How State-of-the-Art Makerspace Stations Contribute to Differences in Students' Learning: A Mixed Methods Case Study of a Bilingual High School in Kuwait

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Declaration

This thesis results entirely from my own work and has not been offered previously for any other degree or diploma. I declare that the word length conforms to the permitted maximum (49991 words).

Signature: Sayed Mahmoud

Acknowledgements

I dedicate this study to those who travelled this long journey with me.

To my wife, Amal, for the sacrifices she made and the time she offered to support me during this journey.

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Abstract

As a means to nurture innovation and better prepare students for the world of tomorrow, schools are establishing makerspaces. Consequently, school makerspaces are gaining momentum in recent years. While makerspaces have been studied mostly in museums and libraries, little research has been conducted inside K–12 school makerspaces. The purpose of this exploratory mixed-methods case study was to examine the perceptions of teachers and students concerning learning in a standalone school makerspace, how the identifiable indicators of learners' learning differ by station and to identify how such learning may assist students in being future-ready.

Data collection is performed using mixed methods. The sample included 79 high school students and seven teachers who worked at five makerspace stations on different projects. Data were collected via online surveys, reflective journals, and observational notes. The tinkering learning dimensions framework, 21st-century skills framework, Gibbs's reflective cycle, and the makerspace quadrant guided the design of data collection tools and discussion of the findings. This study contributes to the field by demonstrating how this school makerspace facilitated learning during a crisis through long-term projects using a novel blended projects model developed in this study.

The cross-case analysis revealed that social and emotional engagement was the most visible learning dimension across all stations. The study results reveal that school makerspaces offer a context to develop 21st-century skills, becoming a hub for exploring many career pathways and providing real-life connections. The evidence also shows there to be a potential relationship between the makerspace stations and the learning dimensions. For example, while students at the technology station with no hands-on work had the lowest level of learning indicators, those at the 3D printing station had higher levels of learning indicators. The findings contribute to the ongoing scholarly conversations about the educational values of school makerspaces, and the discussion culminates in recommendations for practice and research.

Keywords: making, maker, makerspace, school makerspace, maker-centred learning

List of Abbreviations

3D	Three-Dimensional
AbD	The Agency by Design
CNC	Computer Numerical Control
NGSS	Next Generation Science Standards
NJR	Jointly Negotiated Research
P21	Partnership 21st-Century Learning
SACGC	The Sabah Al-Ahmad Centre for Giftedness and Creativity
STEAM	Science, Technology, Engineering, Arts, and Mathematics
The Four Cs	Cooperation, Collaboration, Creativity, and Critical Thinking
TLD	Tinkering Learning Dimensions
WHO	World Health Organization
VR	Virtual Reality

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Chapter 1: Introduction and Background

1.1 Overview

Makerspaces can help in improving education because creativity and innovation are not supported by the current educational system (according to Robinson & Aronica, 2015). As schools start to create makerspaces, data proving how these facilities benefit students would be useful, and solid scientific evidence is required to inform policymaking in the field of makerspaces in education and training (Vuorikari et al., 2019). Additionally, given the greater emphasis placed on fostering 21st-century competencies including the four Cs (cooperation, collaboration, creativity, and critical thinking) and career skills, exploration of the topic is vital (Bowler, 2014). This study will explore learning in one type of makerspace: a standalone makerspace in a bilingual school in Kuwait, equipped with advanced tools. As a result, the focus of this study is limited to standalone school makerspaces rather than other forms of school makerspaces, such as library makerspaces or fab labs.

This first chapter provides background information and context for the study. It also details a history of making and explores different definitions of school makerspaces as this technology-related concept and practice is continually evolving. Furthermore, this chapter states the study's purpose, the research problem, and the research questions.

1.2 Education and Makerspaces in Kuwait

At the westernmost point of the Arabian Gulf, Kuwait, an oil-rich nation, borders Saudi Arabia to the south and Iraq to the north. Kuwait's geographic position makes it a port for commercial routes that connect it to many nations. Consequently, Kuwaiti people are influenced by different cultures (Alhassan, 2011). Over the past several decades, Kuwait's educational system has undergone profound changes and has witnessed growth due to the discovery of oil in the late 1930s (Fruit, 2003).

Makerspaces are collaborative workspaces where people gather to tinker, create, invent, and learn while sharing their knowledge and interest in making various artefacts (Hughes, 2017; Woolls, 2018). The present research focuses on a makerspace in a bilingual high school in Kuwait. Kuwait's maker movement is growing fast and is having an impact on education and schools (Mohammadi, 2019), although there are only a few makerspaces in place to date. The first makerspace in Kuwait was established in May 2010 as an initiative launched by the ruler of the country (About us, n.d.). This makerspace, the Sabah Al-Ahmad Centre for Giftedness and Creativity (SACGC), aims to nurture Kuwaiti people who are gifted in science, technology, and other subjects. Although the word “makerspace” is not mentioned in its title, it is considered a public makerspace as it contains all the elements of makerspaces. In other Gulf countries such as Saudi Arabia, the first fab lab (similar to a makerspace) was launched in 2011(Farhat, 2015). SACGC is ‘dedicated to facilitating the integration of knowledge and intelligence by sponsoring gifted and creative individuals’ (Almutiri, 2014, p. 1). By funding potentially ground-breaking ideas, it demonstrates Kuwait’s commitment to nurturing its citizens’ talents. SACGC develops different workshops and training to motivate the talents of individuals to work on their innovative projects (About us, n.d.). Moreover, it helps Kuwaiti inventors register their patents locally and internationally to protect their intellectual property rights (Almutiri, 2014). Some inventions have emerged with the help of this centre and a number of Kuwaiti people have benefited from its support. For instance, Hassan Al-Shammri created a surgical needle holder that makes it easier for surgeons to move the needle in tight spaces (Serra, 2018). This example supports the belief that the maker movement, driven by advanced technology and tools, has helped some people become inventors and creators rather than mere consumers of technology (Martinez & Stager, 2013).

Another example of a Kuwaiti invention that was developed with the help of makerspaces and shows how individuals can innovate and start their own businesses is Naser Al-Khaldi and Ahmed Al-Saleh’s Ebot. In 2014, Naser Al-Khaldi and Ahmed Al-Saleh, two Kuwaiti inventors, participated in the New York Maker Faire to display their invention, Ebot, an open-source microcontroller device. This prototyping platform, known as the Ebot Innovation Platform (software/electronics/mechanical parts), enables quick and easy prototyping and has won numerous national and international awards (Ebot Microcontroller, 2016). It is vital to consider whether these inventors could have designed this solution (Ebot) without the aid of the makerspace. As the maker movement in Kuwait gained traction in the private sector (Mohammadi, 2019), schools began to investigate how to incorporate maker initiatives into teaching and learning given that Kuwait lacks maker studies that deal with integrating makerspaces into K–12 education.

1.3 History of Making

People have been makers (Fleming, 2015) to survive since the beginning of time. Making things enabled early humans to feed, clothe, shelter, heal and transport themselves. Humans have crafted various personalised artefacts to communicate with their environment and meet other needs in their lives (Hallett, 2019). Making is a type of activity that engages students in activities and 'involves traditional craft and hobby techniques (e.g., sewing, woodworking, etc.), and it now often involves the use of digital technologies, either for manufacture (e.g., laser cutters, CNC machines, 3D printers) or within design (e.g., microcontrollers, LEDs)' (Martin, 2015, p. 2).

This idea was explored in *Invent to Learn, a* book by Sylvia Martinez and Gary Stager (2013). In this book on making, the authors explored how teachers can join the maker movement and turn school classrooms into centres of innovation. In the following passage, they summarised the concept of making:

> Making things and then making those things better is at the core of humanity. Ever since early man started his first fire or clubbed his first seal, humans have been tinkerers. Farming, designing weapons for hunting, and building shelter were early forms of engineering. Th-roughout history, art and science, craft and engineering, analytic thinking, and personal expression have coexisted in communities, industry, culture, commerce, academia, and in the heads of creative people. (p. 46)

Conclusions can be drawn from this introduction to the history of making. There is an iterative design methodology of modern making as people try different tools to fit their needs. The experience of making is a student-centred learning activity that creates opportunities for students that they may never have encountered on their own. Makers are self-assured, knowledgeable, and inquisitive citizens in a new universe of potential (according to Martinez & Stager, 2013). Making is defined as the process of 'developing an idea and constructing it into some physical or digital form, often with educational values' (Sheridan et al., 2014, p. 507).

1.4 School Makerspaces

The term "makerspaces" appeared in 2005 with the publication of *Make Magazine*, but the first formal makerspace emerged in 2011 at Fayetteville Free Public Library in New York (Egbert, 2016). Fleming (2015), author of *Worlds of Making*: *Best Practices for Establishing a Makerspace* *for Your School*, defines a makerspace as ‘a physical place where learners can explore their own interests and make creative projects through different types of tools and materials’ (p. 3). A makerspace can be an entire area, one station or a cart or be mobile (Robinson, 2018). Learners’ curiosities can be piqued, and their problem-solving and critical-thinking skills developed as they tackle the challenges and problems they encounter while working in the makerspace. In makerspaces, students take the lead in determining the scope and direction of their own learning; thus, this type of learning is characterised as student-centred learning or, in the makerspace, maker-centred learning (Nadelson, 2021).

The term “school makerspaces” in this study refers to standalone makerspaces in K–12 schools (starting at the age of approximately 5 years to Grade 12 at approximately 18 years) to support science, technology, engineering, arts, and mathematics (STEAM) as well as other subjects (Hughes, 2017). There is no single description of a makerspace as it depends on the context and community developing it (Gomez, 2019). In a report prepared by the California Council on Science and Technology in December 2017, the authors stated that the definition of makerspace is somewhat variable (Lindsey & DeCillis, 2017). Other researchers indicated that the term makerspace is poorly named since it implies that creating is confined to a certain location and environment (Gerstein, 2019). In international schools, a makerspace is sometimes referred to using different terms, such as an innovation centre, Yes Lab, Ideal Lab, Spark Tank, the Link or STEAM Lab. Because the author of this thesis could not find a description of the standalone school makerspace, he adopted a definition for this study (see Figure 1.1). Based on this definition, a school makerspace is a physical place inside a school that comprises four elements:

1- A space partitioned into stations and outfitted with sophisticated instruments and machinery.
2- Artefacts (digital/ physical)
3- Process
4- Students and staff

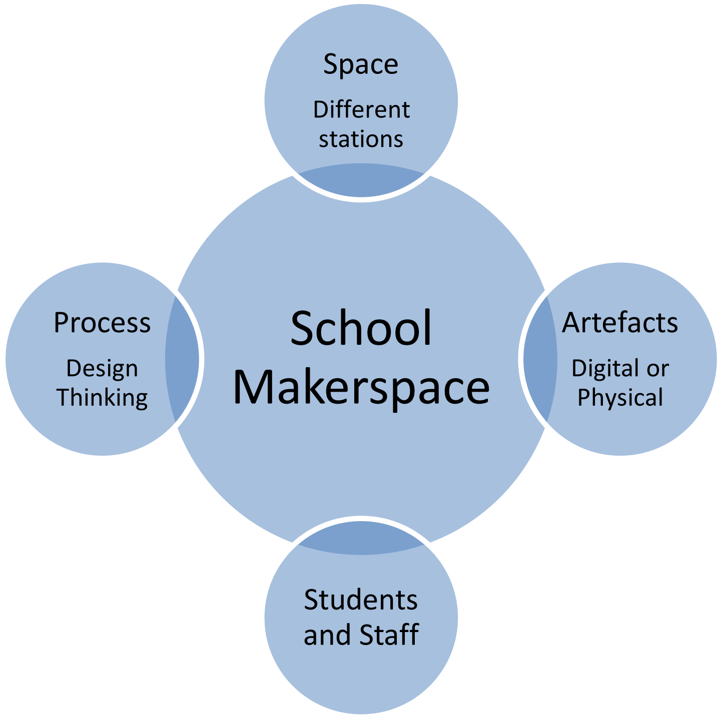

Figure 1.1 The Author's Definition of a School Makerspace.

1.4.1 COVID-19 and School Makerspaces

Beginning in 2020, when COVID-19 began to spread across the globe, the author of this thesis started researching this study. The COVID-19 pandemic affected teaching and learning and forced teachers to customise their teaching methods to suit online learning in schools (Shu & Huang, 2021). During this period, many teachers began to create online activities to engage students. Blended makerspace projects — a term coined by this thesis's writer and central to this thesis — or projects that have an online component can be used to promote learning in the makerspace. For example, one of the students, Mark (pseudonym) requested assistance with one of his COVID-19-related initiatives (Hands Free) from the author of this thesis.

One of the 11th-grade students at the school where this study was conducted founded the fully volunteer-run non-profit organisation Hands Free. After reading studies showing that viruses can be spread easily via surfaces, especially door handles, the student investigated possible solutions and came up with a workable artefact in the shape of 3D-printed hands-free door-openers that allow people to open doors using their arms or, in some situations, feet rather than their hands, reducing the risk of transmitting the virus. This solution was used in several locations, including the Mayo Clinic and military bases, as COVID-19 spread (Eldebeky, 2021). To help hamper the diffusion of

COVID-19, the student created Hands Free to test, print and install the door openers in as many locations as possible (The Solution, n.d.).

1.5 Researcher's Background

The author of this thesis is currently a makerspace coordinator at a private school in Kuwait. Previously, he served as the head of technology in a Finnish school and as an e-learning specialist for a public school in Qatar. His work has included experience with technology, digital resources in libraries and professional development training for other educators.

His research interest in school makerspaces was sparked after he led the creation of a makerspace in a private school in Kuwait. Feedback from teachers and students indicated that they had many questions about learning in makerspaces. Notably, teachers were unsure about which tools might help them. After one year of implementation, the author received a large grant from the Parent Teacher Association (PTA) to redevelop the makerspace. This encouraged him to examine the latest trends in school makerspaces.

Based on undocumented observations, the school makerspace helped students learn in an attractive way and teachers appeared to develop from traditional teachers to student-centred teachers. As a researcher, the author is interested in discovering what types of learning occur in the makerspace and how the latter can prepare students for the future. His research interests are driven by a responsibility to bring the latest trends of making-centred learning to students to give them the opportunity to participate in the 21st-century economy. This study will go beyond anecdotal observations to address whether makerspaces can help students acquire what is referred to as 21st-century skills as they use the different stations in the makerspace, such as 3D printing and robotics.

School teachers have various conceptions of makerspaces. Some believe that makerspaces are noisy, dirty engineering-only spaces whose sole purpose is to make models (Dahal, 2019). Others see makerspaces as encouraging inquiry and innovation, learning through making, collaborating, and sharing. Some educators wonder whether makerspaces can help transform education or are merely a fad or distraction. Furthermore, there may be difficulties with student-centred learning in makerspaces because of the possible contradiction between traditional didactic methods for education and the learning that takes place in these settings (Nadelson, 2021). While research has examined learning in museum makerspaces, little is known about the educational benefits of school makerspaces in terms of learning (Cuddihy, 2020). The present research seeks to fill this gap in the literature based on a case study of Kuwait's first school makerspace.

1.6 Details of the Study

In the following subsections, the research setting, the research problem and the significance, purpose, assumptions, and organisation of the study will be outlined.

1.6.1 Research Setting

The research setting is a bilingual private school in Kuwait that had already established a school makerspace three years before the start of the study. The author of this thesis was motivated not only by the lack of research addressing the educational potential of makerspaces but also by the potential of makerspaces to help students develop 21st-century skills to prepare for the future.

Makerspaces are gaining popularity around the world, which inspired the author's school to build the largest school makerspace in Kuwait, which covers 5,000 square feet. This makerspace was built to aid teachers in fostering learning by enabling them to prepare student-centred lessons, help students solve a problem or rapidly prototype an idea and was intended to serve as the hub for the STEAM lessons. This makerspace comprises eight different zones, which include 3D printing, technology, coding, woodworking, laser cutting, filming, gaming, and tinkering (see Figure 1.2). At the author's school, makerspaces offer numerous advanced tools to support learning across various subjects.

Figure 1.2 A 3D Layout of the Makerspace: Author's Sketch (Eldebeky, 2021).

1.6.2 Research Problem

Although school makerspaces are a growing phenomenon, their educational benefits have not yet been the subject of extensive academic research, and the question of whether students learn in the school makerspace is mostly unanswered (Bevan et al., 2020). Not all teachers agree that the makerspace is essential for learning. As Petrich et al. (2013) pointed out, some may look at making activities and say, 'well, it looks like fun… [pause]… but are they learning?' (p. 52). Consequently, more research should be conducted to identify what learning, if any, occurs in school makerspaces. Nadelson (2021) argued that 'because of the potential benefit to students, we need to keep exploring and empirically documenting the implementation and outcomes of makerspace learning in K–12 education to assure effective use of the spaces to maximise student learning' (p. 106).

Moreover, even though some researchers believe that makerspaces in schools encourage creativity, invention, entrepreneurship and maker empowerment, few studies have explored how they affect teaching and learning (Horton, 2017). As there is a hype around makerspaces in schools (Becker, 2019), there is still a question to address: is there evidence for learning of the making activities that are interesting to students? In his previous experiences and when establishing the current school makerspace, the author of this thesis faced some challenges. First, some teachers did not feel that makerspaces could offer any educational value. Second, it was difficult to integrate the makerspace projects within the formal curricula and assessment practices in some subjects, such as mathematics. Third, some teachers needed help in choosing the appropriate stations for their students' projects and assessing the latter. To mitigate these issues, the author decided to conduct the present research to determine precisely how learning occurs and uncover the contributions and benefits of each makerspace station. To conclude, this case study of a school makerspace examines learning and explores how it may help students prepare for their future.

1.6.3 Significance of the Study

Although it is reported that makerspaces can be 'fun' and interesting to work in, teachers need to understand the value and positive impact of the actual learning occurring in these spaces. To continue supporting makerspaces, the learning outcomes should be identifiable and visible. Maaia (2019) pointed out the need for research that further qualifies and validates making activities to integrate makerspaces into educational contexts. The results of the present investigation seek to help researchers and practitioners better understand the educational potential of makerspaces in schools and provide methods to aid in their creation and maintenance.

Furthermore, this study may help schools incorporate makerspaces into their curricula and create courses, for instance, on life skills or innovation skills connected to the makerspaces and that can be taught in schools. It also offers ideas concerning practices related to how makerspaces can provide unique opportunities to help students prepare for the future.

1.6.4 Purpose of the Study

Every school makerspace is different in terms of size, location, facility, targeted students, tools, and operation. The availability of tools and equipment is one of the unique aspects as it helps students find things that may help them build their models. Consequently, it is important to research learning via these tools in each makerspace zone. Otherwise, tools such as 3D printers may be purchased simply because they correspond to the latest fad in education, with no plan for integrating them into the curriculum (Cross, 2017).

However, some academics and practitioners in the field are beginning to question the efficacy of makerspaces in education (Oates, 2015) even as some schools in Kuwait and elsewhere continue to implement them. The purpose of this study is to understand how the makerspace functions as a learning environment and identify the types of learning occurring at various makerspace stations, applying the existing learning dimensions framework (Bevan et al., 2020) and 21st-century framework (Partnership for 21st-Century Learning, 2019)**.** Using online surveys, observational notes and reflective journals, the author will identify learning as it manifests in five zones of a school makerspace and explore skill acquisition in each zone. This study will address the following overarching research question:

What educational benefits and indicators of learning are identifiable among students who use the different stations in the makerspace, and how could makerspaces help them develop their future career skills?

Five sub-questions are asked:

1- How do high school teachers perceive the educational benefits of the various stations of a school makerspace?

2- How do high school students perceive the educational benefits of the various stations of a school makerspace?
3- What indicators of learning are identifiable among the students using the various stations of the makerspace?
4- How do the identifiable indicators of learners' learning vary by station?
5- How do different stations in a school makerspace contribute to the learners' acquisition of life skills that could help them develop future career skills?

1.6.5 Assumptions

An assumption is defined as an assertion that may be 'presumed to be true' but is not proven (Gay et al., 2015, p. 623). The first assumption underlying this research is that students can acquire 21st-century skills in the makerspace. The second assumption is that some makerspaces stations may be more conducive to learning than others. The third and final assumption is that learning in the makerspace can help students prepare for the future and their future jobs.

1.6.6 Organisation of the Thesis

This thesis consists of seven chapters. Chapter 1 presents the context of the study and the objective and purpose of the research, including the research setting, the researcher's background, and the importance of the research. A review of the literature is provided in Chapter 2. The conceptual frameworks are discussed in Chapter 3. Chapter 4 describes the methods and the reasons for selecting them. The results of the research are laid out in Chapter 5. Chapter 6 proposes a discussion of the results. Finally, Chapter 7 outlines the original contribution to knowledge, the insights gained from the study, suggestions for educators and decision-makers, avenues for future research and the study's limitations.

1.7 Chapter Summary

Chapter 1 introduced the makerspace trend in the context of K–12 schools. These schools' makerspaces, though growing rapidly, are still nascent and necessitate additional academic research. This chapter also addressed the importance of makerspaces in Kuwait and how they have helped Kuwaiti people with their inventions. The next chapter will consist of a literature review focusing on previous studies on school makerspaces and how the present research differs from previous research.

Chapter 2: Literature Review

2.1 Overview

As school makerspaces are a relatively new concept (at the time this study was conceived) and the study concentrates on a school makerspace rather than other types of makerspaces, several methods were used to identify gaps and locate sources for the literature review to address the research questions. The first sources were three books published recently about learning in school makerspaces. Second, Google Scholar was used to find peer-reviewed journals. Third, the Lancaster University Library OneSearch search engine was employed, where beneficial databases were found, such as ProQuest Education and EBSCO. Limiting the searches to these specific databases resulted in searches that aided in narrowing the results more than Google Scholar and focusing on school makerspace learning**.** Furthermore, a few PhD studies related to school makerspaces were found. Lastly, Google Search was used to find articles relevant to learning in school makerspaces, as well as the literature recommendations received from colleagues. As a result, recent articles were found providing updated information about school makerspaces and statistics about their usage.

Several strategies were adopted to search for resources for this study. To retrieve relevant resources from databases, the following phrases were utilised in a Boolean format: school makerspace, the four Cs, life skills, and career skills. Combining these terms with the “and” command enabled the retrieval of information pertinent to these specific topics. This method allowed the researcher to search for full-text copies of multiple databases and resources. Lastly, communication with experts in the field helped obtain updated resources related to the study.

Several criteria were used to identify the publications and resources included in this review. The materials were limited to the last ten years, although a few older resources were chosen because they contained useful information. The second criterion for selecting sources for analysis was to restrict the search to full-text peer-reviewed journals, dissertations, and books to ensure that the resource was rated for credibility and quality by experts in the relevant field. Third, resources in four categories were selected: learning in school makerspaces, cooperation, collaboration, critical thinking, and creativity (the 4 Cs), life skills, career skills and previous studies on school makerspaces related to research questions to help in identifying the knowledge gap. School library makerspaces were later added to the list because they contained a few resources crucial to school makerspaces. Consequently, the initial scope was modified from K–12 school makerspaces to include school library makerspace resources, which increased the number of resources used in this study by eight.

This literature review explores learning in school makerspaces as well as the benefits of learning in makerspaces. The review begins by defining the maker movement, its theoretical roots and providing background information on the history and context of the current problem of practice in school makerspaces. The second section of this chapter is a review of learning, or the skills and benefits highlighted in the literature. Particular attention is given to the skills specifically learnt in school makerspaces and how they can help students be future ready. The third section of this review includes a discussion of the previous studies of school makerspaces and related themes.

2.2 The Maker Movement

In 2005, Maker Media, a global platform for connecting makers with each other, published the first edition of Make Magazine, which contained do-it-yourself projects using electronic computer software and hacks and building artefacts with digital fabrication software and technologies. Approximately a year after the first release of Make Magazine, the world's first Maker Faire took place in California. A Maker Faire is an annual event for makers to demonstrate a wide range of hobbies, experiments, and projects (Bevan, 2017). Following these two events, a global community of do-it-yourselfers, hackers, tinkerers, hobbyists, entrepreneurs, and educators began to communicate to form the maker movement.

Papert is credited as the father of the maker movement by Halverson and Sheridan (2014) for his writing on learning by doing and his idea of constructionism. Furthermore, Lacy (2018) defined the maker movement as 'a community of people engaged in the creative production of artefacts, with an emphasis on the use of digital fabrication technologies and who share their artefacts in both physical and digital spaces' (p. 19). The author of this thesis considers that this definition is not accurate as makers sometimes depend on tools other than digital fabrication technologies, such as hand tools. For example, using a bandsaw can help in creative work in school makerspaces. Maker Faires, makerspaces, and fabrication (or fab) laboratories in which participants actively build physical products to share with the world are three examples of entities that the maker movement has advocated for to further maker-centred learning (Martin, 2015).

The “maker movement” refers to the new trend in which a group of people are working to make physical or digital artefacts for ‘both playful and useful ends’ (Martin, 2015, p. 30) and share them with other makers (Halverson & Sheridan, 2014). The term “additive innovation” is used to define the process through which groups of makers can acquire knowledge from one another (Jordan & Lande, 2016). Put differently, in a dynamic and failure-positive setting, makers learn by collaborating and exchanging ideas to develop skills. In addition, additive innovation can be applied in both physical makerspaces and digital interactions.

According to Rosa et al. (2017), there are three common elements of the maker movement: tools, people, and mindset. Tools vary by location—for example, some locations have advanced technology tools like 3D printers and laser cutters, while others prefer hand tools or power tools like bandsaws and art tools. The second element, people (or “community” in the literature) (Litts, 2015) involves collaboration and sharing ideas. The maker movement’s primary characteristics are creativity, motivation, and knowledge sharing, as described by maker movement leader Dougherty (2016). In a study about successful academic library makerspaces, the researchers noted that passion and enthusiasm are two characteristics of the maker culture found in all their interviews (Benjes-Small et al., 2017).

The maker movement spread quickly around the globe for two reasons: the reduced cost of digital fabrication software (e.g., Fusion 360, SolidWorks) and the increasing affordability and accessibility of technologies or tools (e.g., CNC routers, laser cutters, 3D printers, Arduino microcontrollers) (Sheridan et al., 2014). As a result of the democratisation of technology, more individuals are engaging in producing activities (Sung, 2018). Supporters of the maker movement perceive it in different ways. For example, it was described as a joyful learning approach for STEAM education by Martinez and Stager (2013) and a way for students to integrate their personal and academic lives to find a solution to a problem in their own neighbourhoods by Barton et al. (2016). It was also presented by Kalil (2013) as a way to become involved in STEAM-related fields. Meanwhile, Clapp et al. (2017) characterised it as ‘a rising interest in sharing and learning from others while working with one’s hands within interdisciplinary environments that combine a variety of tools and technologies’ (p. 2). Hatch (2014) viewed it as a way to enable students to be successful entrepreneurs. Finally, Andria (2019) incorporated innovation and exploration: ‘The Maker Movement is based in a philosophy of exploration and has been embraced as a way to encourage American manufacturing, innovation, and entrepreneurship’ (p. 11).

Research has shown that making can contribute significantly to student learning (Kiley-Rendon, 2019). The way makers approach learning is called the "maker mindset" (the third element of the maker movement). Dougherty (2013) sees the maker mindset as empowering students to foster creativity and innovation, risk-taking, and problem solving through playful interaction with the physical world. The maker mindset encourages students to develop creative confidence and a sense of agency, so they are prepared for 21st-century jobs (Hibbard, n.d.). The maker mindset, as per Welbourn (2019), extends beyond the makerspace's physical location and its collection of tools and materials. According to Martin (2015), this mindset is defined by four characteristics: it is playful, growth oriented, failure-positive and collaborative. Hielscher and Smith (2014) identified some of the key elements of the maker movement's ethos:

• The importance of informal, hands-on learning through play and tinkering.

• Collaborative work practices.

• Knowledge sharing and advocacy for open source and open access.

• The impact of new technologies on manufacturing and culture as a new industrial revolution. (p. 2)

Following a brief discussion of the central tenets of the maker movement's philosophy, this subsection will define making as an activity or the process of making for makers.

2.2.1 Making as an Activity

Although scholars have proposed various definitions of making, there is general agreement that making is an activity that encompasses the ideation, design, and production of physical or digital products (Vossoughi & Bevan, 2014). Even though learning by making is an old technique, it has developed as a result of improvements in computers, communications technology, pedagogy, and library science (Koole et al., 2017). To engage in a making activity, a framework is necessary for its implementation (Hughes, 2017). Numerous frameworks, such as design thinking and engineering design, are used in developing making activities and project-based learning. Students' motivation and interest in learning can both be stimulated by placing learning within the context of making (according to Schweder & Raufelder, 2021).

Supporters of making hold varied views. Dougherty (2012) pointed out the importance of making on several levels: at the personal level when makers are happy with their achievements and their final models; at the social level when makers learn from each other and share their work with other makers in local or online communities; and at the economic level when makers make models to sell them or start their own businesses. Consequently, making can help countries increase exports and industries. Bevan (2017) distinguished between three forms of making investigated in previous research: entrepreneurial making, making to improve STEAM workforce skills and educational making, often known as maker-centred learning. Similarly, Herro et al. (2021) indicated that making activities offer multiple opportunities for collaborative problem solving, the advancement of individuals and sharing knowledge.

