While this level of experience was beneficial for some of the survey questions, it may have produced some bias with regard to teachers' optimism about and acceptance of maker-centred approaches.

Finally, since no BC provincial database of ADST or STEM teacher exists, the research was conducted based on a convenience sample that included participants recruited from two particular school districts in an urban area of British Columbia. As a result, the extent to which the findings can be generalized to a larger population and other areas of the Province is limited.

6.4.2. Recommendations for future research

As discussed above, given the present enthusiasm for using maker-centred pedagogies in formal school contexts, there is a need to conduct more research relevant to these settings. Based on the findings of this study and the review of scholarly literature, the following are some recommendations for future studies:

As indicated in this study, teachers appear to believe that maker-centred pedagogies can be widely applied in different subject areas. Future research can investigate the applications of maker-centred teaching and learning in disciplinary areas other than ADST related and STEM subjects, such as Fine Arts, Languages, and Social Studies.

Due to the different natures and characteristics of each discipline, the applicable learning strategies relevant to making are likely to differ. Future studies should examine the usage and effectiveness of different strategies to support maker-centred teaching and learning in different disciplinary areas, such as mathematics, science, technology and the arts.

Future research should examine the outcomes of maker-centred learning by grade levels and disciplines. Studies should consider the specific dynamics of teaching and learning in various grade levels and disciplines, explore how teachers plan for maker-centred pedagogies in different learning contents, and prepare materials to adapt to these different contexts. Finally, given the increasing demands on teachers to make their classrooms as inclusive as possible, research should examine the strategies teachers use to meet different learning needs and to foster all students' maker-centred learning in the most effective ways.

Further study should also focus on what is necessary to sustain maker-centred teaching practice – that is, how to create and maintain a sustainable ecosystem for maker-centred teaching and learning (resources, curriculum-based practices, activities, strategies, etc.), including the evaluation and assessment of the effectiveness of maker-centred pedagogies in formal classroom settings.

The researcher hopes the results of this study may provide some insight and possible directions for these future studies.

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Appendix A. Online Survey Questionnaire

Perceptions and Applications of Maker-Centered Teaching and Learning

This research is being conducted by the investigators from the Faculty of Education of Simon Fraser University. The purpose of this study is to investigate the applications and the potential of maker-centered teaching and learning in ADST (Applied Design, Skills, and Technologies) and STEM (Science, Technology, Engineering, and Math) education in K – Grade 12 public schools in BC.

The results of the study will have implications for the development and implementation of ADST and STEM in curricula at the school level, provide practical suggestions for the ADST/STEM classroom practices, and may lead to recommendations for school districts integrating maker-centered approaches to implement the new curriculum more effectively.

Part One. Teaching Background

Please provide the following information about your teaching background.

1. Indicate the grade level(s) you currently teach:

2. Indicate the course/grade levels that you have taught, and indicate if you feel that they fall into one of the categories below. Please select all that apply.

Elementary Course(s)
Secondary Course(s)
Sciences (e.g., Chemistry, Physics ...)
Technologies (e.g., Woodworking, Programming ...)
Engineering (e.g., Electronics, Game Design ...)
Mathematics
Arts (e.g., Foods, Textiles, Fine Arts ...)

3. How would you describe your familiarity with maker-centered teaching and learning?

Never heard of it.
Have heard of it, but never use it in my own classroom.
Have used maker-centered approaches a few times.
Often use maker-centered approaches in teaching.

4. If you have ever used the maker-centred teaching approach, please list the courses and grades you use this method:

Part Two. Understanding and Views on Maker-Centered Teaching and Learning

For each statement, please check the appropriate response. Please rate the following on a 5-point scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree):

Statements	1	2	3	4	5
1. Much of ADST (Applied Design, Skills, and Technologies) and STEM (Science, Technology, Engineering, and Math) teaching has a heavy emphasis on theory and overlooks hands-on practice. :					
2. Students usually do not have enough opportunities to make things in ADST-related and STEM subject classrooms. :					
3. Making-based activity is an important part of ADST-related and STEM classrooms. :					
4. Maker-centered learning increases student engagement in ADST/STEM classrooms. :					
5. Maker-centered approaches increase achievement in ADST / STEM subject learning. :					
6. Maker-centered teaching and learning are useful in subjects not related to ADST and STEM. :					
7. Gender factors have an impact on the outcomes of maker-centered learning activities. :					
8. Specific resources/tools are necessary for maker-centered teaching and learning. :					
9. Maker-centered teaching requires development of specific strategies to facilitate students' learning. :					
10. Collaboration is important in maker-centered learning. :					
11. Developing the ability to design and make, acquire skills, and apply/use technologies is important in education today. :					
12. ADST and STEM educators should act as technology-literate facilitators/guides rather than transmitters of information. :					

Part Three. Open-ended Questions

Please provide your opinions/comments on the following questions:

1. How do you think maker-centered teaching is different from other teaching approaches?

2. What strategies support maker-centered teaching and learning?

3. What technologies or tools have you used in maker-centered teaching/learning?

4. What other features/considerations are important in a classroom in which making-based activities take place?

5. Have you received any training on maker-centered teaching and learning? If yes, in what disciplinary areas?