Dougherty (2012) expressed his concerns that efforts to institutionalise making will impede the creativity and innovation that drive the "maker revolution". The author of this thesis disagrees with his idea because many makerspaces in schools (at the time this study was conceived) seek to be a hub of innovation as schools connect makerspaces with innovation. For example, Dwight School Dubai described its makerspace, the Spark Tank, as follows:

> Spark Tank is Dwight's incubator, a program designed to nurture student innovation, entrepreneurship, and leadership skills beyond the classroom. All Dwight students can participate in the Spark Tank Program to develop their ideas for new businesses, non-profits, or products. (Spark Tank Program, n.d.)

Furthermore, the findings of Timotheou and Ioannou (2021) suggested that making activities can foster the development of young learners' creativity. The present study will focus on how making as a learning activity in a K–12 setting prepares students for the future and helps them acquire career skills. The next section discusses the theoretical roots of the maker movement and the early scholars who contributed to its rise.

2.2.2 The Maker Movement's Theoretical Foundations

The maker movement reflects the early ideologies of educational scholars who advocated for hands-on, problem-based, real-world forms of learning. In 1912, for instance, Maria Montessori proposed the idea that children can learn by playing and building with interesting tools and materials. In the same vein, German educator Friedrich Froebel, who created the kindergarten, urged teachers to use resources and involve practical work in lessons because humans are productive and creative (Attewell & Murray, 2020)**.**

Similarly, Uno Cygnaeus was one of the most influential Finnish figures in the history of education. As one of the first leaders to promote the use of technology and craft in education, he is known as the father of elementary schools in Finland and the father of technology education. In 1860, he was asked to write a proposal to improve education in Finland and suggested the now-famous "Finnish Folk School". This concept laid 'the foundation of what students do (or try to do) worldwide today in the study of technology education' (Rasinen et al., 2010, p. 18). Cygnaeus stressed the significance of helping students learn how to use their hands rather than memorise facts from books. He was a great promoter of craft education, and he recognised the educational value of working with materials and processes as well as creating products with practical or aesthetic value. Thus, it seems reasonable to suggest that if Cygnaeus were alive today, he may have been one of the first supporters of makerspaces and maker-centred learning.

Many educational researchers argue that the theoretical reasoning behind school makerspaces emerged from Seymour Papert's constructionist learning theory in which learning is both a mental and physical activity (Blikstein & Worsley, 2016). In addition, Papert (1980) proposed to teach mathematics through programming, at the nexus of the physical and digital worlds. In the following subsections, two theories will be discussed that form the theoretical reasoning behind school makerspaces and provide the genesis of the maker movement and makerspaces. These two theories will be reflected in the findings of this study.

2.2.2.1 Constructionism

Papert and Harel (1991) stated that rather than transferring knowledge (teacher-centred learning) to students, educators should guide them through the process of producing knowledge. Making as a method of learning and external artefacts as proof of learning are supported by constructionism (Litts, 2015). Constructionism, the theory that underpins the maker movement, is also known as "learning by doing" or "learning by making", as described by Papert and Harel (1991). According to the constructionist view, learning involves making new things (both in terms of knowledge and physical objects). When learners build artefacts, they represent knowledge and interpret it in the form of these artefacts. Constructionism argues that people learn through creativity and by making physical artefacts (Halverson & Sheridan, 2014). Furthermore, making activities are discussed in terms of learning via the production of objects, with the underlying philosophy being Papert's constructionism (Papavlasopoulou et al., 2017). Shively et al. (2021) stated that makerspaces 'embody a growing movement of educators promoting constructionist learning with physical materials and digital technologies, such as 3D design and 3D printing' (p. 1).

Students can face many challenges during the process of making; instead of quitting, they may need to embrace mistakes as a way to learn. For Papert (1980), making mistakes supports an iterative process of construction and reconstruction as "debugging", which works as the "essence of intellectual activity" in making (p. xiii). Although constructionism interprets the learning occurring in the makerspaces, Papert urged researchers not to 'confine constructionism to making as it is multifaceted and has deeper implications for learning' (Papert & Harel, 1991, p. 1).

By incorporating constructionism as a theoretical framework, this study acknowledges the value of active construction, collaboration, reflection, and metacognition in the context of makerspaces. It recognises the power of hands-on, experiential learning and highlights the potential of school makerspaces to facilitate constructivist learning experiences that promote innovation, engagement, creativity, and career skills among students. Overall, the methodological approach in this study is underpinned by the principles of constructionism as a theoretical framework and basis.

2.2.2.2 Participatory Culture Theory

Henry Jenkins introduced the participatory culture theory, which contends that people can be active creators of media and not merely passive consumers of it (Jenkins, 2009). This view is aligned with the maker movement, which is built on the notion that individuals are creators and makers rather than simply consumers (Hughes, 2017; Otieno, 2022). Furthermore, it reflects that teachers are not the only source of information. Consequently, teachers and students should share information while they work on projects. In a report funded by the Gates Foundation, Jenkins and his team developed the PLAY acronym, which stands for Participatory Learning And You! They identified five core principles of participatory learning:

1. Participants have many chances to exercise creativity through diverse media, tools, and practices.
2. Participants adopt an ethos of co-learning, respecting each person's skills and knowledge.
3. Participants experience heightened motivation and engagement through meaningful play.

4. Activities that feel relevant to the learners' identities and interests.
5. An integrated learning system – or learning ecosystem – honours rich connections between home, school, community, and world. (Jenkins, 2012, p. 1)

These five core principles of participatory learning align with the maker mindset and can be reflected clearly in makerspace projects. For example, makerspaces offer a form of participatory learning where students work together to explore their own interests in a playful environment. After introducing these two theories, which serve as the foundation for the makerspace learning environment, the next section will describe the various types of makerspaces.

2.3 Makerspace Types

Making in the 21st-century has been revolutionised by the advent of do-it-yourself activities including robotics, electronics, and digital manufacturing (Peppler & Bender, 2013). Makers began to create physical spaces known as makerspaces or fab labs in informal and formal learning contexts, such as libraries, museums, and K–12 classrooms as the maker movement grew (Lacy, 2016). Moorefield-Lang (2015) noted variations in makerspaces in terms of tools and technology. To summarise, one of the maker movement's effects on formal education (K–12 schools) is the emergence of "school makerspaces".

Loertscher et al. (2013) defined a makerspace as 'a place to reinvent old ideas with new conceptual frameworks, utilise advancements in thinking and doing, and investigate and construct a hybrid of fine arts, sciences, crafts, industrial technologies, foods, inventions, textiles, hobbies, service learning, digital media, upcycling, STEM/ STEAM, and DIY (do it yourself) and DIT (do it together) concepts' (p. 1). According to Koul et al. (2021), a successful school makerspace 'is grounded in a clear vision of purpose and pedagogy, develops the capacity of the participants (students and teachers), encourages exploration and play, and provides an openness to risk-taking and failure' (p. 16). These definitions describe making as a valuable practice for producing creative work in one place and exploring ideas. Dougherty (2012) likened makerspaces to libraries, where all books and materials are available to all users. Further, he remarked that makerspaces are democratising because they break down the boundaries between school subjects like science, engineering, and art.

The author of this thesis believes that makerspaces can be simply defined as "a home of making". Makerspaces are springing up all over the world as the cost of technology, electronics, robots, and other resources falls, allowing educators to design a wide range of maker activities (Vuorikari et al., 2019). Makerspaces can take many forms: in public libraries, museums (e.g., Gahagan & Calvert, 2020), schools (e.g., Blikstein, 2013), as makerspace carts (e.g., Smith, 2017) and mobile or pop-up formats (e.g., Crum et al., 2019). Although there are different types of makerspaces, which can be virtual (Huang & Shu, 2021), physical (Tofel-Grehl et al., 2021) or both, they all have one common purpose: 'creating and making something they've never tried to do before' (Graves, 2014, p. 8). In addition to the aforementioned types, Litts (2015) identified three common elements: tools and materials that are readily accessible and visible to students as they work on their projects; maker collaboration to support one another and sufficient space to accommodate all the tools and materials. The next section will elaborate on makerspaces in the context of schools.

2.3.1 Makerspaces in K–12 Contexts

Makerspaces originated as informal spaces for innovation to foster enthusiasm for STEAM (Vongkulluksn et al., 2021). A trend of growing interest in makerspaces is found in the scholarly literature and library databases. For example, a ProQuest Dissertations and Theses Global (PQDT) search from 2022 showed that only two studies were published in 2012, but the number was in the hundreds by the close of 2022.

In its publication *Makerspaces in Schools*, European Schoolnet characterised school makerspaces as physical facilities designed for hands-on, collaborative, creative activity (Attewell, 2020). This publication identified four types of school-based makerspaces: a makerspace within a single school or educational institution; a makerspace shared by multiple schools; a makerspace integrated into a library or a standalone space; and a mobile makerspace located in a bus to visit several schools. Thus, there is no universally applicable makerspace model for schools. Furthermore, three project dimensions were noted: space, products and activities, and mentality (see Figure 2.1).

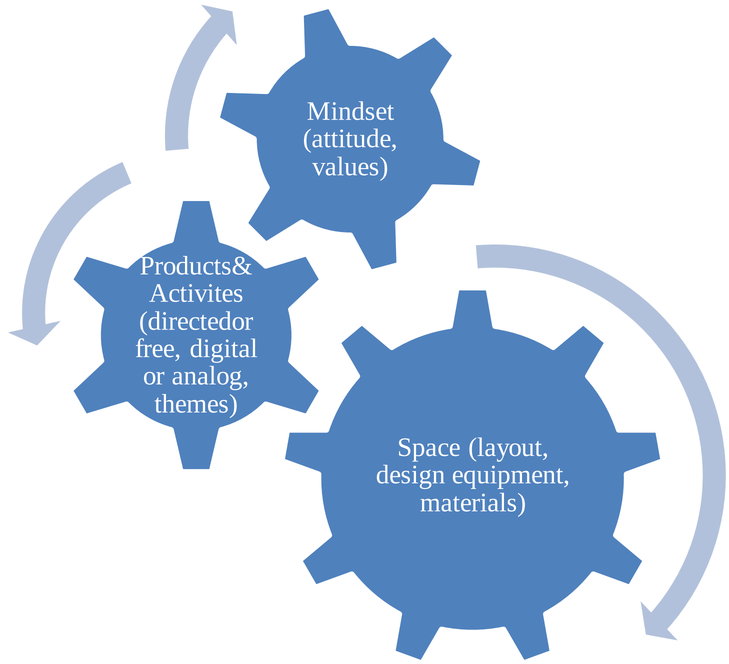

Figure 2.1 The Three Dimensions of Makerspace Projects (Attewell, 2020).

Vuorikari et al. (2019) noted that makerspaces have multiplied in the formal education sector from primary to vocational education, universities, early childhood education and after-school clubs. A school makerspace can offer a wide range of maker activities, including robotics, engineering, 3D printing, coding, filming, carpentry, cooking, electronic textiles, and anything that stimulates students' interest, critical thinking, and collaboration (Hughes, 2017). School makerspaces are places for motivating students to learn joyfully to develop many skills. The number of schools with makerspaces around the globe is difficult to determine because of the variability of formats and titles (Lindsey & DeCillis, 2017). The author of this thesis attempted to do so via the makerspace worldwide directory of the Make: Community, which has been at the heart of the maker movement since 2005 and did not receive an accurate answer.

The next subsection will discuss the justification for creating makerspaces in schools as the number of school makerspaces grows.

2.3.2 Rationale for Makerspaces in School Settings

Makerspaces are not traditional learning spaces and can be created for different reasons and purposes. For instance, some stations or zones allow learners to explore and learn through projects, guided by teachers. Additionally, makerspaces may be created to meet the ever-changing needs of students (Lacy, 2018). The emergence of makerspaces in K–12 education over the past decade is primarily attributable to the potential for positively impacting student learning, notably design-thinking, creativity, STEAM, and social skills (Cohen et al., 2017). Makerspaces are preferred in schools because of their common theme, “the maker mindset”, which allows students to fail and embrace making mistakes as a way to learn. Moreover, previous research has reported that failure is viewed differently compared to formal education (that highlights failing marks) as the maker movement celebrates failure and sees it as an opportunity for learning (Nadelson, 2021). Additionally, a teacher’s position in a maker-centred classroom differs from that of a traditional classroom in that the teacher acts as a facilitator, responder, planner, and designer.

When teachers give students the chance to become makers, they may in fact be giving them a chance to become innovators (Thomas, 2014). Three causes of student disengagement in STEAM classes were found by Washor and Mojkowski (2013) which can be mitigated by having a school makerspace. First, there is a shift away from encouraging students to think critically and creatively and towards a greater emphasis on testing. Second, schools rarely provide opportunities for real-world experiential education. Third, students are not allowed to bring their interests to class, and only classroom learning is considered valid. Further, the researchers added that hands-on learning (maker-centred learning) provides unique opportunities to bridge this gap and help students engage in STEAM classes.

Several arguments can be made for the need to implement makerspaces in schools. First, makerspaces can provide opportunities for students to apply the knowledge and theories they learn in STEAM in real life (Hughes & Dobos, 2022; Martin, 2015). Second, they help students become problem solvers while learning the skills of digital design and fabrication (Lacy, 2018). Third, they prepare students for careers in engineering and other future jobs that have not been shaped yet. Fourth, they offer career development through entrepreneurship (Hui & Gerber, 2017). Furthermore, Holm (2015) indicated that entrepreneurialism is an added maker-specific skill set that teachers encourage students to develop in the makerspace. Other makers may create their artefacts for personal use or fun (Hatch, 2014). Fifth, in the makerspace, students can learn from their failures by encouraging redesign and innovation and embracing failure as a means of learning (Sprinker, 2019). Sixth, makerspaces are closely connected to the promotion of computational thinking (Herro et al., 2021). Finally, school makerspaces can help in improving national economies (Sanders & Kingsley, 2016).

2.3.3 Benefits of School Makerspaces

As school makerspaces proliferate in numerous countries, there is a dire need to identify their learning benefits. Lindsey and DeCillis (2017) summarised the benefits of school makerspaces in four words: “make things and make students”. Additionally, in one of the early books about making in schools, *Makerspace Playbook School Edition*, Hlubinka et al. (2013) wanted to introduce the maker movement into the classroom through the following ways:

1- Creating the context that develops the maker mindset, a growth mindset that encourages us to believe that we can learn to do anything.
2- Building a new body of practice in teaching making and a corps of practitioners to follow it.
3- Designing and developing makerspaces in a variety of community contexts in order to serve a diverse group of learners who may not share the access to the same resources.
4- Identifying, developing and sharing a broad framework of projects and kits based on a wide range of tools and materials that connect to student interests in and out of school. (p.9)

The following aim can arguably be added to the list: preparing students for their future by equipping them with technical, life and technology skills. This goal will be the focus of the present thesis, which goes beyond the details that other studies have explored. Research Question 5 of this study will attempt to explore this topic in depth (see Subsection 5.3.5).

The benefits of learning in the makerspace are classified as primary and secondary outcomes. The primary outcomes are dispositional, such as life skills developing agency, building character and increasing confidence, whereas the secondary outcomes include technical skills and entrepreneurialism (Clapp et al., 2017). For Litts (2015), a makerspace requires a community element, and a classroom cannot be considered a makerspace because there is no such element to it; a community in a makerspace helps makers collaborate to build relationships and artefacts. The significance of makerspaces lies in the development of identities as makers and a sense of belonging to the makerspace’s learning communities (Dixon & Martin, 2017). The real benefits of makerspaces lie in how makers learn life skills and foster a “maker mindset” (Dougherty, 2013).

The next section will discuss learning in school makerspaces after outlining the justifications for and advantages of makerspaces in schools.

2.4 Learning in Makerspaces

The Chinese proverb "I hear, and I forget, I see, and I believe, I do, and I understand" references learning when the "do" and "understand" words are written together, creating the primary distinction between traditional education and maker-centred learning. Educators claim that school makerspaces can be a solution to find new ways to deepen learning. This aligns with an Indian research initiative that listed makerspaces and design thinking as two of the top five buzzwords in education (Network, 2022). Martin (2015) highlighted a significant question about learning in making and its role in education: 'what do youth learn through making? Because interest in making as an educational activity is new, empirical evidence specifically about making is still limited' (p. 36).

Although the academic outcomes of makerspaces are largely unknown (Andria, 2019), a few studies have listed the benefits of learning in informal and formal makerspaces. For instance, Loertscher, Preddy and Derry (2013) state that learning in makerspaces can involve designing, playing, tinkering, cooperating, enquiring, mentoring, experimenting, problem-solving and inventing. The authors identified some benefits, such as improving entrepreneurial skills and transforming students from consumers into creators. Fleming (2015) supported this opinion, adding that the makerspace activities can nurture an entrepreneurial spirit. Other researchers indicated how makerspaces can help learners in business 'Makerspaces could also be places that create a conducive environment as an incubator for future social innovations and business start-ups' (Vuorikari et al., 2019, p. 8); and makerspace activities are often connected with many skills, such as critical thinking, creativity, collaborative problem-solving, digital competences, and entrepreneurship. Lacy (2016) noticed that the educational successes or learning examined in previous studies (Kafai et al., 2014) may be attributable to the context of these informal settings from which the everyday tensions of regular classes, examinations and the separation of subjects are absent.

Making provides participants with opportunities to learn and apply multidisciplinary (e.g., science, technology, engineering, mathematics, and art) knowledge while tinkering, hacking, designing, building and expressing themselves with multiple audiences both online and in-person (Barton et al., 2016). Martinez and Stager (2013) and Martin (2015) indicated that making provides many opportunities to disrupt K–12 educational practices like high-stakes testing. Further, Baker and Alexander (2018) noted that makerspace activities might increase test scores in academic courses. Vuorikari et al. (2019) identified four elements of learning in makerspaces:

1- Making as a learning space, where makerspaces are a hub of specific learning outcomes and are connected to the curriculum.
2- Making as a methodology, with maker-centred learning applied to any discipline in the school.
3- Making as a community, a group of people that meet to learn and share ideas to create things.
4- Making as a life skill, with pop-up makerspaces in malls, for instance, to help people design solutions to their personal problems, such as repairing their devices at home.

These four elements highlight how makerspaces can be utilised in education based on their type and purpose. Chapter 6 will discuss the findings based on these four elements.

The European Schoolnet's publication, *Makerspaces in Schools: Practical Guidelines for School Leaders and Teachers,* is considered a comprehensive resource for schools that want to establish makerspaces (Attewell, 2020). In this publication, teachers and principals from 15 schools across nine nations – Austria, Belgium, the Czech Republic, Ireland, Italy, Luxembourg, Portugal, Switzerland and Turkey – were interviewed to identify the learning approaches that school makerspaces enable, including constructivism, inquiry learning, collaborative learning and project-based learning.

Only schools with makerspaces were involved, and their experience with creating such spaces was explored. The main focus of the publication was on the creation and use of makerspaces in schools (Attewell, 2020). Although it is a comprehensive guide, the following limitations should be kept in mind: the students' voices are not included, and the numbers of students in most of these schools was small compared with other schools that can comprise more than 1,000 students.

This publication listed numerous benefits of the makerspaces, which were identified by the Italian Government's National Institute for Documentation, Innovation, and Educational Research (INDIRE) and confirmed by evidence from case studies. Furthermore, it highlighted the different ways that school makerspaces can benefit teaching and learning. Additionally, it is based on empirical research rather than anecdotal evidence or observation. Scholars have used different terms to describe learning in school makerspaces, such as educative making (Blikstein & Worsley, 2016), critical making (Hughes, 2017), makeology (Peppler et al., 2016) or maker-centred learning (Clapp et al., 2017). The next subsection will describe learning in makerspaces or maker-centred learning.

2.4.1 Maker-Centred Learning

In the prologue to *Maker-Centred Learning*, Ron Berger stated that students in his school did not focus on learning to pass but rather made 'great things' (Clapp et al., 2017). He added that parents were proud of their children as they developed a strong work ethic, problem-solving skills, and high standards for quality. In addition to building the same academic skills as in other schools, his students did something with a deep purpose and passion for implementing what they had learnt and connecting it with their community. For example, they created road signs for the public in their small village. In this way, makerspaces can help educators add a practical dimension to technology education to make a connection between the abstract (school-based subjects) and the concrete (real-life needs).

The Agency by Design (AbD) research team discovered that 'while making is not new in education, maker-centred learning created a new kind of hands-on pedagogy' (Clapp et al., 2017, p. 4). Furthermore, maker-centred learning is student-centred learning, as underlined by Nadelson (2021): 'what makes the spaces particularly unique is the nearly obligatory focus on student-centred learning' (p. 105). When introducing makerspaces into schools, teachers may raise several questions: what is the potential of bringing makerspaces into schools? What might students learn from them? How can school makerspaces help students be well-prepared for their future jobs? As a makerspace coordinator, I have sought to explore these questions in the present study.

2.4.1.1 Maker-Centred Learning Components

A maker is a person who makes something with his or her hands or with the help of technology. He or she is a part of the maker community and shares its practices, norms, and responsibilities. Making can encompass different skills and it can occur in different places, such as classrooms, libraries, after-school programmes, school makerspaces or university makerspaces. Three constellations have been used by the AbD research team to define maker-centred learning:

1: The constellation of community characteristics: collaboration, distributed learning and teaching, drivers, skills and expertise, and an expectation to share information and ideas.

2: The constellation of the process: curiosity-driven, rapid prototyping, problem-solving and flexibility.

3: The constellation of the environment: open spaces, accessible spaces and tool and media spaces. (Clapp et al., 2017)

The three constellations mentioned above accurately describe learning in makerspaces as they include three elements: people (the community constellation), teaching or learning (the process constellation), and tools or machines (the environmental constellation). Interestingly, the process constellation emphasises the importance of the skills learnt rather than the final artefact. The three constellations are more thorough than the three elements (tools, people, and mindset) spotlighted by other scholars (Rosa et al., 2017), as mentioned previously (see Section 2.2). The next subsection discusses the previous research on school makerspaces and future jobs.

2.4.2 School Makerspaces and Future Jobs

The complex challenges of today's world, including climate change and global warming, require unique educational approaches to address the evolving demands of students. The education system must help learners apply a variety of skills while attaining broad and deep knowledge to solve the challenges of today and tomorrow. According to Toro (2019), teachers must adapt their curricula to the fast-changing demands of the 21st-century workforce. This finding is in line with Leopold et al.'s (2016) prediction that 65% of students in schools will have vocations that do not yet exist. Their study revealed that students need to demonstrate skills like creativity, critical thinking, cooperation, and communication to succeed in the future labour market. Many researchers and practitioners contend that makerspace activities can help students develop these abilities (Koole et al., 2017).

In the same vein, today's workers should possess the new, 21st-century skills that allow them to be problem solvers, innovators, and collaborators. Makerspaces can help to improve teaching and learning with hands-on, creative technological activities. Moreover, they can empower students to invent, prototype, develop heuristic thinking skills, and to make artefacts with low-cost technology tools, such as microcircuits, or very advanced technology tools, such as 3D printers and computer numerical control (CNC) routers (Cross, 2017). A makerspace offers students the opportunity to perceive themselves as scientists or mathematicians and develop their heuristic thinking skills to prepare them for the future (Tate, 2012). As there is a connection between makerspace projects and the actual world, they also provide vocational prospects that are deemed essential for students nowadays. The hands-on experiences that teachers are expected to foster in makerspaces can help students develop skills that make them future-ready.

In response to changes in the workplace, students should be given the opportunity to develop skills for success in new types of work by learning the new language of work (Cazden et al., 1996). When students work together to build things, they can develop soft skills or future-ready skills (Welbourn, 2019) that they will need for their future jobs, regardless of the type of career they choose (Bolkan, 2018). Furthermore, Bowler and Champagne (2016) indicated that makerspaces can introduce students to technical fields and entrepreneurial thought whilst also producing innovative solutions and, thus, providing pathways for employment **(**Vuorikari et al., 2019). Consequently, implementing makerspaces in schools can give students the opportunity to explore various career pathways (Loertscher et al., 2013).

There are potentially interesting and unexpected benefits to learning in school makerspaces when students apply what they have learnt to solve a problem in their life. For example, in Attewell and Earl's (2020) report, the makerspace coordinator in an international school in Turkey told the story of a girl who worked on makerspace projects to participate in a robotics competition. The student explained to the makerspace coordinator that she fixed a leaking tap at her house during the summer school break without the help of a plumber by changing the seal herself. She claimed that she would not have been able to resolve this issue by herself had she not worked in the makerspace because doing so gave her the confidence to try (Attewell and Earl, 2020).

Both informal and formal educators believe in the power of the maker movement to transform STEAM education and prepare students for future careers (Martin, 2015). Farmer (2018) added that 'the maker movement appears to easily lend itself to those looking to engage in career exploration and enhance career adaptability' (p. 50). As some schools are motivated by preparing students for their future careers, the European Schoolnet's publication *Makerspaces in Schools: Practical Guidelines for School Leaders and Teachers* listed some ways this can be achieved:

- To prepare students for the pursuit of studies in areas facilitated by access to the latest technologies that are important for their future lives and employment.
- To increase the number and variety of career paths available to students.
- To direct individual students towards the best careers for them.
- To make technical education more attractive, especially for girls.
- To promote the ethical use of technology by students.
- To help students become creators rather than just consumers of technology.

(Attewell, 2020, p. 32)

This list describes some skills that are required in the 21st-century, such as the ethical use of technology which should be involved in makerspace activities. Chapter 6 will describe the findings related to how a school makerspace may help prepare students for their future jobs. Next, the emerging research on school makerspaces will be discussed.

2.5 Emerging Research on School Makerspaces

In this section, four key areas will be considered: previous studies on learning in school makerspaces, the relationship between prior research and the present study, the research gap, and the need for the study. Researchers have noted that there is minimal empirical research connecting making with learning (Litts, 2015; Bevan, 2020). Furthermore, most of the research on making in education has focused on informal learning environments (Vossoughi & Bevan, 2014), such as museum makerspaces. To date, studies of learning on making link learning to engineering (Blikstein, 2013) and media literacy, such as digital stories (Kafai et al., 2009), examine how young people perceive making (Sheridan et al., 2014) and approach it as a hub of innovation (Sung, 2018). Recent research suggested three characteristics of makerspaces: the freedom to fail, a learner-centred approach and the use of design spaces (Hansen, 2018).

In sum, most studies on making in education have focused on informal learning environments. Interest in making and school makerspaces as a learning process is new (Martin, 2015), and research on making in a K–12 setting is still in its infancy (according to Vossoughi & Bevan, 2014). Furthermore, because makerspaces in formal K–12 school settings are relatively new, researchers are still looking for ways to examine learning and appropriately assess it in school makerspaces. The next section will highlight studies of makerspaces implemented in K–12 and similar contexts, such as after-school activities. Studies conducted on public makerspaces, university makerspaces or public libraries are excluded.

2.5.1 Learning in School Makerspaces: Previous Studies

One of the first studies to incorporate making into K–12 environments involved the makerspace activity process (MAP) framework abilities (Koole et al., 2017), which demonstrates how makerspace activities—curating, relating, and creating—are interconnected through networking practices (see Figure 2.3). Although this framework is valuable for educators at all levels, from kindergarten to postsecondary, testing and tweaking the artefact, which is a fundamental step in the development process, was not included in this framework.

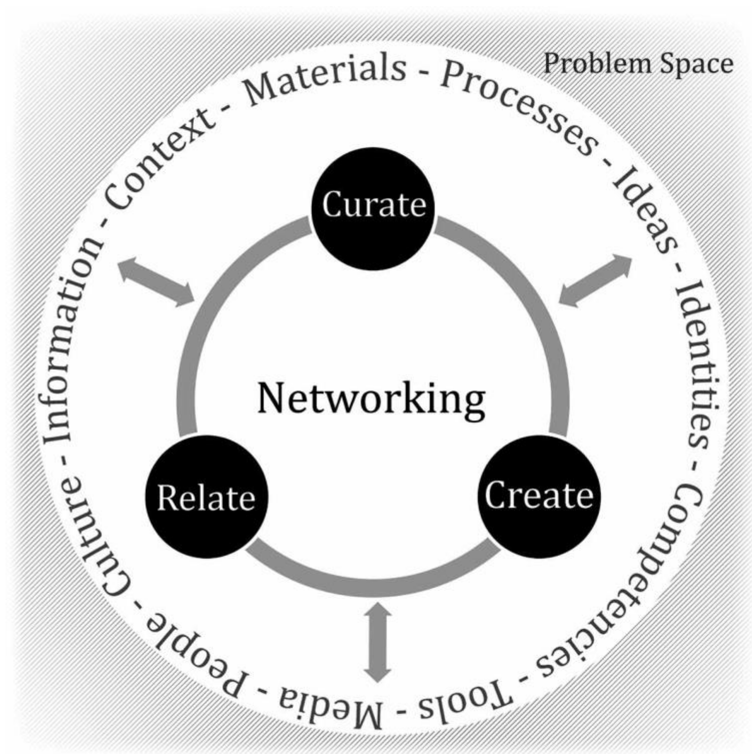

Figure 2.2 The Makerspace Activity Process (MAP) Diagram (Koole et al., 2017).

In a different study, Hansen (2018) noted that there is a paucity of research on how to educate teachers to facilitate maker activities in a way that promotes rich learning. He examined how the design and facilitation of two science activities at a Maker Faire influenced the learning opportunities for children. As the concluding assignment for their science methods course, preservice teachers collaborated in small groups to design and implement an activity aligned with the Next Generation Science Standards (NGSS). She used a case study approach to examine two distinct groups of preservice teachers. At the first station, students created slime to learn about different states of matter, while at the second station, they experimented with various materials to create models of magnetism.

The case study (Hansen, 2018) mobilised several data collection instruments, such as surveys, course observation, and interviews. Nonetheless, the researcher relied on video analysis but did not mention how she utilised the other sources of data in her study. According to a thorough video analysis of the activity design, it was shown that preservice teachers' facilitation, and indicators of children's learning, through the design and the facilitation had a significant impact on what the children could do and learn at each of the stations studied.

Compared to children who attended the slime station, children who visited the magnetism station (the second station) showed considerably more learning indicators. As the researcher noted, the two stations were examples of two pedagogical approaches: student-centred learning and teacher-centred learning and the main reason for the difference in learning between the two stations was the teaching approach at each station (Hansen, 2018). At the magnetism station, the learner-centred approach produced more observable markers of learning among children, in particular for the dimensions of creativity and self-expression. There were few indicators of learning at the slime station because of the teacher-centred approach. The most salient indicators at this station were initiative and intentionality.

Although Hansen (2018) provided further evidence that children learn more when they are given 'the opportunity to explore and question the world around them on their terms, rather than following prescribed steps from an adult, memorising facts for eventual regurgitation' (p. 160), several limitations prevent the generalisation of the study's results. First, the study only investigated the facilitation of two activities. Second, it was conducted in a school Maker Faire, which differs from a school makerspace or a class. Third, the teachers were not fully qualified teachers but preservice teachers who worked in an informal context and were still novices, learning how to develop their teaching. Thus, this study did not gather evidence from expert teachers in a formal context.

Hansen (2018) argues that his study is unique in that although based in an informal context (a Maker Faire), it connects the informal context of education to the formal one of schools. In other words, the research can be used by educators to guide preservice teachers towards methods of instruction that are effective in a formal (school-based) learning environment. This study contributes to the emergent literature investigating how maker-centred learning can enhance learning. It is one of the examples where Bevan et al.'s (2017) dimensions of learning were tested in an informal context.

In another recent study by Khadri (2022), the four-quadrant technique was adopted to create four distinct potential futures for makerspaces in K–12 classrooms (see Figure 2.3). The first key driver of change is the vertical axis, which represents the approach to learning (connected learning versus traditional learning to achieve the desired learning objectives) adopted in maker activities. The horizontal axis, which depicts the location of the practice-making activities, summarises the second important driver of change as follows: will there be physical makerspaces in schools with limited space or will they be virtual? This study identified some key drivers of change to take into account while examining the potential futures of makerspaces. Although the study opens doors for researchers to reshape school makerspaces, some questions remain. For example, the researcher referred to 32 experts involved in makerspaces in Egypt; yet, as far as the author of the thesis knows, who is from Egypt, there are a few (around three) school makerspaces in Egypt. However, the researcher may have used fab labs or other similar settings.

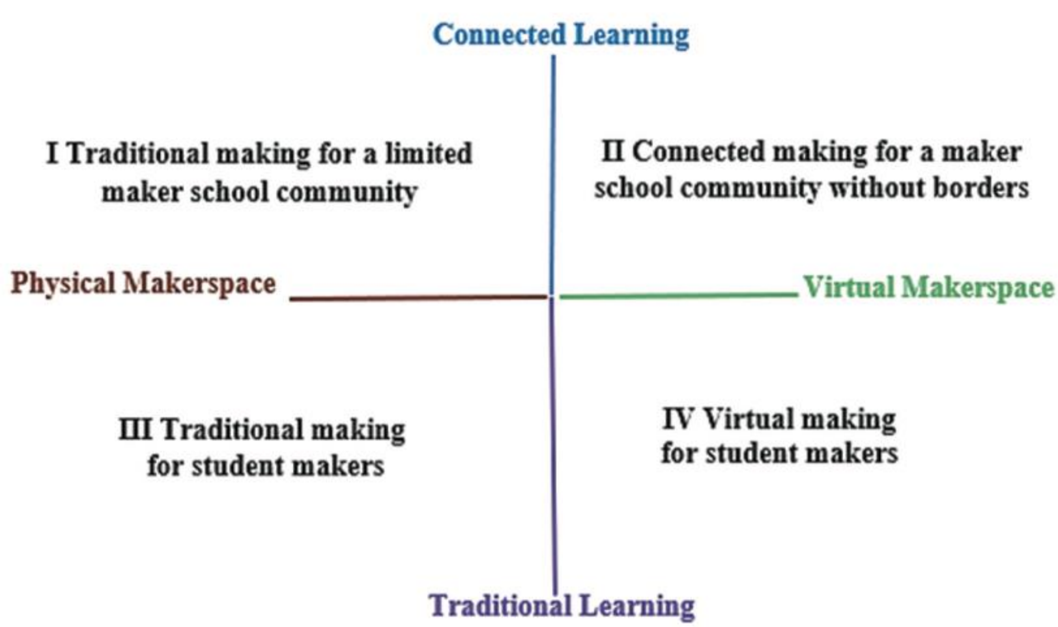

Figure 2.3 Scenario Overviews: Four Futures for Makerspaces (Khadri, 2022).

Makerspace integration into educational contexts is not without criticism (Martin, 2015). Issues with technology, a lack of time and insufficient support from colleagues are some of the obstacles teachers face when trying to incorporate makerspaces into their classrooms (Stevenson et al., 2019). Teachers and researchers from the Exploratorium Tinkering Studio and the Lighthouse Community Public Schools examined how after-school making and tinkering programmes could support learning, responding to doubts about the value of maker activities (Litts, 2015). They organised and documented weekly making and tinkering activities for students in middle school (grades 5–8). After several sessions of discussions about what students learned from these programmes, they created the TLD framework (Bevan et al., 2018). In this project, the researchers made a distinction between making and tinkering activities. While tinkering is a form of creation of open-ended models and improvisational problem-solving, making activities often entail following step-by-step instructions (Bevan et al., 2015). Hence, 'tinkerers can be inspired to pursue further opportunities to engage in design and engineering, whether in everyday classroom, or professional settings' (p. 6). While tinkerers' projects are unstructured and focused on play and inquiry, makers may use linear learning to reach specified goals. To summarise, making is a broad phrase that encompasses both structured projects and unstructured tasks undertaken for the goal of testing or enjoyment.

However, some elements of Bevan et al.'s (2017) framework may require revision. For instance, Hansen (2018) suggested that rather than creativity and self-expression, learning to express emotion should better correlate with the dimension of social and emotional involvement. Additionally, he argued that because of the activity's design, the indicator of asking questions under the dimension of problem-solving and critical thinking did not align with the data analysed in his study. He suggested that this indicator (asking questions) would be a better match for the dimension of initiative and intentionality. However, the author of this thesis disagrees because the name of the indicator refers to seeking ideas, assistance, and expertise from others, which covers more than asking a question and may lead to the first steps of critical thinking. Asking questions as an indicator was mentioned in the 2015 first draft and was modified to "seeking ideas and assistance and expertise from others" in the 2017 draft. As the researcher conducted the study in 2018 and analysed his data based on the 2017 draft, he could have used the third version rather than the first.

In a mixed-method study, Kiley-Rendon (2019) aimed to identify the outcomes of the academic makerspace by comparing two American middle school makerspaces. Her study analysed evidence from standardised tests, interviews, and students' projects. She compared the fourth-grade mathematics, English language arts, and science standardised test scores from before the students used the makerspace to the same students' eighth-grade standardised test scores in the same content areas (Kiley-Rendon, 2019). Her qualitative and quantitative data sought to compare academic achievement in science, mathematics, and English-language arts between frequent and infrequent users of middle school makerspaces. Her findings revealed that both makerspaces did not lead to any explicit academic outcomes for students. But additionally, many important skills had been mentioned by the interviewees. The author of this thesis questions the accuracy of these findings for two reasons. Kiley-Rendon (2019) pointed out that the two makerspaces are not linked to the curriculum and students visit them to work on activities and projects for fun: 'Neither space has a makerspace curriculum, nor do they want one' (p. 68). Thus, it is questionable whether the use of data from standardised tests of academic subjects is relevant. Second, this study focused more on design and description than on the academic benefits of the makerspace.

Although the study revealed the need to adopt other methods to assess students' work, such as rubrics and portfolios, the author of this thesis contests the following statement, which will be explored throughout this study:

> The essence of makerspaces is freedom of choice and experimentation, so schools should be wary of promoting graded assignments through the makerspace. It is possible to create activities that have explicit connections to academic content areas while keeping them ungraded. (Kiley-Rendon, 2019, p. 77)

From the experience of this thesis's author, the essence of makerspaces is freedom of choice and experimentation in the activities related to the curriculum. For example, students are free to choose any tools as long as they will enable them to design a solution to a problem. Thus, teachers sometimes ask students to focus on one tool, such as 3D printers, for pedagogical purposes. Other students who want to try other tools can do it at home or during recess.

2.5.2 Relationship between Prior Research and the Present Study

Prior research on makerspaces can be divided into three categories. The first consists of summaries of surveys of students or teachers assessing the spaces (Litts, 2015). The second category comprises studies related to design makerspaces. The third category is case studies and anecdotal qualitative research. The existing literature on learning through making focuses more on the advantages of making than on the skills acquired. Litts (2015) encouraged educators to design learning environments intentionally and purposefully. The author further advised educators to think about the need for each tool in the makerspace and to remove tools that are irrelevant to teaching and learning. The present study explores learning in five makerspace stations to determine the value of each station in helping educators justify the use of tools and machines.

This study will not focus on tools but rather on categories of possible skills connected with the tools in each station, even though current research on making explores how to produce with specific technologies, and how to make artefacts with certain technologies (Litts, 2015). Some previous studies have identified the skills learnt at school makerspaces and described possible learning opportunities (Mounde, 2020). Nonetheless, further research remains necessary to completely understand and detail how a standalone school makerspace can help equip students with possible necessary skills for their future.

2.5.3 Research Gap

As makerspaces have emerged as spaces that are stated to foster curiosity, inventiveness, and hands-on learning experiences (Hughes, 2017), integrating them into the school curriculum is a topic of growing interest in educational settings in order to enhance teaching and learning. Research has highlighted the need to bridge any existing disconnections and tensions between the traditional curriculum and the innovative environment of school makerspaces (Walan & Gericke, 2022). By doing so, valuable opportunities can arise for students to engage in project-based learning, creative problem-solving, and the application of knowledge in real-world contexts (Dougherty, 2012). To achieve a meaningful integration, educators need to consider the vision of incorporating makerspaces within the curriculum rather than deepening the gap between makerspaces and the curriculum (Halverson & Sheridan, 2014). Moreover, this form of alignment may help in cultivating essential skills and competencies that are vital for students to thrive in an ever-evolving future. Therefore, this study aims to contribute to the alignment between the curriculum and school makerspaces, providing insights that can inform educational practices and enrich students’ learning experiences.

Although it has been suggested by educational scholars that the maker movement might reshape education, some researchers (Halverson & Peppler, 2018) indicated that in formal education, such as in schools, the maker approach has proved challenging to design and apply. To integrate it with learning and teaching, learning in making must be closely examined (Halverson & Sheridan, 2014). Additionally, most schools have only recently started using makerspaces, and there is a dearth of official studies on the subject (Otieno, 2017). With minimal empirical research to support this student-driven learning, some would argue that it is a “fad” in education (Cuddihy, 2020). Makerspaces have been the subject of several articles and reviews about how they can be used, have been developed and operate, with less emphasis on making as a method of learning.

While there are potential benefits to learning through making, research and empirical evidence are lacking (Otieno, 2017), as well as an understanding of how making can be conceived to impact students’ learning. In their paper, Petrich et al. (2013) reported that after observing tinkering activities, people wondered whether this constituted learning. To address this topic, policymakers and practitioners have called for further research. Although the construction of makerspaces is still in its infancy in a number of developing and developed nations (Calvo, 2017), a small number of studies have been conducted in formal education settings, primarily in higher education, middle school (Winters et al., 2021) or elementary learning environments (Bull et al., 2017). The only study carried out in a high school examined a ‘fab lab’ (Lacy, 2016).

Since makerspaces are a recent phenomenon, minimal research and empirical data have been accumulated to demonstrate their effectiveness and their contributions to learning in early models of school makerspaces. These early makerspaces are typically small or part of a library, and they primarily contain digital technological tools, such as 3D printers. These studies have regarded the makerspace as one unit without examining how each tool or station fosters learning.

In contrast, this thesis will explore learning through another model of makerspace, an innovative model that combines digital technology with hand tools like woodworking. This is a large makerspace divided into the following areas: three film-making stations, a 3D printing station, two robotics and coding stations, a woodworking station, a laser-cutting station, two arts and crafts stations, and more. This model is in line with the literature arguing that makerspaces should not be designed exclusively for STEAM projects but for other types of projects as well (Voussoughi & Bevan, 2014).

In short, the maker movement and the integration of makerspaces into schools are relatively new. The limitations of previous studies imply that qualitative and quantitative data may not be representative of an entire population. In addition, most of the previous studies on makerspaces have been conducted over relatively short periods (a few hours to a few weeks). Short periods like these are not sufficient to gain a deeper understanding of makerspaces in schools and gain insightful knowledge about the skills learnt. Moreover, little research has incorporated both students' and teachers' voices. Consequently, it is essential to perform studies on long-term projects. The present research will look into the skills learnt in a school makerspace over one semester and include both students' and teachers' voices. Previous research indicated that 'the makerspaces help individuals identify problems, build models, learn, and apply skills, revise ideas, and share new knowledge with others' (Sheridan et al., 2014, p. 505). Furthermore, studies have revealed a lot of promise for making as a learning process in STEAM education, although they have taken place outside of K–12 classroom settings, in out-of-school makerspaces and museum contexts (Vossoughi & Bevan, 2014). Litts's (2015) study, the first attempt to understand learning in makerspaces, identified three design stances (aesthetic, functional, and pragmatic) that can help teachers understand the types of learning that occur in makerspaces and how to measure it. However, certain concerns have been raised about the use of makerspaces in educational contexts (Martin, 2015). Some researchers have argued that schools may limit the creativity that makerspaces or the maker movement aims to inspire students with a passion for innovating (Halverson & Sheridan, 2014). Based on a review of the literature, McLean and Rowsell (2020) identified six issues that arise when creating is implemented in K–12 classrooms: availability, infrastructure, standardisation, failure, cooperation, and operation. Other researchers argued that the nature of traditional schooling may generate challenges in integrating making pedagogies into classrooms (Hira et al., 2014).

This study will explore learning and indicators of learning at each station to determine which skills students develop. Some researchers have regarded woodworking as a traditional workshop, comparing it with other makerspace stations (Lacy, 2016; Blikstein, 2013). However, a CNC station, which contains woodworking is one of the main stations in the makerspace in this study. Aside from 3D printing stations, which have been explored in many studies (Schnedeker, 2015; Kostakis et al., 2015) but not within a makerspace, the laser-cutting station and other types of stations have not been examined separately in any previous study that the author of this thesis has reviewed. To address this gap in the literature, a mixed-methods study is conducted that differs from past research in the following ways:

- It focuses on an innovative model of a school makerspace with five different stations that are used in different projects and explored to reveal learning indicators for each station.

- It examines learning with tools that have not been studied in the literature, such as the laser cutter.
- It gathers and analyses evidence from both teachers and students.
- It uses different data collection methods, such as reflective journals, which have not been employed in previous makerspace studies.
- It looks at learning indicators and skills in detail based on five project outcomes at each station.
- It investigates how school makerspaces help prepare students for their future jobs through long-term projects.

2.6 Summary of the Literature

This literature review drew on studies that have examined learning in school makerspaces. Prior research has indicated that school makerspaces are still in their infancy, and existing studies focus on how to design these spaces and the types of tools and resources needed. While some research has been conducted on other types of makerspaces, little work exploring learning in school makerspaces has been produced. The gap in terms of learning and types of career skills fostered in school makerspaces should be examined.

As stated previously, the purpose of this literature review was to lay the groundwork for the present study by addressing the following question**:** what educational benefits and indicators of learning are identifiable among students who use the different stations in the makerspace, and how does this help prepare them for their future jobs? This study will contribute to filling this gap by exploring how the school makerspace intersects with learning and helps students prepare for their future. The next chapter will focus on the conceptual frameworks that guided this study.

Chapter 3: Conceptual Frameworks

3.1 Overview

This chapter focuses on the five conceptual frameworks that underpin the present study. It includes a description of each conceptual framework and the reasons for using them. This chapter also provides information on the frameworks' history and relevant previous studies that used them. Aside from constructionism, which undergirds the entire study, these frameworks informed the design of the surveys and the research questions, as well as shaped the analysis.

According to Yin (2009), case studies benefit from the building of a conceptual framework before the research to define appropriate cases and guide data collection and analysis**.** Similarly, other researchers have highlighted the importance of theories and conceptual frameworks in case study research: 'Case study researchers should be aware of existing theories and conceptual frameworks as they frame their research questions and design' (Hancock et al., 2021, p. 36). Given that a case study approach was employed for this research, as detailed in Chapter 4, several educational theories and concepts can serve as lenses to understand the educational potential of makerspaces. In line with this approach, the data collection and analysis were informed by five conceptual frameworks, which provide different lenses through which to gather and view evidence to address the research questions and guide the discussion of the skills that students learn in the makerspace. The next sections will detail these five conceptual frameworks.

3.2 Twenty-First Century Learning Framework

With the rise of new advanced information and communications technologies, 21st-century skills appeared to fulfil the implied, distinct needs of this period. Consequently, educators should find ways to assess 21st-century skills, which involves using additional assessment methods other than traditional ones. Some frameworks, such as the Partnership for 21st-Century Skills (Partnership for 21st-Century Learning, 2019) and the one proposed by the Organisation for Economic Cooperation and Development (2005), provide ways to help educators assess 21st-century skills (Gilbert, 2016). The present study used the Partnership for 21st-Century Skills framework because it describes each skill more thoroughly, includes more detailed indicators for identifying each skill and is more widely adopted by schools and researchers than the other framework**.** In their book *21st-Century Skills: Learning for Life in Our Times*, Trilling and Fadel (2009) stated that 'this P21 design has become the guidepost for the 21st-century skills movement, and a road map to 21st-century learning' (p. 208). Additionally, it lays out a set of skills considered essential to live and work in the 21st-century.

Competencies such as innovation, digital literacy and problem-solving are examples of 21st-century skills that students need to succeed in the modern interconnected world (Partnership for 21st-Century Learning, 2019). These skills are referred to as "transversal competencies" by UNESCO (Koul et al., 2021). The two major components of the P21 framework are student outcomes and support systems. Student outcomes are classified into four categories: core subjects and 21st-century themes, learning and innovation skills (creativity, communication, collaboration, and critical thinking, or the four Cs), information media and technology, and life and career skills (see Figure 3.1). Support systems are areas controlled by teachers and administrators that can impact the success of 21st-century students and comprise four elements: standards and assessment, curriculum and instruction, professional development and learning environments**.** The Framework for 21st-Century Learning influences teaching and learning by defining clear 21st-century skills. This framework was selected because it focuses on student readiness for life and the workplace and includes clear indicators describing each skill.

Battelle for Kids (BFK) is a national non-profit organisation in the United States dedicated to providing students with a high-quality 21st-century education that will prepare them for success now and in the future (Partnership for 21st-Century Learning, 2019). The creator of the 21st-Century Framework (who cooperated with business leaders, education leaders and policymakers) left the P21 to join the BFK in 2018. BFK describes 21st-century learning as follows:

> Deeper learning equips students with not only rigorous academic content but also the ability to transfer their knowledge while using essential skills and mindsets in new, even unexpected, situations. 21st-century learning experiences empower students to be lifelong learners and contributors in this uncertain, ever-changing world. (Partnership for 21st-Century Learning, 2019, p. 11)

Although all components and skills in the framework are interconnected and important for effective learning and teaching in the 21st-Century, the author of this thesis limited the scope of the present study to outcomes related to learning and innovation skills, as well as life and career skills. As in Negal's (2018) study, which identified creativity, critical thinking, problem-solving skills, and collaboration as four primary benefits of school makerspaces, the next subsection will elaborate on each skill.

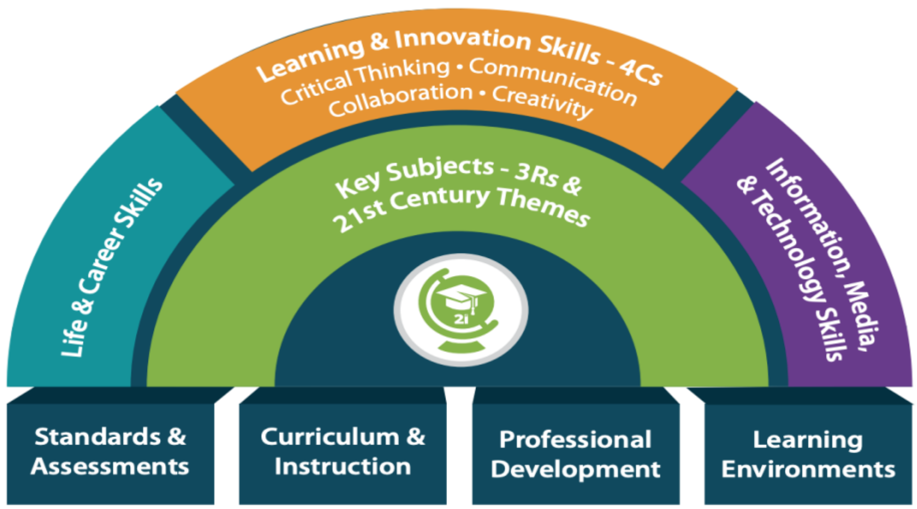

Figure 3.1 Partnership for 21st-Century Learning Framework, reprinted from (Partnership for 21st-Century Learning, 2019) with permission.

3.2.1 Learning and Innovation Skills

The current education system has been described as designed for a society and people that do not exist anymore (Krishnan et al., 2020). Students can achieve success in the workplace and in life in the modern world if they acquire 21st-century skills in conjunction with core knowledge and with the help of support systems, such as standards and assessment, curriculum and instruction, professional development and learning environments (Gilbert, 2016). Learning to think critically, creatively, collaboratively, and communicatively is emphasised in the Framework for 21st-Century Learning as necessary for success in the workplace and in life. While students learn content, they also need to acquire the skills to maintain learning and implement what they learn in real life. It has been argued that the 4 Cs, like many other skills, can be improved through practice over time during students' projects in makerspaces. As this framework contains many skills, in one study (Starr, 2011), a group of leaders from all types of markets were interviewed to identify the most important skills for K–12 schools and today's global society. During this process of refinement, 18 skills were narrowed down to four specific 21st-century competency skills (the 4 Cs). The National Education Association (n.d.) also argued that the 4 Cs were the most important.

3.2.1.1 Creativity

The concept of creativity focuses on learners' abilities to come up with innovative ideas that may enhance their learning processes and personal development in the future (Partnership for 21st-Century Skills, 2009). Because of the need for new services in the market and unique solutions for problems, creativity and innovation score high on the list of 21st-century skills. Sir Kenneth Robinson, a creativity leader, explained that traditional education is more focused on memorisation, basic skills, and test-taking and less on creativity and innovation; in this context, mistakes and failures can be a method to spark students' interest in innovating (Azzam, 2009). Makerspaces foster creativity and invention by providing a venue for individuals to gather and exchange a variety of ideas, as well as trial and error (Hughes, 2017).

Today's labour market does not depend on routines but on skills for communicating with different people from different cultural backgrounds. The National Education Association report remarked that 'creativity and innovation are key drivers in the global economy' (National Education Association, n.d., p. 25). Similarly, if students graduate from a school with no awareness of the importance of innovation, they are not ready for the current workforce in the new global economy. Furthermore, innovation and creativity are connected with other skills like critical thinking, as critical thinkers seek to design innovative and creative solutions (National Education Association, n.d.).

3.2.1.2 Critical Thinking

The ability to think critically is defined as the capacity to analyse and assess one's surroundings and experiences objectively (World Health Organisation, 1994). Learners need to be able to effectively defend their judgements and actions via a critical examination of themselves and their resources, which is why critical thinking is tied to problem-solving abilities. According to the National Education Association report (n.d.), critical thinking can contribute to career success because it enables students to develop other skills, such as 'a higher level of concentration, deeper analytic abilities, and improved thought processing' (p. 9). In the same vein, Cox (2018) asserted that critical thinking is a skill that students will need in many fields after formal education. For example, in business, critical thinking is required to better serve customers and develop new products. Additionally, critical thinking is connected with collaboration because solving a problem sometimes involves working in a team. With the goal of engaging learners in creative, higher-order problem solving through hands-on design, construction, and iteration, makerspaces offer opportunity for various kinds of critical thinking and problem-solving skills (Blackley et al., 2017).

3.2.1.3 Collaboration

Collaboration is defined by the Partnership for 21st-Century Skills as the ability to cooperate effectively and compromise responsibly in different teams to accomplish a common goal. Collaboration abilities are appreciated by businesses and correlated with greater compensation in the current labour market. To help students remain competitive in the modern workforce, educators should not attempt to teach collaborative skills directly; instead, they should discover methods and resources to assist students in developing these skills (Partnership for 21st-Century Learning, 2019). Whereas people often worked individually in the past, much successful work is now done in teams, which sometimes work collaboratively in different countries. Globalisation and the rise of technology have increased the need for collaboration. As an illustration, Wikipedia is a free online encyclopaedia built and revised by volunteers from all over the world to enable universal participation and the sharing of knowledge. Additionally, Google Suite for Education is a free virtual learning environment to help students and teachers collaborate on documents. Teachers can assign multiple students to a collaborative group to allow them to access the same document.

3.2.1.4 Communication

In school makerspaces, project-based learning is one of the teaching strategies that can assist students in building communication skills (Kovalyova et al., 2016). Communication is the ability to express oneself verbally and nonverbally in ways that are culturally and situationally suitable (World Health Organisation, 1994). Students must communicate clearly by articulating ideas and thoughts through verbal and nonverbal instruments of communication (Partnership for 21st-Century Skills, 2019). According to Van Roekel (2014), communication is the ability to encourage and convince people through persuasive discourse. Communication, one of the 4 Cs, which is also included in the P21's information, media, and technology skills, can be acquired using a range of face-to-face and online techniques.

3.2.2 Life and Career Skills

Life skills, career skills, and transversal skills are distinct yet interconnected domains that are crucial for students' learning and development. Life skills encompass competencies enabling effective navigation and adaptation to diverse life situations. They include problem-solving, decision-making, communication, interpersonal relationships, and self-management (World Health Organisation, 1994). In contrast, career skills specifically focus on competencies necessary for job success, often encompassing technical expertise, industry knowledge, and specialised abilities (National Association of Colleges and Employers, n.d.). Transversal skills, also known as transferable or soft skills, possess applicability across contexts and include critical thinking, creativity, collaboration, adaptability, and leadership (European Commission, 2008). While life skills emphasise personal development, career skills focus on specific career requirements, and transversal skills serve as broader competencies applicable across disciplines.

Effective education is no longer about high marks but is rather a system that prepares students for success in careers and citizenship in the 21st-century (according to Johnson, 2009). The World Health Organisation (1994) defined life skills as ‘the abilities for adaptive and positive behaviour that enable individuals to deal effectively with the demands and challenges of everyday life’ (p. 5); they identified six reasons why schools are appropriate places for the introduction of life skills education: ‘the role of schools in the socialisation of young people; access to children and adolescents on a large scale; economic efficiencies; experienced teachers already in place; high credibility with parents and community members; possibilities for short- and long-term evaluation’ (p. 10). Consequently, life skills should be integrated into schools deliberately, strategically, and broadly (Gilbert, 2016). The Partnership for 21st-Century Skills framework consists of five life and career skills: adaptability and flexibility, initiative and self-direction, social and cross-cultural interaction, productivity and accountability, and leadership and responsibility, which will be discussed in the following subsections.

3.2.2.1 Flexibility and Adaptability

Due to the rapid development of technological tools, educators need to adapt to the new jobs that may emerge. Flexibility and adaptability are now essential skills for students to prepare for learning, work, and citizenship in the 21st-century (Partnership for 21st-Century Skills, 2019). The Partnership for 21st-Century Skills has defined flexibility and adaptability (see Table 3.1).

Flexibility and Adaptability
1- Adapt to change Adapt to varied roles, job responsibilities, schedules, and contexts Work effectively in a climate of ambiguity and changing priorities 2- Be flexible Incorporate feedback effectively Deal positively with praise, setbacks, and criticism Understand, negotiate, and balance diverse views and beliefs to reach workable solutions, particularly in multi-cultural environments

Table 3.1 Flexibility and Adaptability (Partnership for 21st-Century Learning, 2019).

3.2.2.2 Initiative and Self-Direction

Employers are now less interested in people who depend on routine and traditional solutions. It is argued that employees should be motivated and self-directed to find innovative ways to work. The Partnership for 21st-Century Skills has defined initiative and self-direction (see Table 3.2).

Initiative and Self-Direction
1- Manage goals and time Set goals with tangible and intangible success criteria Balance tactical (short-term) and strategic (long-term) goals Utilise time and manage workload efficiently 2- Work independently Monitor, define, prioritise and complete tasks without direct oversight 3- Be self-directed learners Go beyond basic mastery of skills and/or curriculum to explore and expand one's own learning and opportunities to gain expertise Demonstrate initiative to advance skill levels towards a professional level

Table 3.2 Initiative and Self-direction (Partnership for 21st-Century Learning, 2019).

3.2.2.3 Social and Cross-Cultural Interaction

As technology connects people around the globe, a trained person who can communicate well in a diverse situation demonstrates an essential 21st-century life skill. Trilling and Fadel (2009) noted that 'students are successfully developing cross-cultural interaction skills both online and face-to-face' (p. 117) and can interact effectively with others. According to Krajcik and Shinn (2014), students achieve the best learning results through social interactions in project-based learning. The Partnership for 21st-Century Skills has defined social and cross-cultural interaction (see Table 3.3).

Social and Cross-Cultural Interaction
1- Interact effectively with others
Know when it is appropriate to listen and when to speak
Conduct themselves in a respectable, professional manner
2- Work effectively in diverse teams
Respect cultural differences and work effectively with people from a range of social and cultural backgrounds
Respond open-mindedly to different ideas and values
Leverage social and cultural differences to create new ideas

Table 3.3 Social and Cross-Cultural Interaction (Partnership for 21st-Century Learning, 2019).

3.2.2.4 Productivity and Accountability

Setting goals, prioritising work and time management are all productivity and accountability skills that support working and learning in the 21st-century (Trilling & Fadel, 2009). These skills can also help students maintain their learning. The Partnership for 21st-Century Skills has defined productivity and accountability (see Table 3.4).

Productivity and Accountability
1- Manage Projects Set and meet goals, even in the face of obstacles and competing pressures Prioritise, plan, and manage work to achieve the intended result 2- Produce Results Demonstrate additional attributes associated with producing high-quality products including the abilities to:
Productivity and Accountability
- Work positively and ethically - Manage time and projects effectively - Multi-task - Participate actively, as well as be reliable and punctual - Present oneself professionally and with proper etiquette - Collaborate and cooperate effectively with teams - Respect and appreciate team diversity - Be accountable for results

Table 3.4 Productivity and Accountability (Partnership for 21st-Century Learning, 2019).

3.2.2.5 Leadership and Responsibility

Education should help students become well-prepared by equipping them with the necessary skills that enable them to guide and lead others in real life. Additionally, teaching and learning should involve activities that enable students to be responsible for their learning and be the leaders of tomorrow. The Partnership for 21st-Century Skills has defined leadership and responsibility (see Table 3.5).

Leadership and Responsibility
1- Guide and Lead Others Use interpersonal and problem-solving skills to influence and guide others towards a goal Leverage the strengths of others to accomplish a common goal Inspire others to reach their very best via example and selflessness 2- Be Responsible Towards Others Act responsibly with the interests of the larger community in mind

Table 3.5 Leadership and Responsibility (Partnership for 21st-Century Learning, 2019).

3.2.3 P21's Framework and Previous Research

The P21 framework has been used by researchers to examine the skills developed using technology tools. Bridge's (2019) quantitative, quasi-experimental study of the use of iPads to improve 21st-century learning examined whether students learning with iPad devices showed statistically significant improvement in the 21st-century skills of communication and collaboration. Forty students in grade 8 (13 years old) from an urban public school in the Midwest of the United States made up the participant sample**.** According to his research, the 10-minute mini-lesson intervention had a statistically significant impact on the improvement of communication skills ($p = .05$) but no statistically significant impact on collaboration abilities ($p > .05$) (Bridge, 2019). The next section will detail the second framework utilised in this current study.

3.3 Tinkering Learning Dimensions Framework

Gutwill et al. (2015) conducted a study in a museum makerspace to define the type of learning taking place there. After examining audio and video recordings of 50 visitors participating in making projects, the Tinkering Learning Dimensions (TLD) framework was developed to measure initiative and intentionality, problem-solving and critical thinking, self-expression, social and emotional engagement, and conceptual understanding (Bevan et al., 2017). It provides educators with indicators and descriptions of learners' interactions for each dimension to help recognise learning in projects (see Figure 3.2).

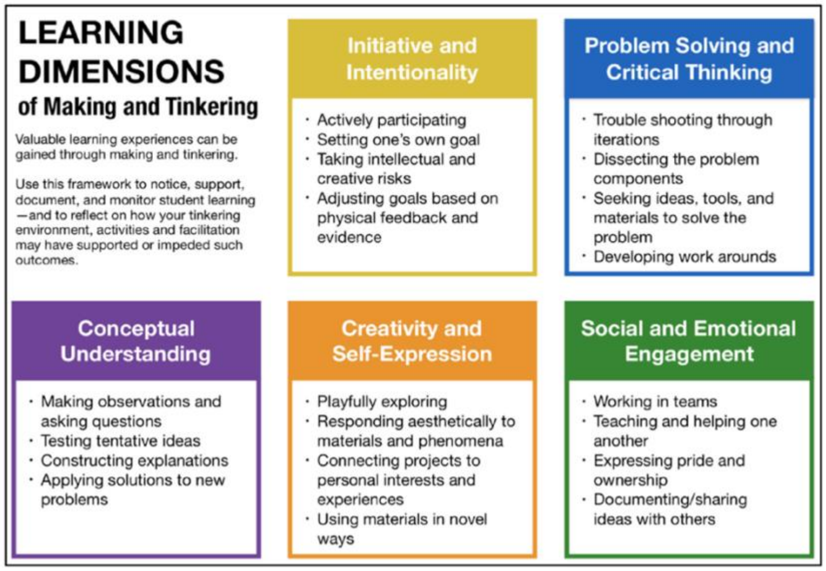

Figure 3.2 Learning Dimensions Framework (Bevan et al., 2020).

This framework is based on one of the earliest studies focusing on learning in maker and tinkering programmes that was conducted in the Exploratorium Tinkering Studio. Educators from the Exploratorium Tinkering Studio and the Lighthouse Community Charter School in Oakland carried out a study in 2015 to explore the learning happening in a maker programme. They examined how maker programmes can support learning. Their research was based on after-school activities. One of the strongest aspects of the study was that the research team was a group of researchers and teachers who worked together over three semesters (2016–2017) to implement and document a maker programme. Circuits and Electricity, Motion and Mechanisms, and Light and Shadow were the three stations that served as the foundation for their research. They gathered data through student surveys, field notes, videos, photographs, student journal entries, audio recordings, observations, and interviews with both adults and students. Because their research was grounded in two interrelated sociocultural theories of education (cultural-historical and critical pedagogy), they focused on the socialisation benefits of the maker programmes and how the learners were supported. Over the three semesters, they developed several different versions of new framework activities (Bevan et al., 2015).

In their article about developing this framework, *A Tinkering Learning Dimensions Framework v 2.0*, Bevan et al. (2017) explained the second version of the framework in detail. They described the type of learning that occurs in making activities as deep learning, in which ‘ideas and concepts are learnt in meaningful and applied contexts, and learning becomes both more resilient and transferable' (p. 1). In the present study, the most recent version of this framework (V3) was employed (see Figure 3.2). The following is a summary of the dimensions proposed in version three:

1- Initiative and intentionality

Initiative and intentionality focus on how students engage with the activity and develop their ideas or set goals for implementing their projects.

2- Problem solving and critical thinking

Students will face many problems and challenges when working on their projects, which will develop their critical thinking skills. Students need to ask for help and engage with experts or teachers to learn how they can fix their problems.

3- Conceptual understanding

To develop their ideas and goals, students must work with concepts and tools. Through design thinking and other frameworks, they can learn from iterative design to redesign and test their prototypes, which will help them develop a deeper understanding of concepts. Making activities provide a context for students to apply, develop and advance their thinking and understanding (Bevan et al., 2018).

4- Creativity and self-expression

Makerspaces and the maker movement are centred on creativity. Students will be creative makers if they develop a unique solution. Creative students can take their designs to the next level and connect them to their local community.

5- Social and emotional engagement

Working in a group can foster students' sense of belonging. Socialisation is at the heart of the makerspace and helps students build their identities as creative makers.

3.3.1 Development of the Framework

The framework's initial early iteration began with four learning dimensions – engagement, intentionality, innovation, and solidarity – but the final version comprises four reworked dimensions: engagement, initiative and intentionality, social scaffolding and developing understanding (Bevan, 2014). In the third version, the researchers focused on how maker activities can deepen students' thinking and understanding (see Figure 3.2) and develop their agency (sense of belonging, self-expression, and self-direction). Additionally, the researchers mentioned STEAM activities and the importance of the complexification of ideas in enabling learners to understand and realise their ideas.

The TLD framework, which is valued by museum professionals and backed by empirical evidence, pinpoints essential categories of learning in the tinkering studio (Bevan et al., 2015). Some aspects of this framework were highlighted by its creators. First, the dimensions do not evolve linearly or hierarchically, and many dimensions are merged as students work on their projects. Second, the triangulation of several data collection methods, such as interviews and video analysis, reveals many of the learning characteristics only over time. Third, educators should pay attention to the nature of the tinkering activities, the environment, and the pedagogy because, without these, the dimensions do not occur spontaneously (Bevan et al., 2020).

This framework can create a strong foundation for thinking about the type of learning that occurs in makerspaces and can help educators answer the question: "It looks like fun, but what are they learning?" (Vossoughi & Bevan, 2014). Additionally, it can aid practitioners in implementing and expanding the maker movement in teaching and learning. Although this framework can be useful in the design and the facilitation of maker programmes, it may also be valuable as an assessment tool to evaluate learning and the final product of students' work in school makerspaces. Like Hansen (2018) and Cuddihy (2020), the author of this thesis believes that further research is needed to fully understand and improve this framework before it can be used effectively in a broad variety of contexts.

This thesis's author also agrees with Lindsey and DeCillis (2017) that additional research is needed to establish strategies to assess students' work in school makerspaces and that evaluations of the learning occurring in school makerspaces are still in progress. By establishing fundamental dimensions of learning through tinkering, the TLD framework contributes to the research on making. However, researchers have updated and evaluated the validity of the learning dimensions to make contributions to the literature that can affect practice. Further implementation of this framework in educational makerspaces other than museum makerspaces is required to investigate and test the dimensions and indicators and, thus, enhance research and evaluation frameworks for various types of makerspaces (Ryoo et al., 2018).

The TLD was selected as a framework for this study because it can provide a baseline for identifying evidence of forms of learning. Additionally, it is the product of jointly negotiated research. Allen and Gutwill (2016) used the phrase "jointly negotiated research (NJR)" to describe studies in which academics and professionals work together in equal cooperation. JNR (Allen & Gutwill, 2016) includes four elements: discussing issues in practice that both academics and professionals care deeply about; advancing theory and practice; exploring and testing new techniques via collaborative design work; and developing the capacity to maintain change beyond the duration of the current research endeavour. The JNR nature of this study shaped its outcomes as well as the uses of these outcomes in practice (Bevan et al., 2020).

The current framework (see Figure 3.2) is a refinement of earlier drafts developed by Petrich et al. (2013) in collaboration with 28 after-school STEAM expert practitioners. Although it is a reliable framework because its efficacy in identifying learning within makerspaces has been demonstrated in previous studies (Oates, 2015), the author of this thesis believes that more revisions and updates are needed to improve it. For example, life and career skills should be added as a separate dimension. For this reason, P21 is included as a second framework to cover skills missing from the LDF. One of the significant contributions of this study is the updating of the TLD (see Subsection 6.1.1.1). The next section will discuss the third framework used in the present study.

3.4 The Makespace Quadrant

Vuorikari et al. (2019) propose four predicted scenarios for the evolution of making by the year 2034: making as a learning environment, making as a methodology, making as a community, and making as a life skill. The four scenarios were designed using a simple four-quadrant graph with two axes marked as "drivers of change" (Figure 3.3). Vuorikari et al. (2019) demonstrated that school makerspaces may correspond to the left-hand corner of Vuorikari et al.'s diagram: making as a learning space to support the school curriculum or making as a community to offer after-school activities. The maker programme category refers to making that may take place with or without a dedicated space, such as a maker cart, makerspace buses or pop-up makerspaces (Types of Makerspaces in Schools, n.d.). This study takes the four stances and considers how they can be implemented in a school makerspace (see Chapter 6). The next section will detail the fourth model utilised in this study.

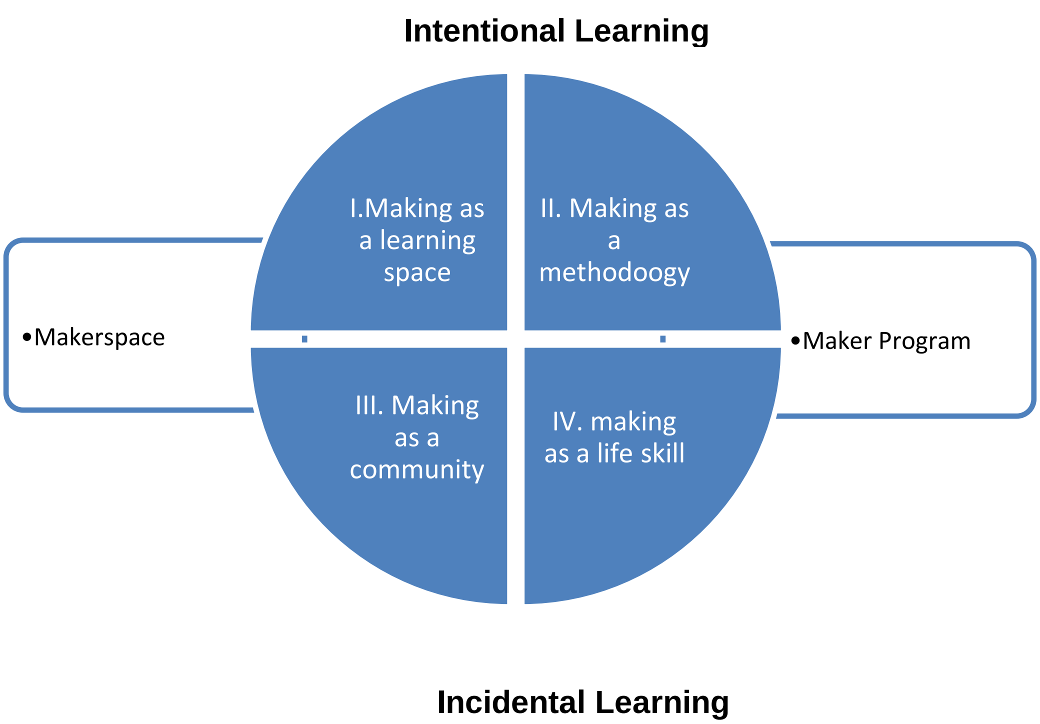

Figure 3.3 Figure 3.3 Future Scenarios for Makerspaces and Making in 2034.

3.5 Gibbs's Reflective Model

Graham Gibbs created the reflective cycle in 1988 to provide a framework for learning from experiences (Reflection Toolkit, 2020). Gibbs's reflective-cycle framework (see Figure 3.4) is a popular model for reflection that can be used to collect research data (Dye, 2011). It helped in designing a reflective journal template to guide students in reflecting on what they had learnt (see Appendix 5). Additionally, it aided in including guiding questions in the reflective journal, which could foster students' growth, particularly their knowledge, skill development, and learner agency (Vuorikari et al., 2019).

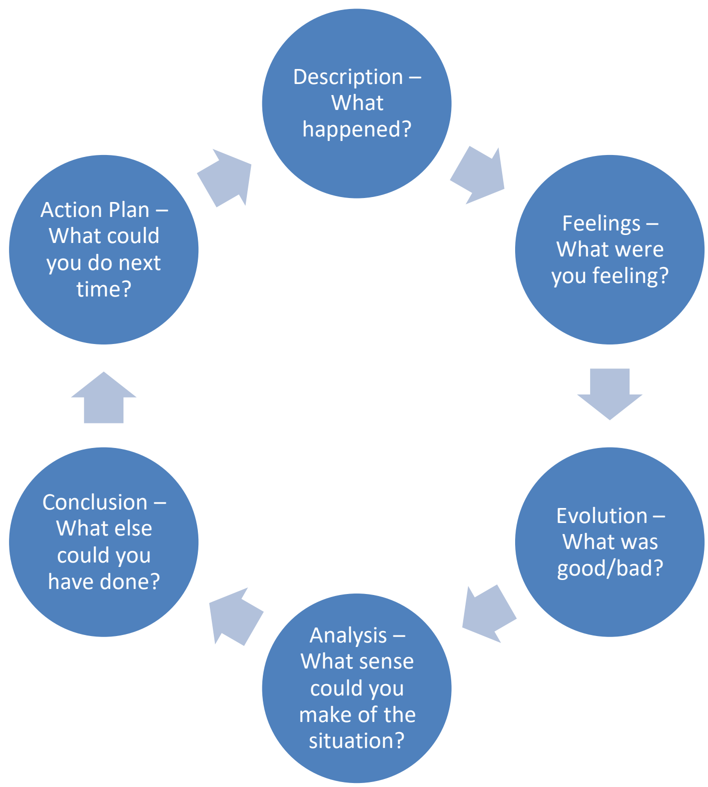

Figure 3.4 Gibbs's Reflective Cycle Model (Dye, 2011).

Gibbs's reflective cycle offers a framework for exploring experiences through its repeated cycle, allowing students to learn and plan from things that worked well or things that did not work well (Reflection Toolkit, 2020). Additionally, it can spark students' interest in innovating by taking their experience to the next level and suggesting ways to improve it. Interestingly, this model was first introduced in the book *Learning by Doing* by Graham Gibbs, which is related to the theme of the makerspace. Using this cycle to construct the reflective journals aligns with the importance of reflection in making models in school makerspaces. In the same vein, Gerstein (2019**)** argued that the reflective process is as significant as the actual making: 'Reflecting deeply on what worked and what didn't work during the doing phase—and exploring reasons why—is an integral component of this framework for maker education' (p. 74). Table 3.6 summarises the six stages of this cycle (Gibbs, 1988).

Element of Reflection	Description of the Element
Description	Students describe the project/experience in detail
Feelings	Students explore their feelings or thoughts during the project/experience
Evaluation	Students write down what worked and what did not
Analysis	Students try to extract the meaning of the project/experience
Conclusion	Students write down conclusions about what happened
Action plan	Students explore how they will act differently to improve their work next time

Table 3.6 Stages of Gibbs's Reflective Cycle Model (Gibbs, 1988).

3.6 Design Thinking

Design thinking is a problem-solving approach that has gained significant attention in school makerspaces. It is 'a human-centred methodology that democratises the design process by providing the structure and tools for every person to think and behave like a designer' (Lee, 2018, p. 24). Integrating design thinking as a framework in school makerspaces can encourage students to identify and understand real-world problems, generate creative ideas, prototype and test, and refine their models.

Employing design thinking in this study helped in designing structured projects, fostering creativity, collaboration, and critical thinking among participants, and addressing real-world challenges within the context of school makerspaces. The study embraced the core principles of design thinking, including empathising with users, defining problem statements, ideating potential solutions, prototyping iterations, and conducting rigorous testing to drive creative problem-solving within the project's context of this study.

3.7 Chapter Summary

In this chapter, the three frameworks and two models used to explore learning in school makerspaces were introduced and briefly discussed. Both the P21 and TLD frameworks call for the creation of new standards and assessments that improve student learning. The P21 focuses on preparing students for global competitiveness in the 21st-century and incorporates life skills. The TLD framework was adopted because it provides additional information about each skill that students may acquire. The makerspace quadrant model was employed to guide the discussion and frame the discussion of a new theory developed by the author. Finally, Gibbs's reflective model was utilised to design the reflective journals to guide students in writing their thoughts. In the next chapter, the methodology, research strategy and justification for the study are discussed.

Chapter 4: Research Methods and Methodology

4.1 Overview

This chapter explains the research methodology and design, covering topics like participant recruitment, population, and the study sample. To set the stage for the research, a detailed explanation of the study site and the projects that comprised the study are presented. Additionally, Chapter 4 concludes with the measures taken to provide reliability and validity, the ethical considerations that guided the study and a chapter summary.

4.2 Introduction

The problem addressed in this study is exploring and describing the type of learning that may occur in school makerspaces. Furthermore, a mixed methods case study approach was employed to describe the skills that a high school makerspace may impart. This exploratory mixed methods design was used to explore the evidence of learning within five stations in a school makerspace and how the identifiable indicators of learners' learning differed by station. To this end, the following questions guided this research:

1- How do high school teachers perceive the educational benefits of the various stations of a school makerspace?
2- How do high school students perceive the educational benefits of the various stations of a school makerspace?
3- What indicators of learning are identifiable among the students using the various stations of the makerspace?
4- How do the identifiable indicators of learners' learning vary by station?
5- How do different stations in a school makerspace contribute to the learners' acquisition of life skills that could help them develop future career skills?

4.3 Research Methodology and Design

In this section, the mixed-methods approach will be introduced, the case study will be defined, and different types of designs for case studies will be explained.

4.3.1 Mixed Methods Research

To answer the research questions and collect the research data, this study adopted a mixed-methods approach which depends on the employment of both qualitative and quantitative research techniques. The textual qualitative data were obtained from reflective journals and observational notes, while the surveys provided both quantitative and qualitative data. Consequently, this approach was selected because it best reflected the purpose and nature of this study. Additionally, the mixed methods design was employed to minimise the biases inherent in using qualitative and quantitative methods when performed alone, by cross-checking the consistency of the results using different methods, such as surveys, interviews, and documents (Patton, 2015). According to Creswell (2017), a mixed-methods approach is more powerful than either qualitative or quantitative research alone.

Peshkin (1993) stated that qualitative research is well-suited for situations in which description and interpretation are the objectives**.** According to Merriam (2009), qualitative researchers ‘are interested in understanding the meaning people have constructed, that is, how people make sense of their world and the experiences they have in the world’ (p. 31). In qualitative research, the purpose of the analysis is to first understand the participants’ perspectives and then to use this information to help address the research questions. Given that the purpose of this study was to investigate, describe, and analyse the experience and acquired skills of high school students in a makerspace, the qualitative part of this study was to code the reflective journals and observational notes.

Crucially, the quantitative portion of this study complemented the qualitative data gathering and processing. First, the quantitative tools facilitated the discovery of new themes through survey analysis. Second, through the survey results, the quantitative data collection and analysis provided statistical and descriptive information regarding 21st-century skills and career skills**.** While the qualitative portion allowed for many perspectives and insights expressed by the sample to be analysed, the quantitative section allowed for a deeper delve into the numbers and percentages of skills learnt. To conclude, the quantitative findings added to the qualitative ones and helped to create a more completed and nuanced picture of the case than would have been possible with just the qualitative interview data alone (Creswell & Clark, 2018).

4.3.2 Case Study

A case study is 'an in-depth description and analysis of a bounded system' (Merriam, 2009. p. 85). According to Yin (2018), case study research is chosen over other methods 'when (1) the main research questions are "how" or "why" questions, (2) the researchers have little or no control over behavioural events, and (3) the focus of the study is a contemporary (as opposed to entirely historical) phenomenon' (p. 32). In addition, he stated that case studies are useful when research issues need an exhaustive and "in-depth" account of a social phenomenon – in this case, "the school makerspace". Similarly, Creswell and Clark (2018) indicated that a case study is used when there is a need to develop, implement, and evaluate a programme and understand the individuals' values and beliefs**.** The types of research questions are the most important factor when choosing the right approach, as pointed out by Rowley (2002). This study is exploratory and evaluative since the research questions are how and what questions.

In a nutshell, the case study methodology is well-suited to addressing the problems of practice in real-life settings (Hancock, Algozzine & Lim, 2021; Yin, 2018). As Merriam (1985) stated, 'The case study offers a framework for investigating complex social units containing multiple variables' (p. 30). To answer the research questions, a case study looking into a school makerspace was conducted, evaluating the different projects undertaken in five stations in one semester during the COVID-19 pandemic at a private high school in Kuwait. Involving five stations allowed for a better understanding of the similarities and differences between each station. Additionally, involving teachers and students helped in building the case and setting it in the context by collecting different voices that represented the learning processes.

4.3.3 Defining the Case Study

There is no universal agreement on what a case study is, and there are significant differences in the available definitions. However, all of these definitions have the characteristic that 'a case study is an in-depth description and analysis of a bounded system' (Merriam, 2015, p. 37). Consequently, a case may involve a student, teacher, principal, programme, school, or class, individuals in a group or separately, as well as a community and activities (Merriam, 1998)**.** To define case studies more specifically, Yin (2009) identifies that there are two primary components (and their subcomponents) in a case study approach:

1. A case study is an empirical inquiry that

a. Investigates a contemporary phenomenon in depth and within its real-life context, especially when

b. The boundaries between phenomenon and context are not clearly evident.

2. The case study inquiry

a. Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result

b. Relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another result

c. Benefits from the development of theoretical propositions to guide data collection and analysis. (p.12)

As per the list above, this study investigates a contemporary phenomenon (a school makerspace), and multiple sources of evidence were gathered. Possible types of case studies will be discussed in the next subsection.

4.3.4 Types of Designs for Case Studies

Case studies can be explanatory, exploratory, or descriptive (Baxter & Jack, 2008). According to Yin (2018), the aim of an exploratory case study is to define the questions or procedures for a subsequent study. The objective of a descriptive case study is to describe a phenomenon within its context, whereas an explanatory case study focuses on cause-and-effect links to explain how the studied events transpired. This case study is exploratory, descriptive, and evaluative as it explored the types of learning happening in the makerspace and evaluated five zones in the school makerspace of the study.

Yin (2018) pointed out that certain cases may even have sub-cases inside them. A case study of a school, for instance, can include sub-cases, such as classrooms or teachers (Hancock, Algozzine & Lim, 2021). Yin (2018) proposed four types of case study design: single or multiple cases examined from a holistic perspective with single units of analysis on the one hand or from an embedded perspective with multiple units of analysis on the other (see Figure 4.1). Consequently, there are four types of designs for case studies; they are: (Type 1) single-case (holistic) designs, (Type 2) single-case (embedded) designs, (Type 3) multiple-case (holistic) designs, and (Type 4) multiple-case (embedded) designs (Yin, 2018).

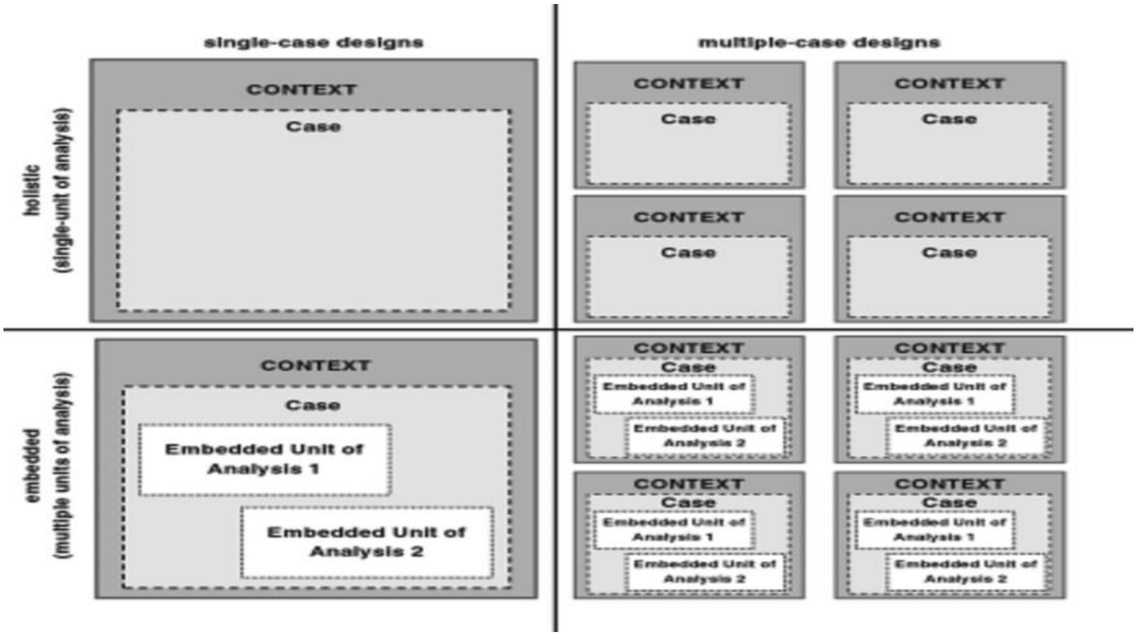

Figure 4.1 Basic Types of Designs for Case Studies (Yin, 2018).

Yin (2018) suggested four conditions for justifying the single-case design: ‘where the case represents (a) a critical test of existing theory, (b) an extreme or unusual circumstance, or (c) a common case, or where the case serves a (d) revelatory or (e) longitudinal purpose’ (p. 90). The single-case design was selected because of access to this makerspace as part of the author’s job. Secondly, because it is a brand-new school makerspace and the only school makerspace in Kuwait, it is worth conducting because descriptive information alone can be revelatory (Yin 2018). Thirdly, by working in the makerspace, the insider-researcher was able to develop some of the research propositions because of the anecdotal evidence that came about due to his personal observations and the teachers’ comments.

This case study focuses on a school makerspace with five different stations, and it was defined as an embedded single case study. Because the focus of the research was on a makerspace and because there was only one makerspace studied, the case was clearly a single case. Nonetheless, the makerspace had five distinct stations, which served as subunits in the analysis. Consequently, there were several units of analysis, and the perspective may be described as an embedded-single case design (Hagan, 1993). This study was boosted using multiple units of analysis (Dubois & Araujo, 2007), which provided significant chances for detailed analysis, boosting the insights into a single instance (Yin, 2018).

4.4 Research Rationale

As previously stated, case studies are a valid choice when the goal is to explore contemporary events, and it is a suitable approach to contribute to our 'knowledge of the individual, group, organisational, social, political, and related phenomena' (Yin, 2009, p. 4). The richly descriptive nature of a case study design was selected to provide readers with an in-depth view of the settings and projects made in a school makerspace and to frame the findings and evidence through detailed descriptions (Merriam, 2009). Additionally, this case study was useful due to offering readers a closer look at the context of the makerspace and the projects completed at the school, as well as how to weigh the findings and evidence (Merriam, 2009). A mixed-methods approach was selected to address the objectives of this study because of the complexities of such a new phenomenon means that the learning outcomes of a new "school makerspace" cannot be effectively studied through one method (Patton, 2002).

The case study format helped to describe and explore how students learn during makerspace projects. The case study's strength is its ability to deal with collecting data from a wide range of sources (Yazan, 2015), such as 'documents, artefacts, interviews, and direct observations, as well as participant-observation' (Yin, 2018, p. 43). Reflective journals, for example, allowed students' voices and maker experiences to be included. Additionally, the use of a case study allowed for a contemporary phenomenon, "a makerspace" that is difficult to separate from its context "school," to be investigated, studying it within the dynamics in the setting of "the type of learning" (Halinen & Tornroos, 2005). As such, the case study approach aligned with the intention of this study to understand the phenomenon of makerspaces as a learning environment in schools.

Although case studies are occasionally criticised for lacking impartiality and rigour when compared to other research methodologies, they are frequently employed because they offer more practical insights than other research methods (Rowley, 2002). Furthermore, quantitative studies when used alone often fail to capture the context and lived experiences of the participants (Radley & Chamberlain, 2012).

4.5 Research Paradigm

This research study embraced the pragmatic paradigm. This is well-matched with this study as it contains both a contextual interpretation and quantification. As Park (2018) indicated, 'The pragmatists focus on devising effective methods to solve problems or achieve objectives' (p. 127). Pragmatism is 'associated with mixed methods research as an overarching philosophy embraced by a large number of mixed methods scholars' (Tashakkori & Teddlie, 2003, as cited in Creswell & Clark, 2018, p. 87).

This perspective enabled a real interaction with and learning from the data as they emerged, as well as an authentic understanding of the data as they were collected. In addition, this paradigm made it possible to understand and investigate how the participants made meaning of their reality through a problem-based, objective-oriented, and practice-centred worldview (Park, Bahrudin & Han, 2020). Furthermore, it helped when selecting the instruments used for the data collection. For instance, reflective journals provided direct access to the participants' thoughts and beliefs (Cucu-Oancea, 2013, as cited in Kriukow, 2017) to enable the researcher to understand the participants' thoughts pragmatically. Pragmatism helped open the door 'to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis' (Creswell, 2009, p. 28). This case study combined the pragmatism of addressing real and current challenges "learning in the school makerspaces" while providing a method to contribute new knowledge to the field.

4.6 Population, Sample and Projects

In the following sections, the participants of the study will be described along with how they were selected. Additionally, the recruitment process and the projects of this study will be described in detail.

4.6.1 Participants

Participants were selected from different grades and subjects. By doing so, the groups reflected the overall school demographics. Purposive sampling was used to identify high school students and teachers based on purposive sampling, which made it possible to identify individuals based on certain criteria (Patton, 1980). High school students were purposively sampled for their participation in makerspace projects that were planned to take more than four weeks (long-term projects). The study recruited male and female participants aged 16 to 18 years old, involving between 60 to 70 students. Most students were Kuwaiti students. Teachers were approached, introduced to the research concept, and the data collection proposed. Consent forms were distributed to all participating educators **(**see Appendix 8**).** Seven teachers who attended the makerspace with their students were involved in the study (see Table 4.1). Teachers were chosen based on the following criteria: (a) they were currently employed as teachers at the school, and (b) they worked at or used the makerspace in projects. Life skills classes in the makerspace were encouraged because the makerspace aligns with the constructionist approach, gaining momentum through the educators' efforts to create opportunities to apply life skills within the formal education setting (Cross, 2017). All teachers and students were given pseudonyms in all evidence collected.

4.6.2 Recruitment

Subject	Role	Participant Qualifications	Makerspace Project
STEAM	Teacher	a master's degree in biochemistry	Drones
Science	Head of Department (HOD)	a master's degree in science	Smart Lamp
Science	Teacher	a master's degree in clinical laboratory sciences	Smart Lamp
Mathematics	Teacher	a master's degree in information systems	Interactive books
Mathematics	HOD	a bachelor's degree in teaching mathematics	Interactive books
Life Skills	Teacher	a master's degree in education	F1 car, Help your community. Maze
Economics	Teacher	a master's degree in education	Smart Lamp

Table 4.1 Summary of the Teacher Participants and Projects Included in the Study.

The recruitment process for the projects in this case study began during the 2019/2020 school year when COVID-19 changed the world and forced many schools to shut down and work online (Gross, Mokhtar & Gross, 2020). The author of this thesis planned, with the assistance of the teachers, all of the projects that were to be conducted in the makerspace between November 2019 and April 2020. Once written approval was received from the teachers, meetings to tell them about the purpose of this study were arranged. Ethical approval was applied for through Lancaster University. Once approval was received about one month into the 2019 spring semester, information about the study was shared with both the students and teachers.

During the 2019/2020 school year, there were a lot of projects conducted in the makerspace. The criteria for choosing the projects included in this study were:

- High school projects
- Different subjects are involved
- Projects should be in English
- Each project should be longer than four weeks

4.6.3 Students' Projects

In May 2019, the projects for this case study were designed. As the school was large, the case study was limited to the high school division only. Three teachers agreed to include their classes for the following academic year (2019–2020). Placing the research in the context of the case, this section details the projects included in this study. At the time of writing, the makerspace supported STEAM courses and other subjects in the school. Additionally, teachers could bring their students in to work on short-term or long-term projects. This study explored learning in the makerspace by examining and observing projects related to different subjects and courses (see Table 4.2).

Station	Project	Subject	Number of Students
3D printing	F1 project	Life Skills	4
	Helping the community	Life Skills	15
CNC	F1 Project	Life Skills	2
Laser Cutting	Designing a maze or a puzzle	Life Skills	15
Technology	Mathematics interactive books	Mathematics	19
Electronics	Smart Lamp	Environmental Science / Economics	12

Table 4.2 Summary of Projects in the Study.

The teachers agreed to connect the students with the makerspace during the COVID-19 period by taking the following steps:

1- In Google Classroom, the teachers created a section for the project and called it "makerspace projects" (see Figure 4.2).
2- A plan was set where the students would design their models and would then be given online access to the machines in the makerspace to enable them to print their models. The students had their models collected from the school gate.
3- The researcher attended many online lessons that were part of the makerspace projects.
4- As the school was closed during the COVID-19 period, only a small number of students were invited to the makerspace for face-to-face sessions.

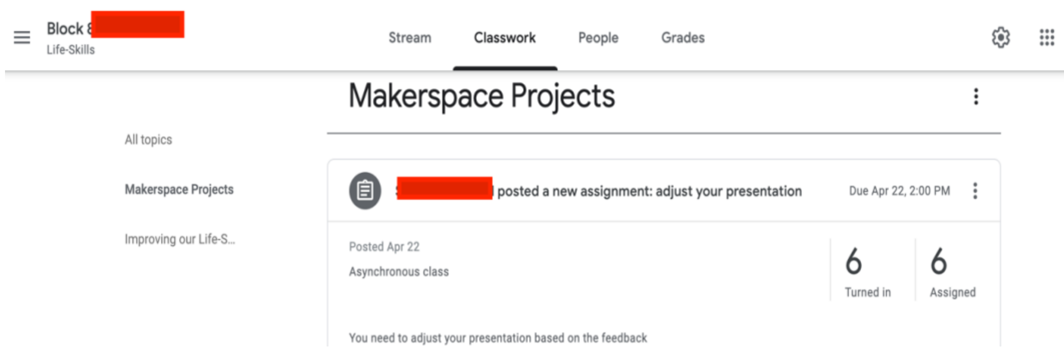

Figure 4.2 Makerspace Section in Google Classroom.

Having this mode of delivery helped to coin new makerspace activities or "blended makerspace activities", which will be discussed in Chapter 6. The main goal of these projects was to stimulate and promote the students' interest in their future careers. The following subsections outline the various projects, which have been divided into three categories: life skills projects, electronics projects, and mathematics projects.

4.6.3.1 Life Skills Projects

Four long-term projects were involved with the life skills classes. Table 4.3 summarises these projects.

Class	Projects	Duration
Class 1 (F1)	Group 1. Designing a car - CNC Group 2. Designing a car - 3D printing	November 2020-May 2021
Class 2 (Helping your community)	Helping your community-3D printing	November 2020 - May 2021
Class 3 (A maze)	Designing a maze or a puzzle- Laser cutter	November 2020 - May 2021

Table 4.3 Summary of Projects in Life Skills Courses.

4.6.3.1.1 Designing a Car Project (F1)

This project included two groups: the CNC router group and the Tinkercad group. Table 4.4 summarises the steps of the project.

Steps	Description
Introduction	Introducing design thinking
Mini challenge	Students used design thinking to design a roller coaster
Introduction	Introducing Fusion 360/Tinkercad/CNC
Making stage	Students designed the car
Peer review	Students revised each other’s work
Presentation	Students presented their work
Reflection	Students completed their reflective journal

Table 4.4 Steps of the F1 Project.

The first group included only two students working at the CNC router station. As digital manufacturing is rapidly changing and transforming the future of making, this project was aimed at enabling the students to design a racing car. The students used the Fusion 360 software to apply the digital manufacturing process. When this project was started, the original plan was to involve all students in learning Fusion 360 to enable them to design the F1 car. However, only two students were able to continue with this plan due to the problems they faced. For example, it was difficult for the students to install or learn Fusion 365. Consequently, it was decided to try an easier software called Tinkercad.

The second group with Tinkercad contained 19 students. Tinkercad Classrooms are designed to simplify the process of signing in for both students and teachers (Bell, 2019). Teachers can manage their classes with more control and visibility of student activity in this way. Students used this software to design their cars. Two students used the CNC router to mill their car. However, the Tinkercad group 3D printed their cars because Tinkercad does not have a CAM feature. Figure 4.3 shows the F1 designs in Tinkercad.

After the students finished making their models of cars, they were asked to prepare a draft of their presentation. The students were asked to peer review each other's presentations and give each other comments to enable them to improve their work. After adjusting their presentations, they were ready for their final presentation. They were given two options for the presentation: a live presentation via Zoom or a recorded presentation.

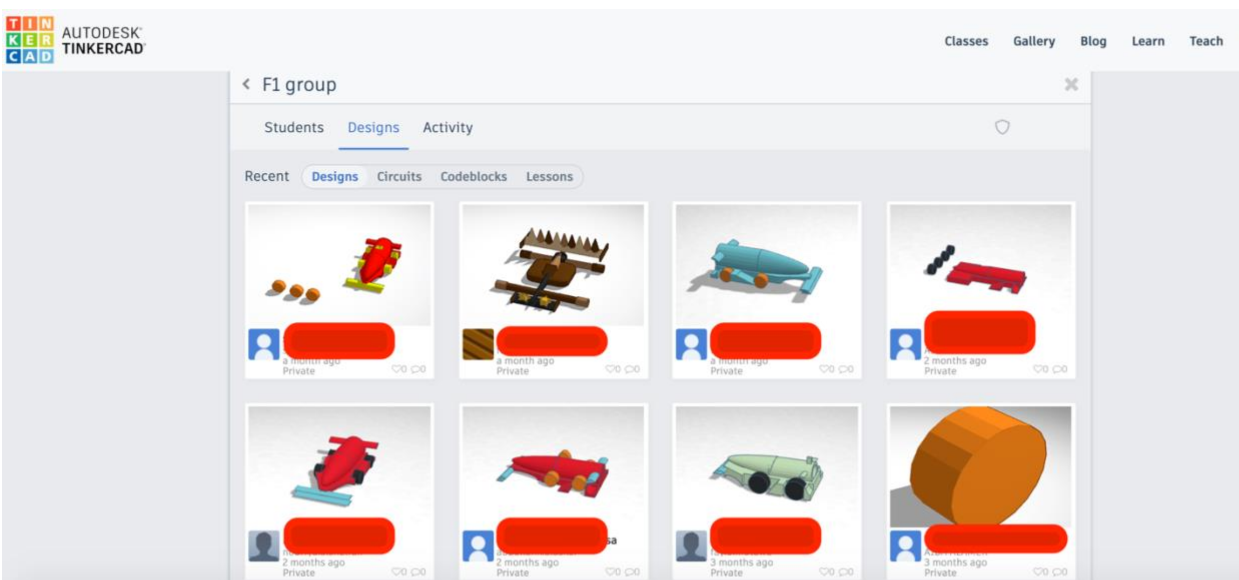

Figure 4.3 Designs in Tinkercad.

4.6.3.1.2 Helping your Community Project (3D Printing Station)

Incorporating approaches that align with the goals of helping and supporting the local community is crucial in the context of makerspaces. These approaches not only contribute to the development of students' technical skills but also nurture their sense of social responsibility and empathy towards others (Taylor et al., 2016).

Helping your community was the second project conducted with 15 life skills students. Table 4.5 summarises the steps of this project.

Steps	Description
Introduction	Introducing design thinking
Mini challenge	Students used design thinking to design a roller coaster
Making	Introducing Tinkercad
	Students designed the model
Peer review	Students revised each other's work
Presentation	Students presented their work
Reflection	Students completed their reflective journals

Table 4.5 Steps of Helping Your Community Project.

In this project, the students used Tinkercad to make a product to help their community. Tinkercad classes were created to enable them to collaborate and share their models with their teachers. The students created four models: a multifunctional tool that can carry items (grocery bags, shop bags), a mask dispenser, a telephone stand, and a door opener.

4.6.3.1.3 Designing a Maze or a Puzzle Project (Laser Cutter Station)

This project was conducted at the laser cutter station. Table 4.6 summarises the steps of the project.

Steps	Description
Introduction	Introducing design thinking
Mini challenge	Students used design thinking to design a roller coaster
Introduction	Introducing Inkscape
Making stage	Students designed/made the puzzle
Peer review	Students revised each other's work

Presentation	Students presented their work
Reflection	Students completed their reflective journals

Table 4.6 Steps of Designing a Maze Project.

The students used Inkscape to design a maze or puzzle to help their community. The puzzle can be used to help young children understand the concepts of mathematics or other concepts used for other purposes. Inkscape was selected for many reasons; it is free software, it is easy to learn, and additionally, Inkscape has vector graphic standards that enable users to change every part of the picture without changing the image quality. The project aimed to help the students create a vector of the puzzle. Vector images are made up of lines, shapes, and other graphic image components, each stored with a mathematical formula (vector) that creates the image elements (see Figure 4.4).

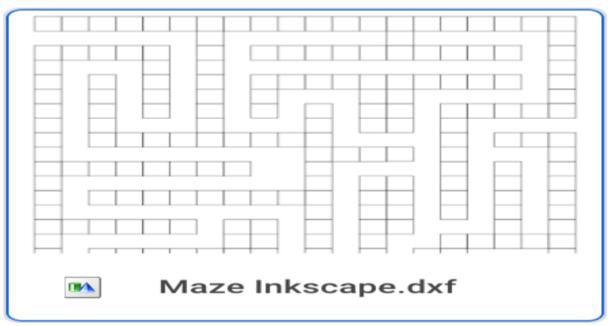

Figure 4.4 A Maze Design.

4.6.3.2 The Smart Lamp Project (Electronics Station)

The students worked together to make a smart lamp that would turn on in the dark and turn off in the light, which means that it only shines when needed. When the light-dependent resistor (LDR) detects light, the Arduino keeps the LED off. When the LDR detects less light (or darkness), the Arduino turns the LED on. Figure 4.5 shows the parts required for this project: an LED light, an Arduino board, an LDR sensor (a light sensor), jumper wires, a 9-volt battery, a breadboard, and two resistors.

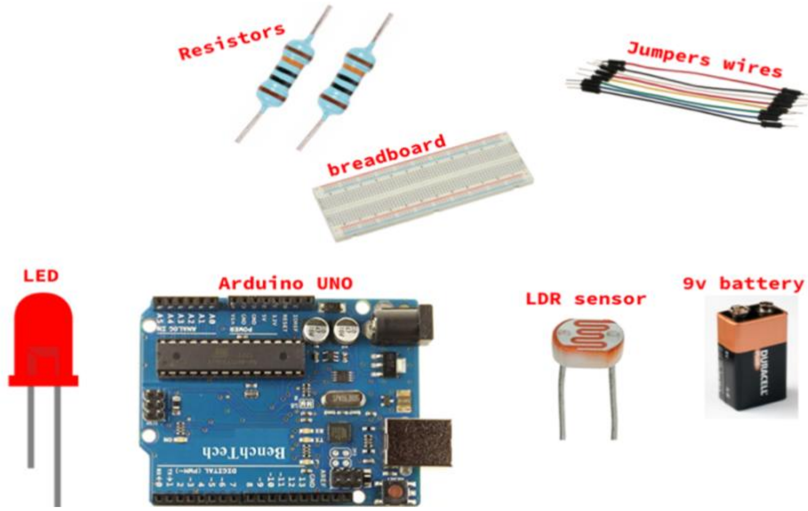

Figure 4.5 Components of the Smart Lamp.

This project was conducted at the electronics station. Table 4.7 summarises the steps involved in this project.

Steps	Description
Introducing design thinking	Design thinking was introduced to help the students implement the project
Designing the 3D cover	Students learnt how to design a cover for the lamp
Coding	Students leant how to code it with Arduino through recorded videos prepared by the teacher
Presentation	Students presented their model

Table 4.7 Steps of the Smart Lamp Project.

4.6.3.3 Mathematics Interactive Book Project (Technology Station)

It was difficult to integrate the makerspace projects within formal mathematics curricula and assessment practices. Furthermore, it was challenging to persuade the mathematics teachers to use the makerspace stations since there were so few digital resources available to support mathematics instruction, something they frequently complained about. Following a meeting with the mathematics teachers, it was decided that the makerspace activities would include designing interactive books. Interactive books can be used to enable students to summarise the content using different types of media, such as videos, drawings, audio, and images. The students used Book Creator to create interactive books for their lessons. As the students created (made) the interactive books, they became content creators rather than content consumers.

Book Creator is a bookmaking tool. It allows students of any age to create, publish, and share online books. Students can join the library "class" using a code, emails, links, or a QR code. Students can record their voices, add a video, and add an interactive map or drawing. The books can be saved in several formats, such as a PDF (see Figure 4.6). Table 4.8 summarises the steps of this project.

Step	Description
Introduction	Teachers introduced designing thinking and Book Creator
Making	Students took four classes over three weeks to design their books
Presentation	Students presented their books
Reflection	Students completed the reflective journal and careers surveys

Table 4.8 Steps of Interactive Book Creation.

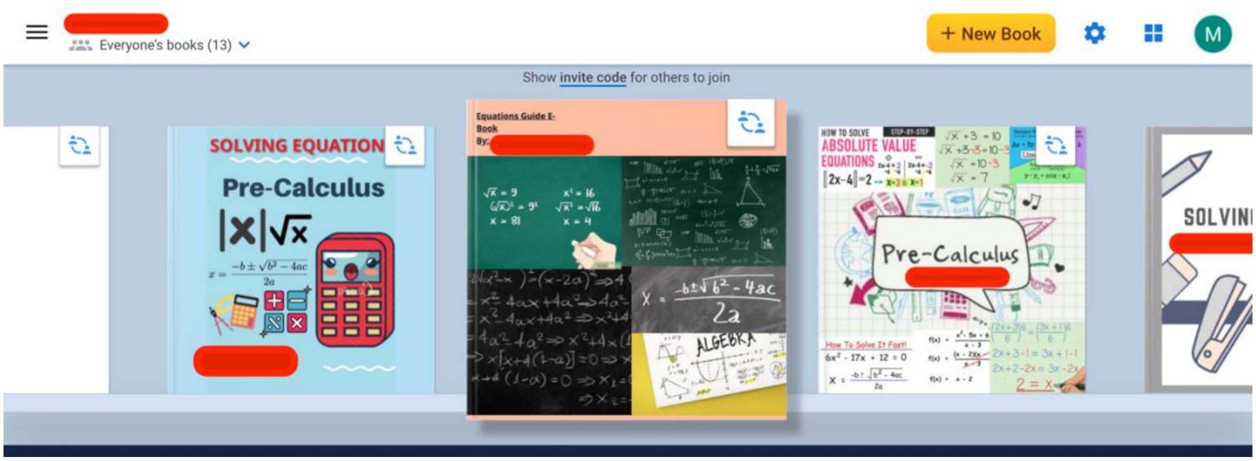

Figure 4.6 Samples of the Interactive Books.

4.7 Data Collection

To give a comprehensive, in-depth, and triangulated understanding of the type of learning in the makerspace, three instruments were employed, collected from both students and teachers. To collect data about students' experiences while working on projects in the makerspace, they were asked to write down reflective journals. They were then asked to complete online surveys, which were emailed to the participants to complete within one week. The third step consisted of asking the teachers to complete an online survey about the projects. Finally, while observing the students, some observational notes were taken by the author.

Yin (2018) proposed four guidelines for case study research data collection: '(a) using multiple, not just single, sources of evidence; (b) creating a case study database; (c) maintaining a chain of evidence; and (d) exercising care in using data from electronic sources of evidence, such as social media' (p. 153). According to Dubois and Araujo (2007), using multiple respondents enables the collection of a range of meanings and views. Consequently, this study used multiple rigorous data collection procedures, specifically observational notes, the students' reflective journals, and online surveys to obtain a deeper knowledge and better inform the research questions (Patton, 2014) of the types of learning conducted in school makerspaces. The triangulation of these data sources helped guide this research and increase the reliability of the outcomes. Moreover, Rowley (2002) identified three fundamental guidelines for the case study data collection that should be followed:

> 1. Triangulation - One of the great strengths of case studies as compared with other methods is that evidence can be collected from a variety of resources. Triangulation uses evidence from different sources to corroborate the same fact or finding.
>
> 2. Case Study Database - A case study database of the evidence gathered needs to be collected. Researchers should create a case study database to strengthen the repeatability of the research and increase the transparency of the findings. The case study database may include surveys, notes, and analyses of the evidence.
>
> 3. Chain of Evidence - Researchers need to maintain a chain of evidence. Within the database, the researchers should make sure that the data collection followed the protocol, and the link between the protocol questions and the propositions should be transparent. (p. 8)

In this study, multiple rigorous data collection procedures, including reflective journals and observational notes, as well as surveys, were used to better address the research questions through evidence of learning. The following subsections describe them in more detail.

4.7.1 Reflective Journals

Reflective journals were the main instrument of the data collection. Reflective journals gave the teachers a chance to hear the opinions of their students by allowing them to write about their thoughts and describe the changes they experienced while learning (Dunlap, 2006). Ahmed (2019) states that reflective journals have been used in the literature to ‘promote students’ learning, develop writing skills, assess students’ reflection level, promote teachers’ professional development, and gather research data’ (p. 1). They can show what happens when a programme or change is implemented and how the participants perceive these events (Bashan & Holsblat, 2017). The students’ reflective journals can offer qualitative evidence of the learning occurring in the makerspace. Furthermore, they provided an opportunity to explore the skills that the students developed.

At the beginning of the first semester, the students received guidelines for journaling. Semi-structured reflective journaling was used as prompts to aid students in relating to both personal and individual elements. Asking questions is recognised as an efficient strategy for eliciting metacognitive reflection from students (Zohar & Barzilai, 2013). A reflective journal template was created using the study research questions and Gibbs's (1988) reflective learning cycle (see Appendix 5).

4.7.2 Observational Notes

An instrument for gathering data, observational notes are produced in the environment where the phenomenon of interest naturally happens (Yin, 2018). According to Merriam (2009), observation is a useful research strategy because it allows researchers to keep track of events as they occur, gain comprehension of the background, learn about individual episodes, and uncover information that other approaches cannot. Working in the makerspace provided the opportunity for researcher to write observational notes. A set of observations of the projects was conducted where notes were recorded, and reflections were captured. Additionally, some observations were elicited from the students’ presentations (their assignments) and work. The projects were observed during the school year 2019/2020, which started in November 2019 and ended in June 2020. Creswell (2007) asserts that observations provide the researcher with the ‘possibility on a continuum from being a complete outsider to being a complete insider’ (p. 132).

Utilising Creswell's (2007) observation protocol matrix, descriptive and reflective notes were recorded, then the same notes were transcribed and analysed. The observation notes were split according to the method of Creswell (2007) into reflective and descriptive comments. While reflective notes were used to record reflections and the final conclusion about the activities, descriptive notes were used to summarise and record a chronological description of the activities. The researcher included teachers' notes, direct quotes, and descriptions, as well as any comments heard in the makerspace and sentences from the students' presentations. The makerspace sessions' observational notes were entered into a Google document afterwards.

4.7.3 Surveys

Two online surveys were utilised in this study, one for students and the other for teachers. The surveys in this study were selected because they can provide a record of the skills developed in the makerspace from the viewpoint of both educators and students. In addition, the use of surveys, vis-a-vis other methods, such as interviews and observations, enabled as many participants as possible to contribute and maximised the range of perspectives and answers given to the different types of questions (Creswell, 2014). It provides a way to collect quantitative data that can be analysed statistically to identify patterns, trends, and correlations. It was crucial to the participants that the survey instrument was anonymous as they could freely describe their experience in the makerspace.

The teacher survey (see Appendix 2) detailed the teachers' perceptions of students' learning in the makerspace. The student survey (see Appendix 4) included 10 multiple-choice questions and four open-ended questions. Predetermined themes were considered prior to the development of the open-ended survey, which was developed based on the four Cs and the life and career skills described by the Partnership for 21st-Century Learning framework (Partnership for 21st-Century Learning, 2019). The surveys included items (the first section) to measure the frequency with which the teachers addressed the development of 21st-Century skills used, as well as items (the second section) to measure the various attitudes of the future skills using scales. The third section identified the obstacles, challenges, and suggestions regarding using the makerspace for learning. Permission to use the questions adapted from Battelle for Kids (see Appendix 1) was received from Battelle for Kids.

The student survey (see Appendix 4) included 16 questions and used a combination of a Likert rating scale and ranking. This survey was customised from the Careers and Enterprise Company

Future Skills Questionnaire. The Careers and Enterprise Company works across England to help young people make choices about their futures (The Careers and Enterprise Company, n.d.). Permission to use questions adapted from the Careers and Enterprise Company was received (see Appendix 3). The survey was divided into two sections; the first section measured how the students changed after working on makerspace projects, and the second section measured the students' career readiness.

The survey instruments were designed and informed by the conceptual frameworks. Both surveys had open-ended and closed-ended response items. The surveys were constructed using Google Forms. Participants received the link to the surveys via their school emails in May 2020. The email message included the survey instructions, the consent form to participate in the research (see Appendix 8), and an embedded link to the online survey. The survey remained open for two weeks and follow-up emails were sent to remind the participants before the final day.

4.8 Data Analysis

It is stated that researchers should be aware of data analysis techniques before collecting the data (Kahkonen, 2014). Using a case study protocol, creating a database, and ensuring the chain of evidence were done to strengthen the reliability of this study, as recommended by Yin (2018). A case study database folder was created using the Google school account to facilitate the organisation of the data and the maintenance of a chain of evidence**.** Separate folders were created for the various coded and categorised data sets to facilitate analysis. The data from the online surveys, as well as the original reflective journals, were stored in a single folder labelled "case study database". The findings from all three data collection methods (reflective journals, surveys, and observational notes) were analysed to generate a theory regarding the use of the school makerspace in learning 21st-Century skills and future job skills to answer the research questions developed for this study.

4.8.1 Data Handling

Data organisation, also known as data cleansing, guarantees that the data are accurate, consistent, and usable (Maletic & Marcus, 2000). Firstly**,** throughout the current study, all observational notes and images of the student work were kept in a password-protected folder. To facilitate retrieval and analysis, all the data were organised, named, and represented by date and topic**.** Secondly, any data errors, irregularities, or corruptions were identified and recovered. Furthermore, the table format of the reflective journals was removed from the files to allow for a suitable view in NVivo, allowing for new visualisation and analysis of the coded data, as well as facilitating the removal of all personal information from the students' responses. The files in the folders were arranged based on the makerspace station they represented.

Prior to initiating the data analysis process, the data were reviewed many times. The analysis of qualitative study data consisted of the following steps: 'preparing and organising the data, reducing the data into themes through the process of coding and condensing the codes, and finally representing the data in figures, tables, or discussions' (Creswell, 2007, p. 148). The following are some of the concepts that a case study analysis should adhere to, according to Rowley (2002):

1. The analysis makes use of all of the relevant evidence;

2. The analysis considers all the major rival interpretations, and explores each of them in turn;

3. The analysis should address the most significant aspect of the case study;

4. The analysis should draw on the researchers' prior expert knowledge in the case study, but in an unbiased and objective manner. (p. 9)

4.8.2 Coding Data Approach

According to Creswell and Clark (2018), the pragmatic approach 'may combine deductive and inductive thinking as the researcher mixes both qualitative and quantitative data as the study proceeds' (p. 88). A combination approach with deductive and inductive coding was selected to suit the multiple data sources. Top-down deductive coding employs a codebook with an initial set of codes from a conceptual framework, in this case, the TLD. To code for the a priori list of codes discovered in the reflective journals, a deductive approach to thematic analysis was utilised. The reflective journals were read through, and codes were assigned to the excerpts, representing different skills in the TLD. This approach was helpful in answering the research questions and exploring the skills gained in the makerspace projects.

An inductive approach to thematic analysis was used to discover the skills and benefits of learning in the makerspace and other areas that were not included in the a priori list of codes based on the TLD. The researcher began with a set of codes through the deductive approach, and then developed more codes and refined the initial set through the inductive approach while processing the data. For example, significant themes were generated through the reflective journals, observational notes, and surveys through this approach, such as long-term projects and blended makerspace projects. The combination of these approaches allowed for the exploration of the relatively unknown (inductive) and what the researcher thought were already known (deductive).

This combination of approaches was chosen to enhance the data analysis procedure and to make use of the benefits of the deductive and inductive approaches. For instance, a deductive approach was employed to extract information and validate the hypotheses, whereas an inductive approach was used to generate hypotheses from the data. Analysing the data through the combined use of different inductive and deductive tools has been utilised in many previous studies (such as Ali & Birley, 1999; Anderson, 2017; Ligurgo et al., 2018; Pacheco-Romero et al., 2021; Park, 2018).

The concept of circular thinking was presented by Park et al. (2020) to 'evolve research through a continuous and relevant series of research methods' (p. 10). Their goal was to capitalise on the benefits of inductive and deductive approaches while compensating for their shortcomings by allowing researchers to reflect on the back-and-forth interaction between them. This combined approach can be used when researchers do not want to make use of a single existing theory to guide their investigations. They may utilise it to develop rather than test a theory. Other researchers indicated the importance of this approach in the data analysis process. For example, Greco et al. (2001) indicated tools that allow the user to 'better comprehend the information domain and to design more targeted analysis processes' (p. 1).

To summarise, this study made use of the advantages of integrating deductive and inductive methodologies. An interpretative method was used with deductive reasoning coming from the theoretical frameworks and inductive coding generated by the emerging themes**.** The reflective journals and observational notes were subjected to a first deductive scan in which each portion of the material was coded according to the skills outlined in the theoretical framework. Deductive coding was followed by inductive coding with new codes indicating new skills or repeated replies**.** Some of the study's participating teachers revised the new codes to ensure the acceptability of the analysis (Akkerman et al., 2008). The analysis of the reflective journals is described in the next subsection.

4.8.3 Data Analysis of the Reflective Journals

After revising the data codes, they were entered into NVivo 12, which helped to visualise and analyse the coded data in new ways. Every reflective journal was read, each sentence was highlighted, and comments were inserted that seemed to reflect the learning dimensions in alignment with the TLD framework. To visualise the relationships between each station and the indicators of learning, NVivo 12 was used to calculate the frequency of each indicator of learning according to each makerspace station. After analysing the data from each makerspace station, cross-case analysis was undertaken to reveal whether any new patterns and insights came from comparing the stations (Miles & Huberman, 1994).

To help make sense of the type of learning occurring at each station, the TLD framework (Bevan et al., 2020) was employed to serve as a priori codes to analyse the reflective journals (Saldana, 2021), helping to put the nodes in NVivo 12 (see Appendix 7). To ensure that the coding adhered to Bevan et al.'s (2020) approach, Bevan (one of the authors of this framework) was contacted to learn more about the framework. Furthermore, before diving into the real data analysis, a video library was utilised as a calibration tool to ensure that the process of interpreting occurrences was done in the same way as described in the 2017 version of the framework. In addition, past studies that employed the TLD framework were read in order to learn from their approach to applying the framework to analysis.

As Yin (2018) indicated, to develop a rich and full explanation to address the initial "how" or "why" questions, the researcher needs to do a lot of post-computer thinking and analysis. For this study, the data were revisited many times to search for patterns, insights, or concepts that seemed promising. Apart from the learning indicators, new emergent themes that seemed to be relevant to learning in the makerspace were discovered, such as the following: connecting the makerspace to real life and future careers, COVID-19, and makerspace blended projects.

4.8.3.1 Steps of Coding Qualitative Data

Creswell's (2009) approach to qualitative data analysis was used in the second phase of the data collection and analysis (see Figure 4.7). The following section will describe each step.

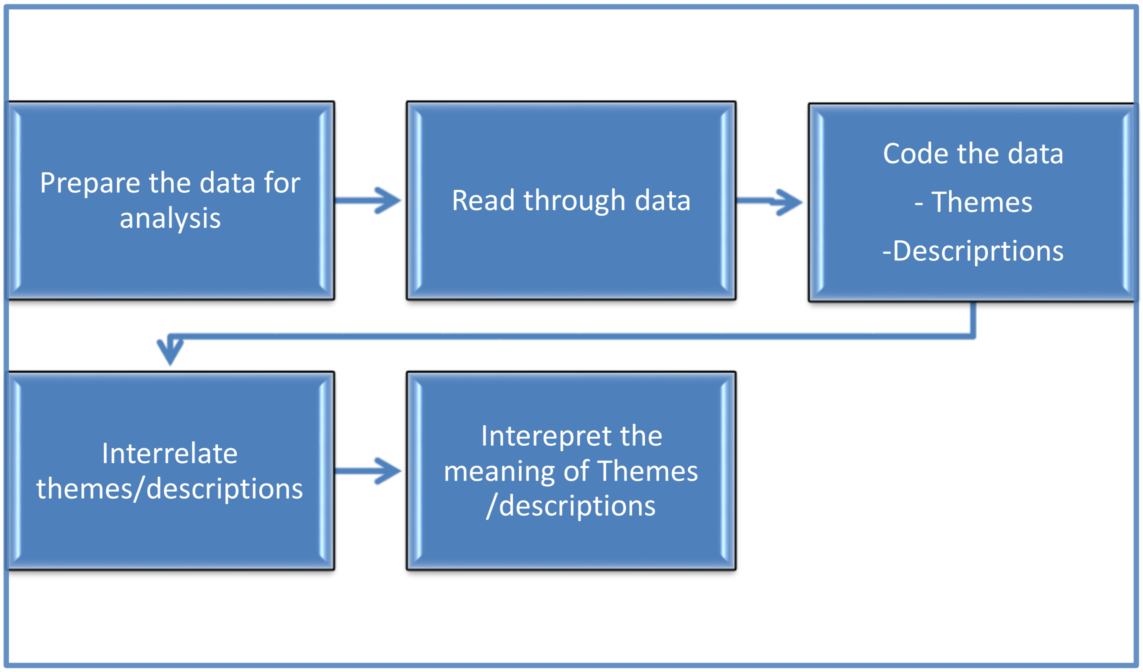

Figure 4.7 Data Analysis (Creswell, 2009, p. 185).

Preparing the Data for Analysis

The reflective journals, survey responses, and observational notes were put into a single folder and five sub-folders were created for each project. Additionally, all repeated parts were deleted, and the format of the files was changed to be suitable when imported into NVivo.

Reading through the Data

After organising the reflective journals in Microsoft Word, each file was read through, and the initial nodes were put as comments to enable other teachers to revise them later. During this step, general ideas about the data were developed. For example, it was discovered that 3D printing was connected to the students' life as it was mentioned in many of the reflective journals.

Coding the Data

Coding was conducted through a multiple-step process. Reading the data and giving codes to different reflective journal extracts comprised the first phase of coding the qualitative data. As previously explained, the codes originally emerged from the research questions and the TLD framework. Five nodes that represented them in NVivo 12 were created. These nodes represented the emerging themes as well as the predicted areas for analysis based on the research questions (see

Appendix 6). Structural coding was the coding technique applied in this phase. It was used to divide up the content of the text into sections according to a predetermined format of the TLD framework with the intention of carrying out further analysis within this format. The reflective journals were read through, and the code was applied to the sections relevant to the TLD dimensions. The process was repeated and revised for a portion of the data by a second coder.

After the first round of coding the data, the codes were organised into a list of categories. There were many ways that these categories could be organised. Within each category, the codes were arranged such that they were grouped together according to how similar they were to one another or how they linked to the same topics or overarching ideas. This process was iterated until reaching a structure that made sense for the analysis.

The second phase of coding consisted of renaming the codes, recoding them, merging them, and reclassifying the work done up until that point. This cycle of coding focused on reanalysis, pattern discovery, and the advancement of ideas and concepts. In this stage, content analysis was employed as a qualitative research analysis approach to interpret the meaning of the texts and groups together, with all extracts related to a certain code. The initial theory was validated or invalidated, and notes were taken to reflect on the interpretations. In addition, a frequency count for the occurrence of each skill code was compiled in the final code list.

The inductive coding approach used in this study was grounded theory, and the researcher followed Strauss and Corbin's (1990) approach to the grounded theory method of analysing qualitative data. Open coding is the first phase of grounded theory in which the textual data were divided into discrete parts (Strauss & Corbin, 1997). This helped to abandon any preconceived beliefs and biases regarding the research. As links between the codes were made, the second phase was entered called axial coding. This helped produce a number of categories that were supported by a set of cleaned up supporting codes viewed as the "axes" around which the supporting codes revolved.

The third phase was selective coding in which a single primary category was chosen to connect every code from the analysis and express the main idea of this study. The goal of this final step in the grounded theory process was to either develop a new theory or revise an existing theory using research. This procedure entailed eliminating any categories or codes that lacked sufficient supporting evidence or had very few instances.

Interrelating the Themes and Descriptions

The nodes and notes that applied to each research question were identified. This process was reviewed by another coder. After these rounds of coding, the codes and categories were taken and used to construct the final narrative. The codes were revised to find the major themes and patterns to determine the categories for the results. The reflective journal, observational notes and surveys produced the following main themes: connecting learning in makerspaces to real life, COVID-19, and blended makerspace projects.

The major categories served to classify the responses for further analysis and to determine patterns and reflections on which skills and types of learning happened in the school makerspace. Additionally, they guided the discussion chapter.

Interpreting the Meaning of the Themes and Descriptions

Narrative passages were prepared based on the themes to convey the findings. Tables and visual illustrations have been included in the findings chapter.

4.8.4 Data Analysis of Observation Notes

The observational notes were analysed manually as there were not many notes. After reading the reflective notes and highlighting the parts that matched the themes discovered in the reflective journal and the surveys, a file in Google Sheets was employed to make the summary of the themes (see Appendix 9). In this study, the observational notes data from the participants and the researcher were used to aid the other sources of data and support the evidence found in them. Many potential codes were discovered related to sub-questions 1, 2, and 5. The following are the final themes that came out of the observational notes after analysing them and deleting or merging themes:

- Learning from mistakes
- Students developed the four Cs skills
- Students connected the projects to their future university preferences
- Students were proud of their projects
- Students faced problems
- Long-term projects

- Students can relate the projects to their life
- Students needed support during COVID-19
- Students related their projects to future jobs

4.8.5 Survey Data Analysis

Two types of data were collected from this study's surveys: quantitative data (multiple-choice questions) and qualitative data (open-ended questions). Deductively, the researcher coded the participants' responses to the multiple-choice questions as per the 21st-century framework used in the teachers' survey and the future jobs pre-defined questions in the students' survey (see Appendix 10). As the surveys were available on Google Forms, the collected data were automatically transferred to Google Sheets for analysis. Descriptive data about the skills, beliefs, and practices in the school makerspace were generated through statistical measures and graphs. These data were contrasted with the findings of the reflective journals to determine the 21st-century and future employment skills learned in the school makerspace.

The same coding strategies used for analysing the reflective journals were followed to analyse the responses of the participants to the open-ended questions. Additionally, the descriptive data (open-ended questions) were analysed to identify new themes and categories (see Appendix 13). Inductively, the comments were analysed based on grounded theory. The coding and analysis of the survey data led to the development of emerging themes to address this research question's findings, such as long-term projects and blended makerspace projects. This part contributed to the development of a new theory about the types of projects that may be implemented in school makerspaces. Chapters 5 and 6 will highlight the new types of projects and other emergent themes.

4.8.6 Cross-Cases Analysis

Using a cross-case analysis, patterns and new insights that came from comparing the makerspace stations were uncovered. Where the purpose of the case study is to uncover new information as Yin (2018) pointed out, cross-case synthesis can be done using an inductive approach. Merriam (2009) indicated that 'The level of analysis can result in a unified description across cases; it can lead to categories, themes, or typologies that conceptualise the data from all the cases; or it can result in building substantive theory offering an integrated framework covering multiple cases' (p. 322).

Additionally, engaging in cross-case synthesis helped to retain a comprehensive perspective and comprehend events in their natural contexts. According to Kriukow (2017), cross-case analysis has four main elements: identifying common themes and concepts across all cases; identifying and comparing patterns and relationships between concepts across different cases; identifying and trying to understand and explain similarities and differences between cases; and 'identifying and exploring 'negative cases', or the cases that did not match the developing 'theory' or explanation' (p.102).

In this study, cross-case analysis was used twice. First, after analysing the reflective journal data, cross-case analysis was employed to compare the skills learnt in the school makerspace across the five stations. Second, it was employed when analysing the surveys to compare each future job skill across the five makerspace stations. The following chapter will detail the cross-case analysis used to compare the five stations of the makerspace in the study.

4.8.7 Role of the Researcher

In this study, the author of this thesis took on the roles of participant and researcher. He participated with the teachers in the planning process of the projects described in this study. As the makerspace projects began, he became a participant observer as the teachers and students directed questions to the researcher or asked him for assistance. He answered the questions that he was asked, co-taught and assisted when requested to solve any technical problems that arose. Additionally, he guided the students in how to use the machines in the makerspace remotely. The teachers were not forced to use the makerspace, and the researcher did not have any role in terms of evaluating teachers' or students' performance. Recognising the researcher's role in the makerspace and his natural bias in the projects was critical when framing the research design of the project. The author of this thesis minimised the bias in the review of data through the use of data triangulation and the use of multiple sources in data collection.

4.9 Validity and Reliability

In keeping with Patton (2002), who indicated that single-method studies may suffer from internal bias, a mixed study approach and an embedded-single case design were employed for this study. According to Yin (2018), a case study can be exemplary if it is substantial, comprehensive, takes other views into account, provides appropriate evidence, and is written in an engaging manner. It has been argued that researchers must collect, analyse, and report data in a valid, reliable manner.

Furthermore, validity can be established when researchers collect and analyse both open-ended qualitative and closed-ended quantitative data to address the study questions (Creswell, 2017).

Throughout the data collection, analysis, and reporting processes, a number of different qualitative research methodologies were utilised to assure reliability and validity. To evaluate the quality of case studies, Gibbert et al. (2008) proposed four criteria: construct validity, internal validity, external validity, and reliability. Moreover, Yin (2018) suggested tactics to use to test case study quality (see Table 4.9).

Tests	Case Study Tactics
Construct Validity	Use multiple sources of evidence
	Have key informants review a draft case study report
Internal Validity	Pattern matching
	Explanation building
	Address rival explanations
	Use logic models
External Validity	Use theory in single-case studies
	Use replication logic in multiple case studies
Reliability	Use the case study protocol
	Develop the case study database
	Maintain a chain of evidence

Table 4.9 Case Study Tactics for Four Design Tests (Yin, 2018).

In the next subsections, some of the employed tactics mentioned in Table 4.9 will be discussed.

4.9.1 Validity of the Case Study

Using multiple evidence sources, establishing a chain of evidence, and having key informants review the case study reports are all ways to ensure construct validity, as stated by Stuart et al. (2002). In this study, the mixed data approach offered data triangulation, which is a method used to increase the research validity (Creswell, 2017). To ensure the validity of the study's results, several procedures were established. First, the researcher 'used rich, thick descriptions to convey the findings' (Creswell, 2014, p. 202). Second, the different data sets were triangulated when answering the research questions (see Table 4.10). Third, a variety of informants conducted online surveys. Fourth, the data were obtained from several sources. Additionally, the construct validity of the study was bolstered by the chain of evidence: all research procedures were meticulously documented, and the original evidence was meticulously organised and saved in a Google folder database. Finally, another strategy to enhance the validity of this study was the use of member checks (Baxter & Jack, 2008). The member check process enabled the teacher participants to make valuable comments on the researcher's interpretations.

In crucial ways, the quantitative component of this study aided the qualitative data collection and analysis. First, the quantitative methods aided in the identification of new themes that were discovered through analysing the surveys. Second, the quantitative data collection and analysis provided statistical and descriptive information regarding 21st-century career skills through the results of the surveys. Finally, to increase the validity of the surveys, questions were taken from an existing survey instrument and an existing framework. Utilising pre-existing questions is useful in surveys as they have been tested at the time of their first use (Hyman, Lamb & Bulmer, 2006).

To confront biases, throughout the study, all participants were encouraged to be honest and forthright when completing the surveys and reflective journals. Furthermore, propositions were developed, outlining the assumptions based on the work of Yin (2018) and Stake (1995). Propositions supported the direction, scope, and data collection of this study, providing a useful guide for the study (Stake, 1995). The propositions were as follows:

- Students will develop different skills in the makerspace.
- Students will develop the four Cs (creativity, collaboration, communication, and critical thinking).
- Students will develop employability skills in the makerspace.
- Different makerspace stations may have different learning dimensions.

Research Question	Data Source	Data Source	Data Source
1- How do high school teachers perceive the educational benefits of the various stations of a school makerspace?	Teacher Survey	Observational Notes	
2- How do high school students perceive the educational benefits of the various stations of a school makerspace?	Student Survey	Observational Notes	Reflective Journals
3- What indicators of learning are identifiable among the students using the various stations of the makerspace?	Reflective Journals		
4- How do the identifiable indicators of learners' learning vary by station?	Reflective Journals		
5- How do different stations in a school makerspace contribute to the learners' acquisition of life skills that could help them develop future career skills?	Student/Teacher Survey	Observational Notes	Reflective Journals

Table 4.10 The Triangulation Table Process.

4.9.2 Reliability of the Case Study

In addition to the study's validity, another factor used for judging the quality of research was its reliability. This refers to 'the extent to which research findings can be replicated' (Merriam, 2009, p. 220). This is founded on the assumption that there is a single reality and that repeated examination of it will produce the same outcomes (Merriam, 2009). Furthermore, he added, the researcher can use triangulation, peer examination, the investigator's position, and the audit trail to ensure consistency, dependability, and reliability.

Using a case study protocol and creating a case study database, according to Yin (2018), can boost the study's reliability (see Table 4.9). In the current case study, these recommendations were followed. For instance, a database of the case study was created: the evidence was acquired, the steps of the research process followed, and the survey questions and processes meticulously documented, enhancing reliability.

Yin (2018) also suggested using other researchers to test the bias and tolerance of any conflicting findings. The early findings should be communicated to two or three critical peers for them to give other interpretations. In this study, the participant teachers reviewed the case reports, discussed the interpretations and conclusions and discussed the results with the school leaders. Finally, to address any possible bias by the researcher, the qualitative coding process was repeated by a second coder.

Although some measures were taken to address the reliability and validity of this study, threats to the reliability and validity remain. Firstly, the surveys were subject to the bias of both the author and the respondents (Fink, 2015). Secondly, this study focused specifically on five projects conducted in one type of school makerspace.

4.10 Ethical Considerations

As the author of this thesis worked closely with both the teachers and students by asking them to express their opinions, emotions, and personal development, it was essential to elicit their confidence and respect. This research study received ethical approval from Lancaster University. It was not necessary to solicit the approval of parents as the school policy (agreed upon by the parents) was to use students in research to improve their academic performance and for other academic purposes. This policy was clarified with the school director at that time.

To protect the participants and the school, all personal information and connections to the school remained confidential. The data collected from the surveys, reflective journals, and observational notes were stored on the researcher's computer. As the data were stored on the researcher's personal computer, requiring a login password, others were prohibited from access. Additionally, as a further precaution when maintaining the privacy and security of data, the researcher assigned pseudonyms to participants and instances of the learning indicators (see Appendix 11) to protect their identities. All signed informed consent forms and documents were locked in a filing cabinet in the researcher's private school office. Throughout the study, the participants were advised that they might withdraw at any time if they felt uncomfortable. During the 2022 spring semester, a subset of the findings was shared with the school director to help improve the students' learning experiences, while no personal information was revealed about the participants.

4.11 Summary

Chapter 4 details the development of a mixed-methods design where a single embedded case study approach was used to answer the research questions. The case study format was employed to collect qualitative data from reflective journals and observations, while quantitative data were collected from surveys. Through the design of a mixed-method case study, the research design included both exploratory and descriptive research, which helped the researcher triangulate the insights from the various points of view. The data analysis for the five stations in the school makerspace is presented in the next chapter, first as an individual case and then as a cross-case analysis.

Chapter 5: Presentation and Analysis of the Study Findings

5.1 Overview

This chapter provides a summary of the study's findings organised in accordance with its research questions. Using the pre-existing tinkering learning dimensions framework and the 21st-century skills framework which served as a priori codes to analyse the obtained data, 32 files including reflective journals, observational notes, and 79 survey responses were analysed (Saldana, 2021). Both frameworks had learning dimensions and indicators which will be described in greater detail within this analysis.

The central question presented in this study was as follows:

What educational benefits and indicators of learning are identifiable among students who use the different stations in the makerspace, and how could makerspaces help them develop their future career skills?

The study's central question was subdivided into five sub-questions aimed at distinguishing between the teacher and student viewpoints on the makerspace:

1- How do high school teachers perceive the educational benefits of the various stations of a school makerspace?
2- How do high school students perceive the educational benefits of the various stations of a school makerspace?
3- What indicators of learning are identifiable among the students using the various stations of the makerspace?
4- How do the identifiable indicators of learners' learning vary by station?
5- How do different stations in a school makerspace contribute to the learners' acquisition of life skills that could help them develop future career skills?

Following this introduction, the first portion of the chapter will offer a summary of the sample, the participants, and the data analysis procedures. The second section of the chapter presents the results based on the research questions, while the last section provides a summary of the chapter's key points.

5.2 Summary of the Study Site, Participants, and Data Collected

This research is a case study of a new standalone makerspace at a bilingual school in Kuwait. The stakeholders involved in the study were teachers and students. Seven teachers and sixty-two student participants were recruited from the high school division.

Ethical approval for the data collection was provided by Lancaster University and the school director of the study site. The data analysis followed the first cycle of coding, as recommended by Saldana (2021). First, the data collected from the reflective journals were differentiated, and the online surveys were initially analysed separately. Second, the first coding cycle began with the process of familiarisation with the data, followed by NVivo coding (Saldana, 2021). NVivo coding involved using qualitative data from the selected reflective journals and surveys. Thematic analysis (Yin, 2014) supported a review of all data, and any phrase or piece of data that seemed particularly important or related to the research questions was noted. Next, using the NVivo software, the areas noted to be of importance were coded with key terms that described their content. These codes were organised into clusters to see what patterns developed for each station and across the cases (see Appendix 6). Finally, the themes were synthesised to develop an overall description of the type of learning that happened in the makerspace as they were applied to the research questions.

The observational notes in this study's findings provided opportunities to link the participants' shared perceptions during the projects to the findings and gave evidence for the other themes found in the reflective journals and surveys. Consequently, the findings of the observational notes do not have a separate section but are embedded in the sections when appropriate.

5.3 Data Presentation and Findings

A mixed-methods approach was selected for this study to answer the research questions based on its ability to confirm the findings from different data sources (Creswell, 2014). The presentation of this study's findings is included in this section, and it is organised into six subsections to address the research questions, with another section for the emergent themes. The first subsection addresses the first research question through the results of the teachers' surveys. The second subsection addresses the second research question, and the third research question is addressed in the third subsection through the presentation of the students' reflective journals. The fourth subsection handles the fourth research question as well, and the fifth subsection addresses the fifth research question with the presentation of the connection of school makerspaces in preparing students for their future jobs alongside.

5.3.1 Sub-question 1: How do high school teachers perceive the educational benefits of the various stations of a school makerspace?

To answer this question from the teachers' viewpoints, a survey was designed based on the 21st-century skills framework. This framework helped to design the teachers' survey, as well as analyse and guide the discussion. The purpose of the survey was to evaluate, from the educators' perspective, how makerspace projects influence how the students apply the 4 Cs and life and career skills. Seven teachers participated in this survey. The following is a summary of the responses and an analysis of how school makerspaces tend to nurture the four Cs in students.

Creativity and Innovation

Out of seven participants, six (85.7%) teachers ranked using a wide range of idea creation techniques, such as brainstorming, as the most frequent learning indicator used by the students to develop creativity and innovation (see Figure 5.1). Five (71.4%) of the teachers indicated that makerspace projects helped the students to be open and responsive to new and diverse perspectives. Four (51.1%) of the teachers indicated that makerspace projects helped their students elaborate, refine, analyse, and evaluate their ideas; develop, implement, and communicate new ideas to others effectively; and helped their students view failure as an opportunity to learn and act on creative ideas to make tangible and useful contributions to the field. Only three (42.8%) of the teachers referred to the demonstration of originality and inventiveness; the creation of new and worthwhile ideas; including the acting out of the ideas to make tangible and useful contributions as their skills developed in the makerspace.

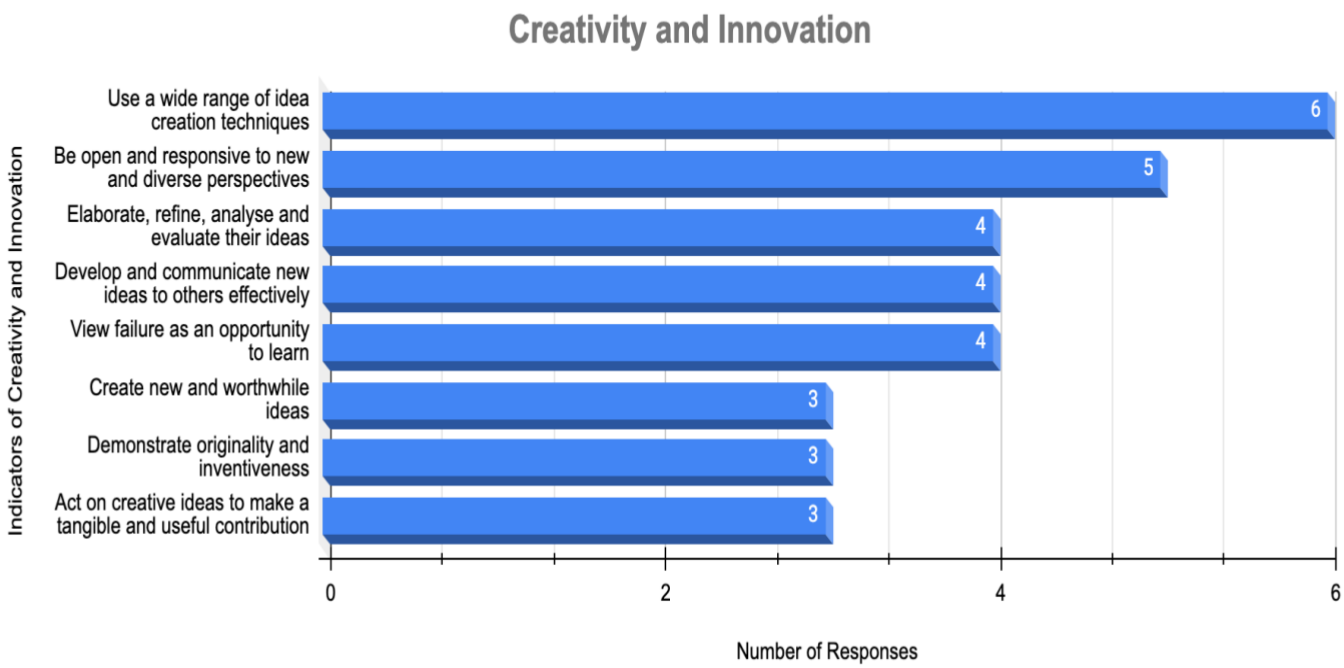

Figure 5.1 Creativity and Innovation.

The link between the makerspace and creativity was clear in terms of the creation of many ideas in the projects. For example, one of the students involved in the racing car project designed a new model for the racing car but did not follow the instructions and steps (provided by the teachers) to design it. Creativity can be piqued when students learn in a joyful environment or when engaged in playful making (Gerstein, 2019). Furthermore, innovation can be seen in makerspaces through empathy and experimentation (Falck, 2014).

Critical Thinking and Problem Solving

Five (71.4%) of the teachers ranked the analysis of how parts of a whole interact with each other to produce overall outcomes in complex systems and an evaluation of major alternative points of view as the most frequent learning indicators in developing critical thinking and problem-solving (see Figure 5.2)**.** Four (51.1%) of the teachers stated that makerspace projects helped their students to interpret information and draw conclusions, allowing them to critically reflect on their learning experiences and processes, solve different kinds of non-familiar problems in both conventional and innovative ways, and identify and ask significant questions that clarify various points of view and lead to better solutions. Three (42.8%) of the teachers indicated that their students learnt how to use various types of reasoning as appropriate to the situation and effectively analyse and evaluate evidence, arguments, claims, and beliefs. Only two (29%) of the teachers mentioned that the students developed synthesis and made connections between the information and their arguments.

These findings were echoed by Graves (2014) who emphasised the importance of critical thinking and problem solving when preparing students for the future. Overall, these results agree with Mansbach (2017) who argued that when learners plan, design, construct and make, they are involved in one of the highest levels of critical thinking.

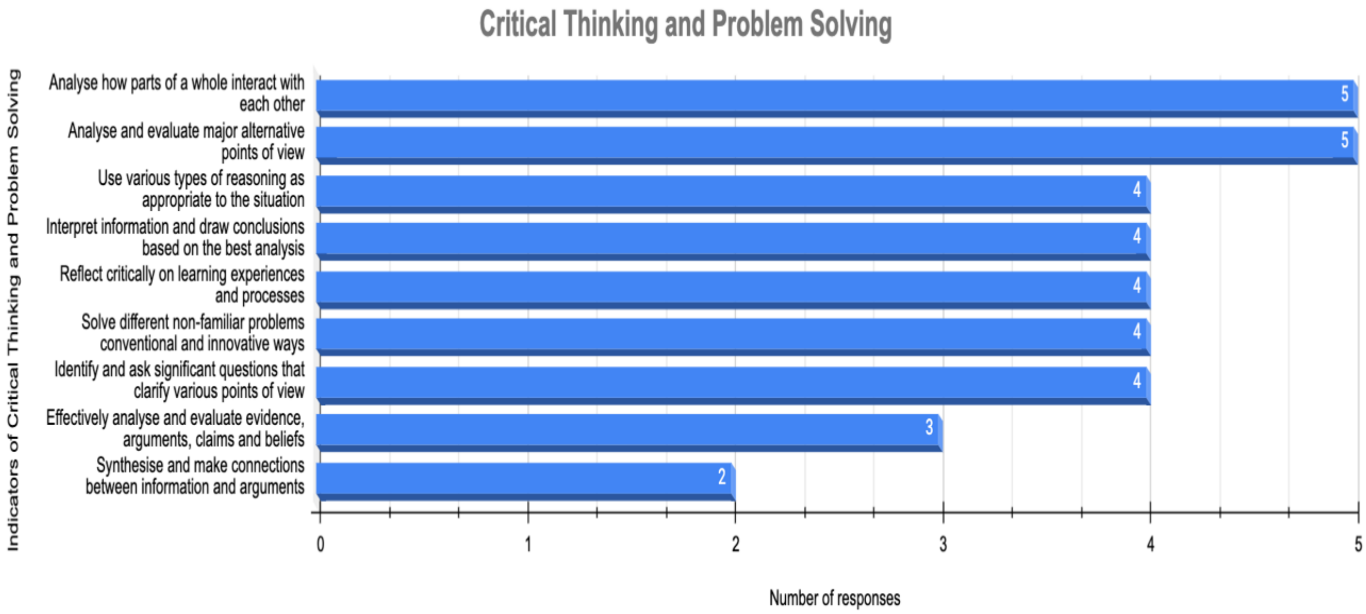

Figure 5.2 Critical Thinking and Problem-Solving.

Communication

In terms of developing communication skills, six (85.7%) out of the seven teachers ranked utilising multiple media and technologies and knowing how to judge their effectiveness and using communication for various purposes as the most frequent indicators. These findings reflect the rich nature of makerspaces, which provide access to technology and different types of media. Another highly ranked communication skill, as indicated by five (71.4%) of the seven teachers, was the development of the ability to listen effectively to decipher meaning including knowledge, values, attitudes, and intentions. Four (51.1%) teachers indicated that their students effectively articulated their thoughts and ideas using oral, written, and nonverbal communication skills in various forms and contexts and that they communicated efficiently in diverse environments (see Figure 5.3). Students can develop communication skills in school makerspaces when they listen and speak to each other during the projects. This also happens when the students reflect on their projects and present their work. These results align with the observational notes as one student shared that whenever he or she faced any difficulty, he or she asked his/her partners for help.

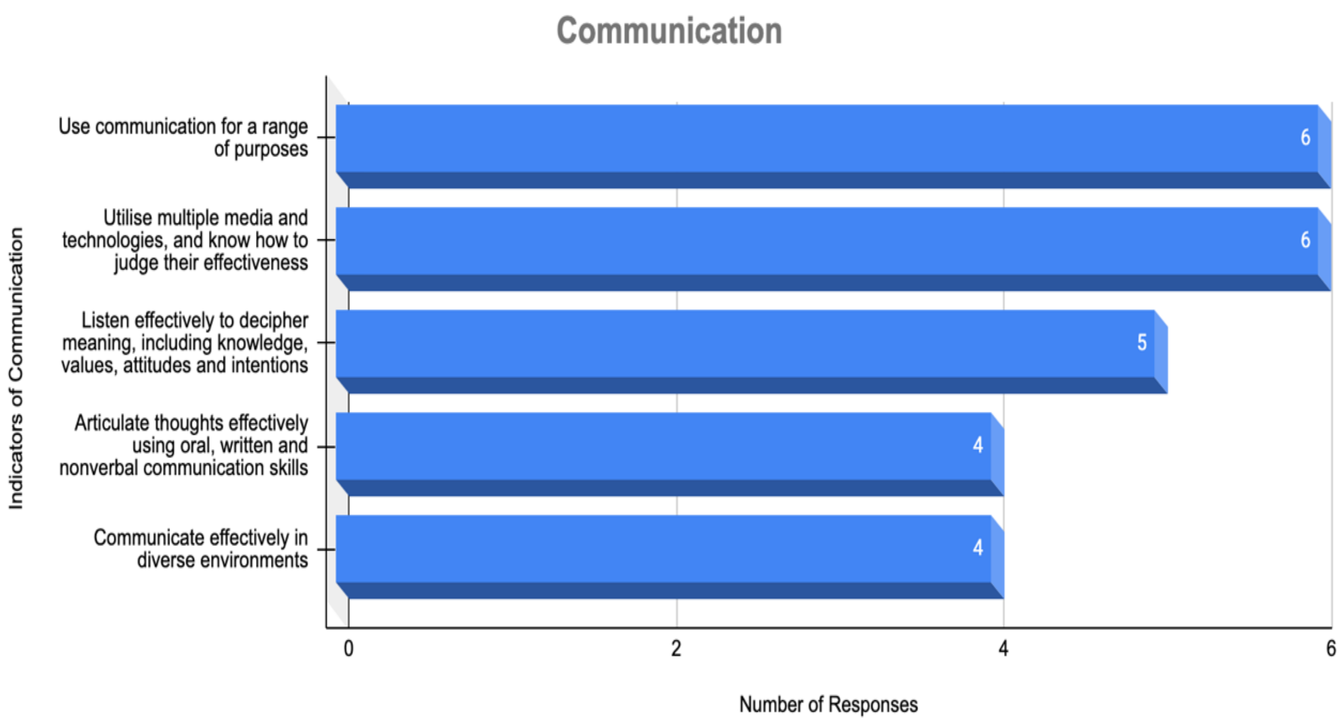

Figure 5.3 Communication.

Collaboration

All the teachers (7) ranked assuming shared responsibility for collaborative work and valuing individual contributions as the most frequent indicators of developing collaboration skills (see Figure 5.4). Six (85.7%) of the teachers indicated that their students demonstrated the ability to work effectively and respectfully within diverse teams. Five (71.4%) of the teachers indicated that their students exercised flexibility and a willingness to make the necessary compromises to accomplish a common goal. In accordance with this result, Clapp et al. (2017) documented the various ways in which students collaborate in a makerspace including working on a project together, sharing information and materials, teaching one another, and providing feedback on what they were creating and how it could be improved. Furthermore, collaboration is visible when the students exchange information, ideas, resources, and get feedback. Collaboration in the makerspace refers to when two or more students work together to make something. Consequently, most projects that students do in school makerspaces are naturally collaborative (Koul et al., 2021).

These findings were also echoed by Martinez and Stager (2019) who argued that collaboration is one of the most important 21st-century skills 'when the collaboration is authentic, students will gain a greater appreciation for the benefits of collaborating, and the result of the experience will be richer' (p. 163). Additionally, the findings reveal that one of the characteristics of maker education noted by the research was that it is marked by a collaborative learning community who seek help from others or share the final models or designs.

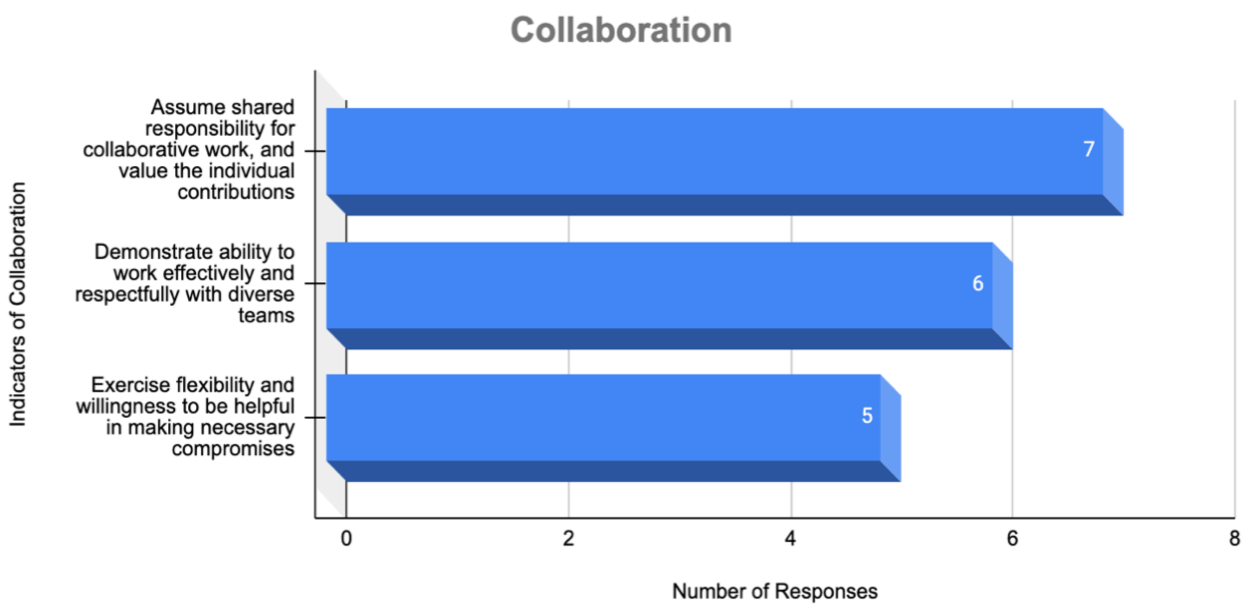

Figure 5.4 Collaboration.

5.3.1.1 Summary

The results revealed that the four Cs – critical thinking, collaboration, communication, and creativity – were considered by the teachers to be developed to varying extents with some factors more commonly reported than others during makerspace projects. In addition, the teachers indicated that working in makerspaces allowed the students to practice being problem-solvers, collaborators, and team workers. These results echo those of previous studies (Collins, 2017; Feinstein et al., 2016). Additionally, some of the findings in the observational notes showed evidence of the students developing the four Cs, echoing the online survey's findings (see Figure 5.5). For example, during one of the projects, Ali (pseudonym) helped Heba adjust his design and worked as a mentor.

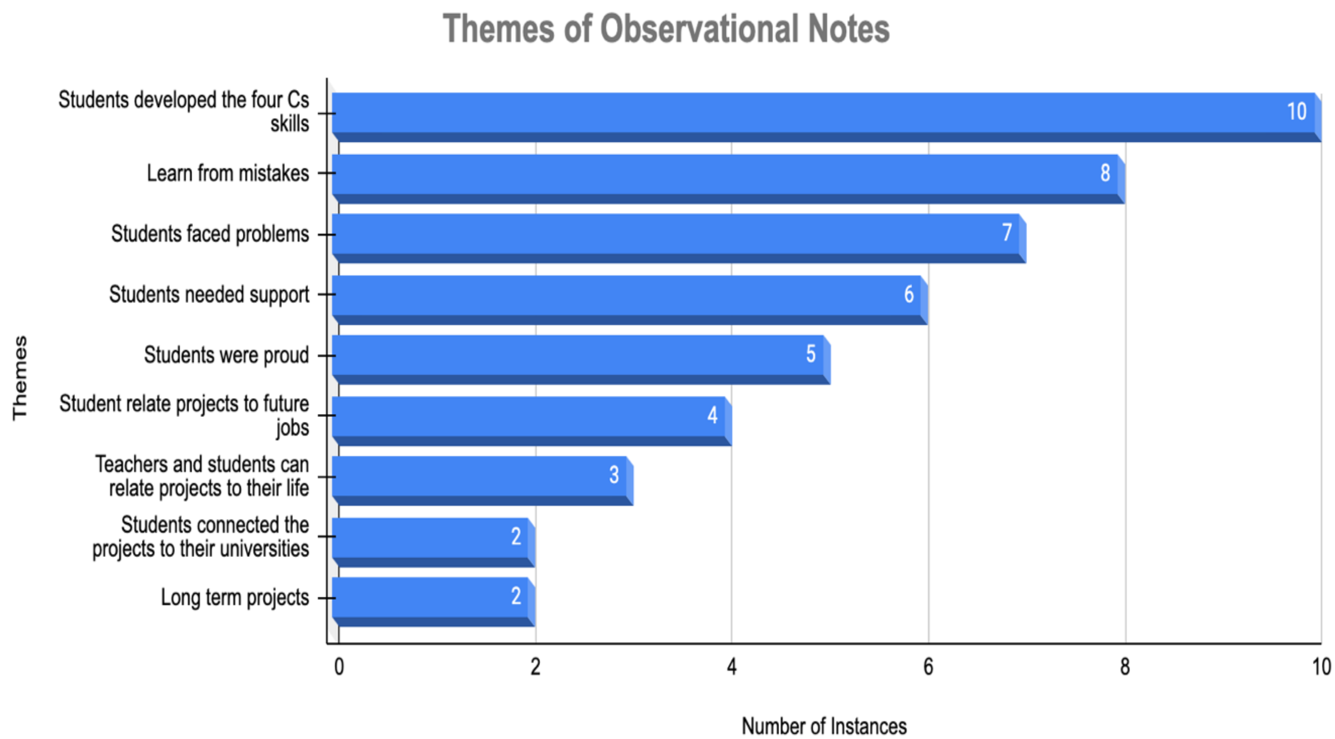

Figure 5.5 Observational Notes Data Themes.

The findings of this case study support the view of Kitagawa, Pombo, and Davis (2018) who indicated that adopting a makerspace will allow teachers to create a secure learning environment for children to acquire 21st-century skills, such as critical thinking, creativity, communication, and collaboration. Additionally, they support the claim that makerspaces can enable learners to develop a sense of collaboration (Clapp et al., 2017), computational thinking (Herro et al., 2021), problem-solving skills (Bowler, 2014), and critical thinking (Evans, 2017). The four Cs overlap and sometimes lead to each other; collaboration and sharing, for example, can lead to creativity (Gerstein, 2019).

5.3.2 Sub-question 2: How do high school students perceive the educational benefits of the various stations of a school makerspace?

To answer this question from the students' point of view, a reflective journal was developed based on the reflective cycle developed by Graham Gibbs (Reflection Toolkit, 2020). Thirty-two reflective journals were analysed, and some students completed their reflective journals in groups of two or three. Analysing the students' reflective journals helped identify the emergent themes that answer this second research question. The findings were reported as themes reflecting the major topics analysed across the reflective journals. The following section summarises the emergent themes related to how the students perceived the educational benefits of the various stations of the school makerspace:

Learning from Mistakes

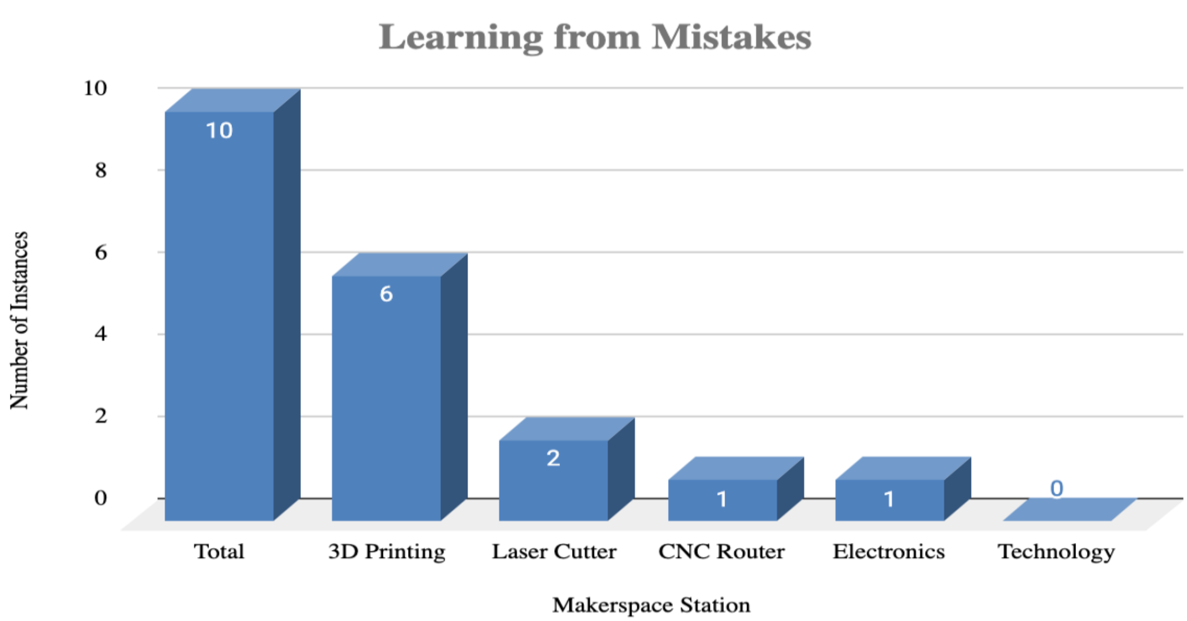

Figure 5.6 Learning from Mistakes.

The data reflect the age-old saying, "One man's fault is another man's lesson". Learning from mistakes was the most evident theme in the 3D printing station with six instances reported. The laser cutter station contained two instances, and there was only one instance in the CNC router and electronics stations (see Figure 5.6). The technology station did not include a learning from mistakes instance due to the nature of this project; it was entirely online, with no physical activities.

These results align with one of the maker movement principles of giving students the right to tweak, tinker, hack, and bend any technology to their will (Martin, 2015). Additionally, these results echo the results in the teachers' survey, as four teachers indicated that makerspace projects enabled the students to embrace failure as an opportunity to learn and act on creative ideas to make a tangible and valuable contribution to the field (see Figure 5.1). After analysing the observational notes, nine examples of the theme "learning from mistakes" were discovered (see Figure 5.5), correlating with the reflective journals' findings. Moreover, Otieno (2022) indicated that working in makerspaces allowed learners to fail and retry, bounce ideas off one another, and work together to build a prototype. Consequently, it is expected that students will face problems during this hacking and tinkering process and then learn from their mistakes. Solving these problems can help foster creative problem-solving skills and critical thinking (Martinez & Stager, 2019). The student participants shared that:

> *Participant 1 (NN CNC station)***:** *Throughout this process, there were bumps in the road, and one of them was having to redo the project because the measurements were off. I have learnt that you should always stay ready so you would never need to get ready. A moment I got stuck while working was when I didn't know how to mirror my work to make it into the full shape that I needed. I dealt with it by watching multiple videos to help me in understanding what mirroring was and how to do it exactly.*

> *Participant 2 (AA laser station): During the project, we've faced many challenges, at some point, we almost gave up, but we quickly rose back up and decided to be confident in ourselves.*

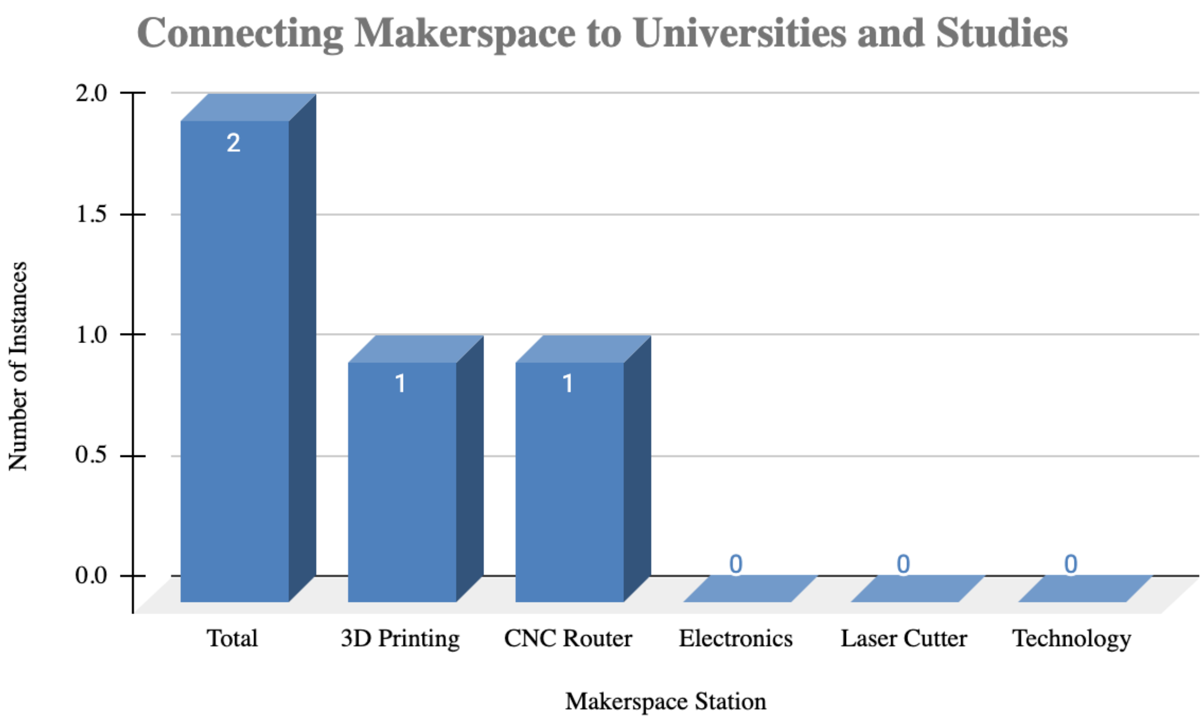

Figure 5.7 Makerspaces and Students' Future University Preferences.

Students connected their projects to their universities and studies preferences (see Figure 5.7). The 3D printing station and CNC both had an equal number of instances (one instance). Two examples of connecting makerspaces to universities and studies, as a theme, were found in the observational notes after the analysis, correlating with the reflective journals' findings (see Figure 5.5). While connecting makerspaces to universities and studies is mentioned in relation to only two stations, it does not mean that the makerspace project cannot be related to universities in other stations. This might be because some students have not yet decided which universities or studies they are going to attend or because they are unaware of the nature of their future studies. For example, although no student in the electronics station indicated a connection between the makerspace, universities, and their studies, one of the students approached the researcher to write a recommendation letter and include all the makerspace projects he or she had worked on.

Maker portfolios are one new admission criteria for universities to identify 'best-fit' candidates, especially in fields such as engineering and art. Peppler and Keune (2019) define maker portfolios as curated 'collections of projects or projects-in-progress, documenting the development of skills and knowledge over time and across spaces' (p. 244). In the same vein, Hunt (2021) describes maker portfolios as evidence used during the university admissions process to showcase work that supports creativity and skills through their previous projects. As the makers' portfolios play a significant role in the admissions procedures for both higher education and jobs, the work on portfolios is currently gaining new traction, serving makerspaces in youth makerspaces (Litts et al., 2016). In 2013, Massachusetts Institute of Technology (MIT) introduced "maker portfolios" as an option for admissions to enable students to show their creative projects. In addition, other universities, such as Washington University, Tufts, Carnegie Mellon, Stanford, and California College of the Arts have started to include maker portfolios in their admissions. The MIT website describes the Maker Portfolio, and its content as follows:

> an opportunity for students to showcase their projects that require creative insight, technical skill, and a hands-on approach to learning by doing. Members of the MIT Engineering Advisory Board review all maker portfolios. If you would like your technically creative work to be reviewed by academic and instructional staff, then it might be a good fit for the Maker Portfolio. For your Maker Portfolio, you may submit images, video totalling no more than 120 seconds, and up to one PDF of technical documentation and/or specifications via SlideRoom. You may document one project or many, and your work may have been done inside, or outside, of school, and alone or with a team; just make sure you explain it to us! (Creative Portfolios, n.d.)

In a nutshell, makerspace projects can be connected to students' future university preferences in that they help students prepare their portfolios. In the makerspace, students may demonstrate projects requiring creative ideas, technical abilities, soft skills, and a hands-on learning-by-doing approach. The students shared that:

> *Participant 1(NM Technology Station): This project is relevant to our personal experiences because we are both going into AP Calculus, so it is good to acquire a baseline knowledge on topics like these.*

> *Participant 2 (AAHC 3D printing): There are many things in the makerspace that could help me a lot, so it could get me prepared before heading to university.*

Connecting Makerspaces to Life

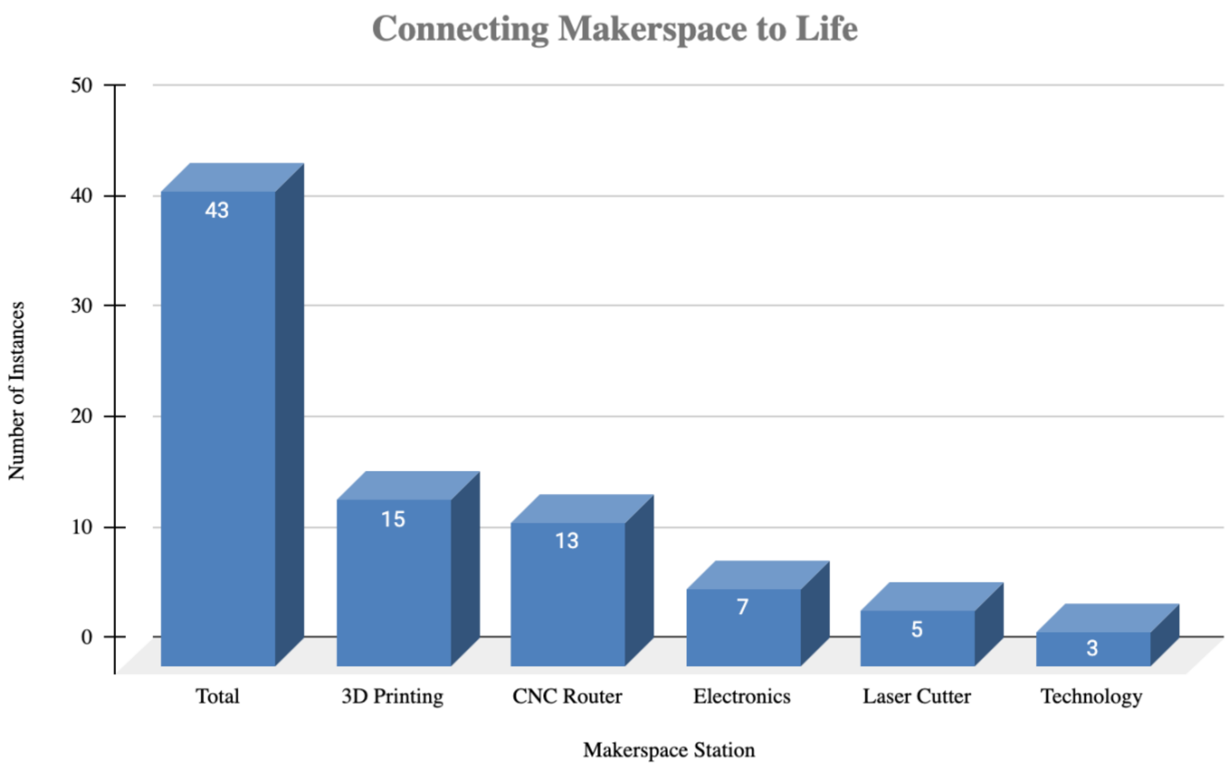

Figure 5.8 Connecting Makerspace to Life.

There were more apparent instances of the makerspace connecting to the life theme. It was most evident in the 3D printing station with 15 instances arising, electronics with seven instances and the CNC station with 13 instances (see Figure 5.8). A few instances were mentioned in the laser cutter station (five) and the technology station (three). These results support Hughes and Dobos' (2022) statement that 'the students, in many cases, moved beyond working for the sake of marks and instead elevated the learning process to something more personal and connected to the real world' (p. 17). The students shared that:

> *Participant 1 (AAHC 3D printing): We improved our communication skills because we were working together and resolved issues as a group.*

> *Participant 2 (NM technology station): Makerspace increases creativity and allows for more thinking outside of the box in relation to projects and creative works which will help with future projects.*

One student indicated how he changed his opinion of the school makerspace after he finished his 3D project and how he considered working in a school makerspace as a life skill:

> *Considering this is a life skills class, and we did 3D printing at first, I thought there was no life skill to get from it but after looking at 3D videos online and what it has been made, I was shocked at how important it is. I now consider it a life skill because of what you get from it. Another life skill I got from this was creativity (FA car).*

To connect school and real life in the context of makerspaces, literature highlights the valuable role of makerspaces in experiential education. Gert Biesta's book World-Centred Education emphasises creating learning environments that bridge the gap between classroom learning and real-world experiences (Biesta, 2021). Makerspaces offer hands-on activities fostering creativity and collaboration, aligning with the notion of learning through doing. In line with this perspective, Halverson and Sheridan (2014) underscore the potential of makerspaces to cultivate a connection between school-based learning with the outside world. By incorporating insights from Biesta's work, along with research by Halverson and Sheridan, and considering the findings of this study, it is demonstrated that makerspaces play a crucial role in bridging the gap between traditional schooling and real-life experiences, offering students valuable opportunities for meaningful experiential learning.

Connecting Makerspaces to Career Skills

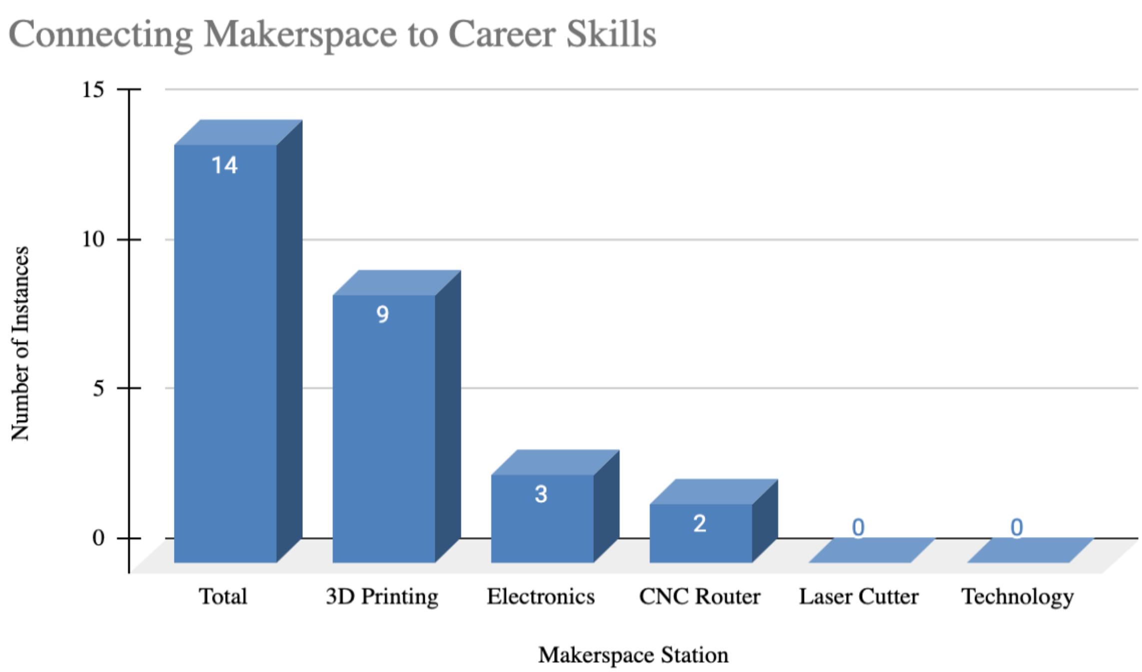

Figure 5.9 Connecting Makerspace to Career Skills.

Connecting makerspace activities to career skills was most commonly reported in 3D printing with nine instances (see Figure 5.9). It was mentioned in a few cases in the other stations; electronics (3) and CNC station (2). Four instances of the theme "connecting makerspace activities to labour skills" were discovered in the observational notes following the analysis (see Figure 5.5), which match the findings from the reflective journals. As part of the curriculum work in the makerspace of this study, a career survey was conducted, and the results showed that most students were interested in working as engineers, designers, and entrepreneurs, which are jobs that can be developed during the makerspace projects. According to a similar survey by Evans (2017), among parents, district administration, and community members, integrating STEAM and project-based learning, which are applicable in the makerspace, is the greatest approach to promoting employment skills. Some students shared in their reflective journals that after working on 3D printing projects in the makerspace, they were inspired to open a company or start their own business. The students shared that:

Participant 1(AWHC 3D printing): In the future, we plan to open our own company and sell our 3D printed designs.

Participant 2 (AWHC 3D printing): Sure, we can open a business one day and put our plans into action.

The story told by Attewell and Eral (2020) describes a student who worked on a makerspace project and later utilised the knowledge she learned to fix a leaking tap in her home. This supports the evidence for how the makerspace can be linked to life. The following paragraph summarises this story:

> An interesting and unexpected benefit has been that sometimes students are able to adapt knowledge gained in the makerspace to solve real-life problems. For example, Kadir tells the story of a girl who worked in the makerspace in order to participate in a robotics competition. Later, she told Kadir that during the school summer break there was a leaking tap in her home which she fixed by changing the seal herself instead of calling a plumber. Before working in the makerspace, she would not have been able to work out how to fix the tap or would not have had the confidence to try. (p.10)

5.3.2.1 **Summary**

The student participants perceived the educational benefits as preparing them for their career skills, university preferences, and future life (see Table 5.1). Additionally, the students indicated the benefits of the makerspace in terms of learning from their mistakes. For example, one student shared that:

> *When we started the project, our communication skills were weak, we would barely talk to our peers about issues when working during the project, but over time, our communication grew (AA the laser station).*

Station	Connecting the makerspace to career skills	Connecting the makerspace to life	Connecting the makerspace to the university and studies	Learning from mistakes
3D Printing	9	13	1	6
CNC Router	2	3	1	1
Electronics	3	0	0	1
Laser Cutter	0	5	0	2
Technology	0	7	0	0
Total	14	28	2	10

Table 5.1 Summary of Educational Benefits Instances of the Makerspace.

The findings in the previous sections align with Burke (2014) who indicated that learning has 'real-world connections for students beyond what they are learning in chemistry' (p. 27). These discoveries echo the findings of the observational notes as the students learnt from their mistakes, connected their makerspace activities to their life, and connected the projects to their career skills. For example, during one of the projects, one of the students shared, 'After the presentation, one student asked his colleague if he had plans to sell it and he would be his customer'. In another note, the students learnt from their mistakes. Another example is that during the 3D printing projects, the students were unable to 3D print on the first attempt due to a design error in which they had made thin layers (see Figure 5.10). After numerous attempts, the students were able to successfully 3D print their model.

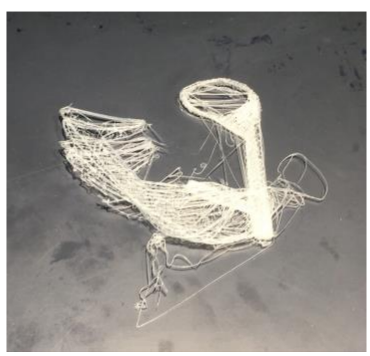

Figure 5.10 Mistakes in 3D Printed Models.

5.3.3 Sub-question 3: What indicators of learning are identifiable among the students using the various stations of the makerspace?

Individual Case Analysis

The results from the reflective journals written down by the students are presented in this section for each station. The learning dimensions that the students developed during their makerspace projects were identified using the TLD framework. The students' reflective journals revealed various degrees of the five learning dimensions in the framework being reported: conceptual understanding, creativity and self-expression, social and emotional engagement, initiative and intentionality, problem-solving, and critical thinking. The sections that follow demonstrates how students' interactions with the makerspace projects at each makerspace station revealed each of these dimensions.

3D Printing Station

The five dimensions of learning at the 3D printing station are represented by frequencies shown in Figure 5.11. Overall, of the indicators coded, the students who worked at the 3D printing station demonstrated *social and emotional engagement* almost twice as frequently as any other dimension. The high frequency of this dimension may well have been due to the fact that all projects in the makerspace were done in groups. *Conceptual understanding* was the second most prevalent dimension of learning with 27 instances arising across all 3D printing projects. Lastly, the students at this station demonstrated 17 instances for the dimension of *creativity and self-expression*, with 10 and 11 instances for the dimensions of *problem-solving and critical thinking* and *initiative and intentionality*, respectively.

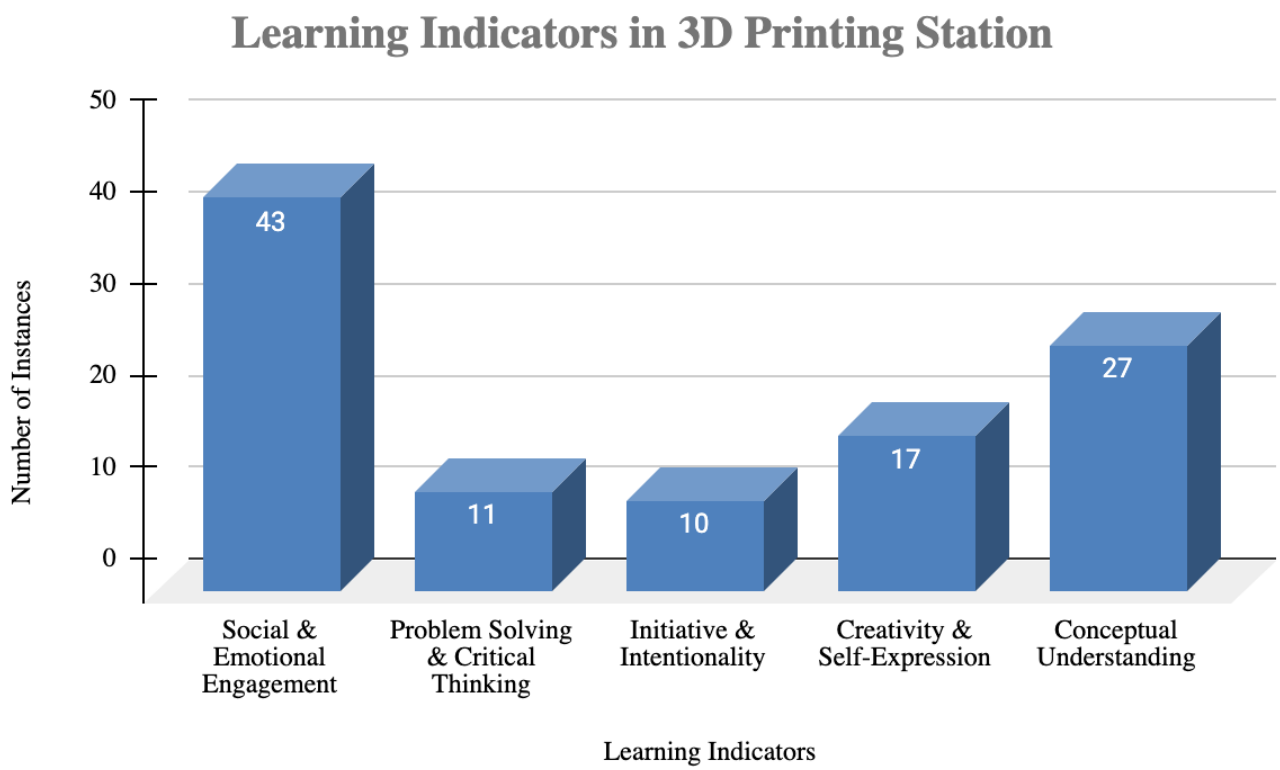

Figure 5.11 Frequency of the Dimensions of Learning in the 3D Printing Station.

For each dimension, there are some specific indicators to help practitioners and researchers recognise and interpret the learners' behaviour. A closer look at the data on the visible dimensions in 3D printing reveals the different indicators that appeared in the 3D printing station projects. Ranked by the most frequent instances in terms of the indicators is *the expression of pride and ownership* with 19 instances. The next most frequent indicators are *teaching and helping one another* and *making observations and asking questions* with 12 instances each. See Table 5.2 for the sub-codes under this indicator of learning which are varied in their visibility from 0 to 19. The indicators are displayed in the same order as defined by the TLD framework for consistency.

Dimension/Indicators	**3D Printing Station**	**Number of Instances**
Dimension 1	Initiative & Intentionality	10
Indicators	Actively participating	2
	Setting one's own goals	6

Dimension/ Indicators	3D Printing Station	Number of Instances
	Taking intellectual and creative risks	1
	Adjusting goals based on physical feedback and evidence	1
Dimension 2	Problem-Solving & Critical Thinking	11
Indicators	Troubleshooting through iterations	3
	Dissecting the problem components	1
	Seeking ideas, tools, and materials to solve the problem	3
	Developing workarounds	4
Dimension 3	Conceptual Understanding	27
Indicators	Making observations and asking questions	12
	Testing tentative ideas	0
	Constructing explanations	7
	Applying solutions to new problems	8
Dimension 4	Creativity& Self-Expression	17
Indicators	Playfully exploring	4
	Responding aesthetically to materials and phenomena	1
	Connecting projects to personal interests and experiences	10
	Using materials in novel ways	2
Dimension 5	Social & Emotional Engagement	43
Indicators	Working in teams	9
	Teaching and helping one another	12
	Expressing pride and ownership	19
	Documenting/sharing ideas with others	3
Total Number		108

Table 5.2 Frequency of Indicators of Learning in the 3D Printing Station.

CNC Router Station

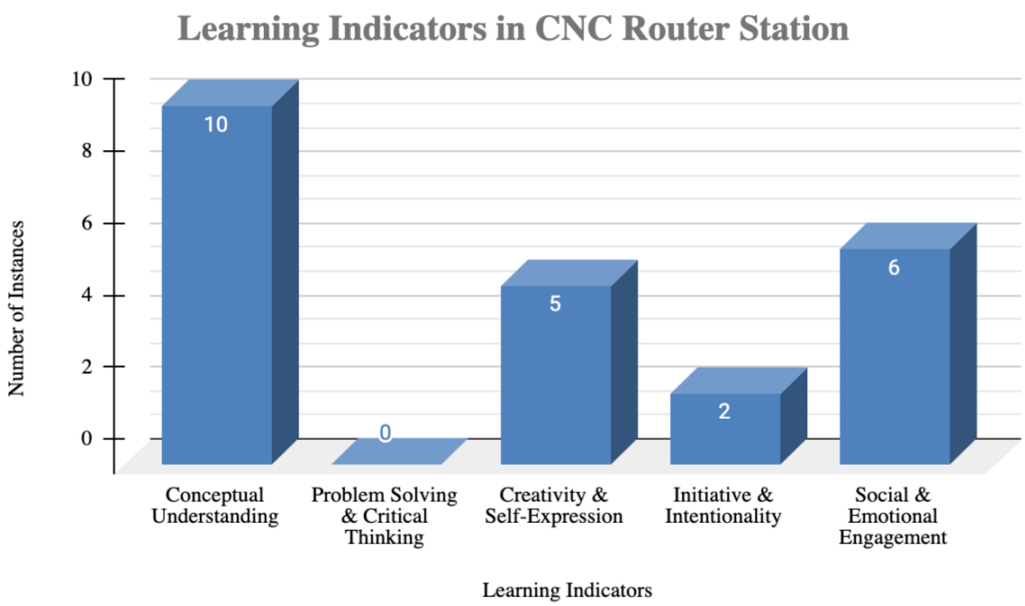

Figure 5.12 Frequency of the Dimensions of Learning at the CNC Router Station.

In the CNC router station project involving two students, *conceptual understanding* was the most frequently occurring learning dimension with 10 instances (see Figure 5.12). This result perhaps reflects the station's nature, which contains many technical terms and concepts that the students needed to learn. *Creativity and self-expression* (5) were closer to *social and emotional engagement* (6). In this project, no instances of *problem-solving and critical thinking* were demonstrated at this station since only two students participated in it, and the makerspace staff did the practical work because the students were online and there were some issues with the CNC router. Table 5.3 illustrates an overview of the indicators in each dimension.

Dimension/ Indicators	**CNC Router Station**	**Number of Instances**
Dimension 1	Initiative & Intentionality	2
Indicators	Actively participating	1
	Setting one's own goals	1
	Taking intellectual and creative risks	0

Dimension/ Indicators	CNC Router Station	Number of Instances
	Adjusting goals based on physical feedback and evidence	1
Dimension 2	Problem-Solving & Critical Thinking	0
Indicators	Troubleshooting through iterations	0
	Dissecting the problem components	0
	Seeking ideas, tools, and materials to solve the problem	0
	Developing workarounds	0
Dimension 3	Conceptual Understanding	10
Indicators	Making observations and asking questions	3
	Testing tentative ideas	0
	Constructing explanations	4
	Applying solutions to new problems	3
Dimension 4	Creativity& Self-Expression	5
Indicators	Playfully exploring	2
	Responding aesthetically to materials and phenomena	1
	Connecting projects to personal interests and experiences	2
	Using materials in novel ways	0
Dimension 5	Social & Emotional Engagement	6
Indicators	Working in teams	1
	Teaching and helping one another	2
	Expressing pride and ownership	3
	Documenting/sharing ideas with others	0
Total Number		23

Table 5.3 Frequency of the Indicators of Learning in the CNC Router Station.

The most frequent indicator of learning in the CNC router station was constructing explanations (4). Interestingly, three indicators (*expressing pride and ownership*, *making observations*, *asking questions*, and *applying solutions to new problems*) were visible three times (see Table 5.3). Five indicators (*actively participating, setting one's own goals, adjusting goals based on physical feedback and evidence*, *responding aesthetically to materials and phenomena and working in teams*) appeared only once.

Laser Cutter Station

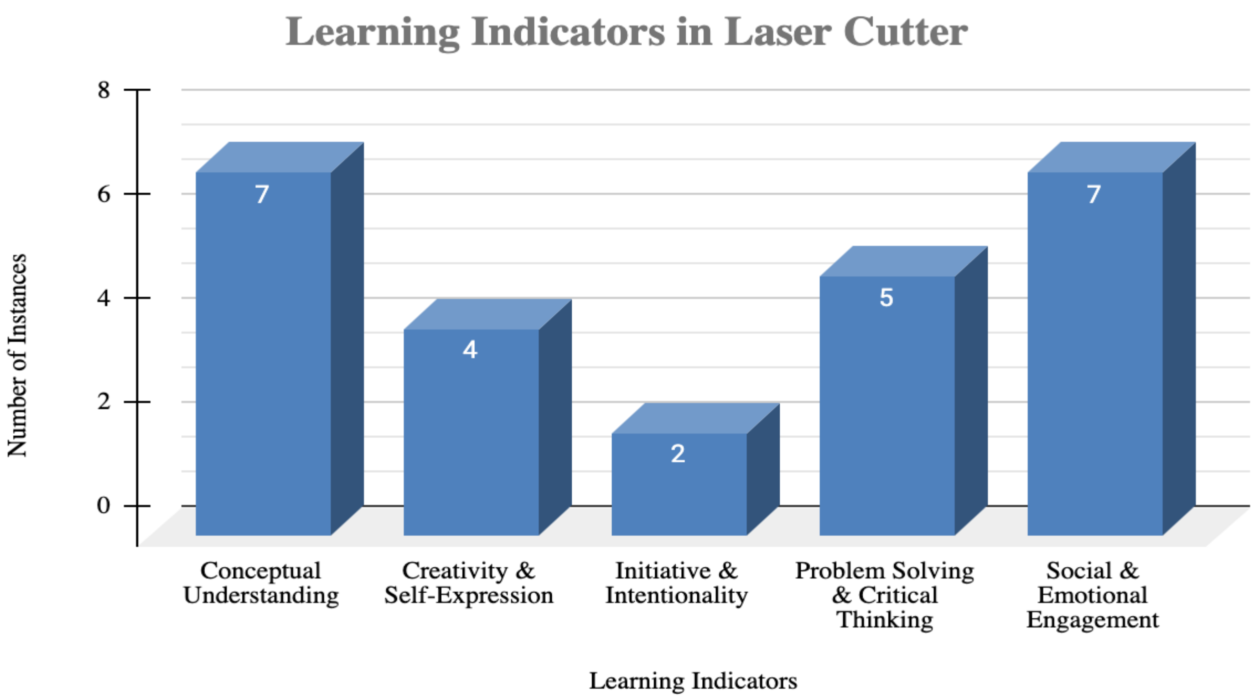

Figure 5.13 Frequency of the Dimensions of Learning in the Laser Cutter Station.

Figure 5.13 shows the same number of instances in this station regarding *conceptual understanding* and *social and emotional engagement* (7). Additionally, there were five occurrences of *problem-solving and critical thinking*, and four occurrences of *creativity and self-expression*, but only two occurrences of *initiative and intentionality*. Table 5.4 presents the visibility of each indicator in each dimension.

Dimension/ Indicators	Laser Cutter Station	Number of Instances
Dimension 1	Initiative & Intentionality	2
Indicators	Actively participating	0
	Setting one’s own goals	2
	Taking intellectual and creative risks	0
	Adjusting goals based on physical feedback and evidence	0
Dimension 2	Problem-Solving & Critical Thinking	5
Indicators	Troubleshooting through iterations	0
	Dissecting the problem components	1
	Seeking ideas, tools, and materials to solve the problem	1
	Developing workarounds	3
Dimension 3	Conceptual Understanding	7
Indicators	Making observations and asking questions	3
	Testing tentative ideas	0
	Constructing explanations	3
	Applying solutions to new problems	1
Dimension 4	Creativity& Self-Expression	4
Indicators	Playfully exploring	0
	Responding aesthetically to materials and phenomena	0
	Connecting projects to personal interests and experiences	3
	Using materials in novel ways	1
Dimension 5	Social & Emotional Engagement	7
Indicators	Working in teams	2
	Teaching and helping one another	0

Dimension/ Indicators	CNC Router Station	Number of Instances
	Expressing pride and ownership	5
	Documenting/sharing ideas with others	0
Total Number		25

Table 5.4 Frequency of Indicators of Learning in the Laser Cutter Station

The most frequent indicator of learning is *expressing pride and ownership* (5 instances). Interestingly, four indicators were recorded three times: *constructing explanations*, *making observations*, *asking questions*, *connecting projects to personal interests*, and *developing workarounds*. No instances were indicated for the nine indicators (see Table 5.4).

Electronics Station

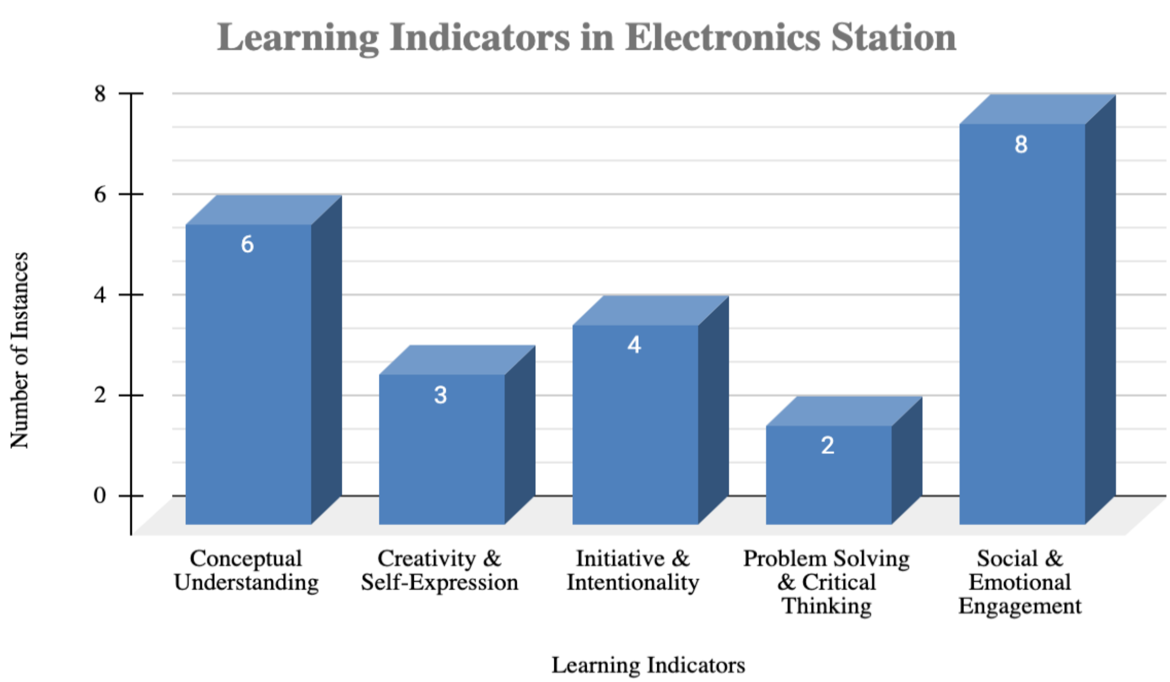

Figure 5.14 Frequency of the Dimensions of Learning in the Electronics Station.

Figure 5.14 shows that the most frequent dimension in the electronics station was *social and emotional engagement* with eight instances arising. The second most frequent dimension was *conceptual understanding* with six instances. The least frequent dimension was *problem-solving* *and critical thinking* with just two instances reported. The total number of occurrences for each indicator across all dimensions is presented in Table 5.5.

Dimension/ Indicators	**Electronics station**	**Number of Instances**
Dimension 1	Initiative & Intentionality	4
Indicators	Actively participating	0
	Setting one's own goals	4
	Taking intellectual and creative risks	0
	Adjusting goals based on physical feedback and evidence	0
Dimension 2	Problem-Solving & Critical Thinking	2
Indicators	Troubleshooting through iterations	0
	Dissecting the problem components	0
	Seeking ideas, tools, and materials to solve the problem	0
	Developing workarounds	2
Dimension 3	Conceptual Understanding	6
Indicators	Making observations and asking questions	1
	Testing tentative ideas	0
	Constructing explanations	4
	Applying solutions to new problems	1
Dimension 4	Creativity& Self-Expression	3
Indicators	Playfully exploring	2
	Responding aesthetically to materials and phenomena	0
	Connecting projects to personal interests and experiences	1
	Using materials in novel ways	0
Dimension 5	Social & Emotional Engagement	8
Indicators	Working in teams	1

Dimension/ Indicators	Electronics station	Number of Instances
	Teaching and helping one another	0
	Expressing pride and ownership	2
	Documenting/sharing ideas with others	5
Total Number		23

Table 5.5 Frequency of Indicators of Learning in the Electronics Station.

As shown in Table 5.5, the most frequent indicator of learning was *documenting and sharing with others* (5 instances), which reflects the nature of this learning during the period of the COVID-19 pandemic where the students had to work online and share files and documents in the same manner. *Constructing explanations* and *setting one's goals* were the second most frequent indicators (4 instances). Ten indicators were invisible in the projects (see Table 5.5).

Technology Station

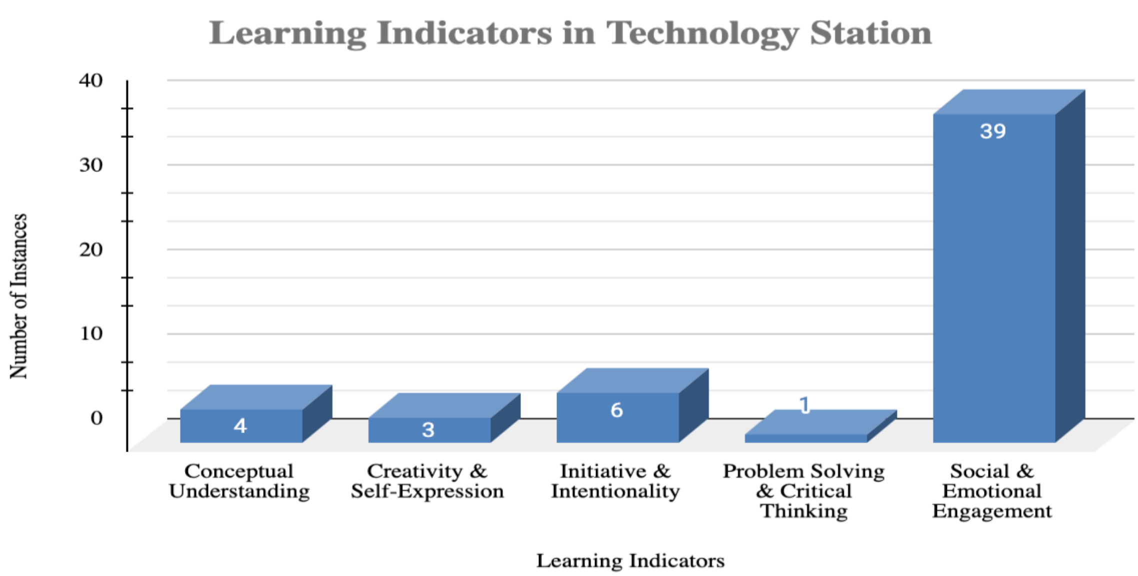

Figure 5.15 Frequency of the Dimensions of Learning in the Technology Station.

In the final part of this subsection, Figure 5.15 shows that the most frequent dimension in the technology station was *social and emotional engagement* with 39 instances arising. The next most frequent dimensions of learning were *initiative and intentionality* (6) with slightly fewer instances of *conceptual understanding* (4), *creativity and self-expression* (3), and *problem-solving and critical thinking* (1) (see Figure 5.14). Table 5.6 illustrates the total for each indicator in each dimension.

Dimension/ Indicators	**Technology Station**	**Number of Instances**
Dimension 1	Initiative & Intentionality	6
Indicators	Actively participating	0
	Setting one's own goals	6
	Taking intellectual and creative risks	0
	Adjusting goals based on physical feedback and evidence	0
Dimension 2	Problem-Solving & Critical Thinking	1
Indicators	Troubleshooting through iterations	0
	Dissecting the problem components	0
	Seeking ideas, tools, and materials to solve the problem	1
	Developing workarounds	0
Dimension 3	Conceptual Understanding	4
Indicators	Making observations and asking questions	3
	Testing tentative ideas	0
	Constructing explanations	0
	Applying solutions to new problems	1
Dimension 4	Creativity& Self-Expression	3
Indicators	Playfully exploring	2
	Responding aesthetically to materials and phenomena	0

Dimension/ Indicators	Technology Station	Number of Instances
	Connecting projects to personal interests and experiences	1
	Using materials in novel ways	0
Dimension 5	Social & Emotional Engagement	39
Indicators	Working in teams	11
	Teaching and helping one another	13
	Expressing pride and ownership	15
	Documenting/sharing ideas with others	0
Total Number		53

Table 5.6 Frequency of Indicators of Learning in the Technology Station.

It is apparent from Table 5.6 that *expressing pride and ownership* was the most frequent indicator (15). Furthermore, seven indicators do not have instances in this project (see Table 5.6), reflecting the nature of this station as fully digital with no physical work involved.

5.3.4 Sub-question 4: How do the identifiable indicators of learners' learning vary by station?

Cross-Case Analysis

In this section, the same five dimensions utilised for the individual instances are reviewed, but this time, they are examined in terms of the patterns and variance that occurred throughout the five makerspace stations for each learning dimension. The purpose of this cross-case analysis was to find patterns and new insights that arise from comparing the instances; these new patterns, emerging themes, and insights will be further examined in the next chapter. Additionally, the cross-case analysis revealed how learning indicators varied by station. Cross-case analysis, according to Merriam (2009), is a method for examining the similarities and differences between each case "station" as a case to acquire a greater knowledge of its uniqueness.

The cross-case analysis of the reflective journals revealed that social and emotional engagement was the most visible learning dimension. The evidence also showed there to be a potential relationship between the makerspace station and the learning dimension. For example, all five learning dimensions were higher in the 3D printing station than the rest. A summary of how each of these dimensions was defined inside the learning dimensions framework and how each dimension was manifested at each makerspace station follows.

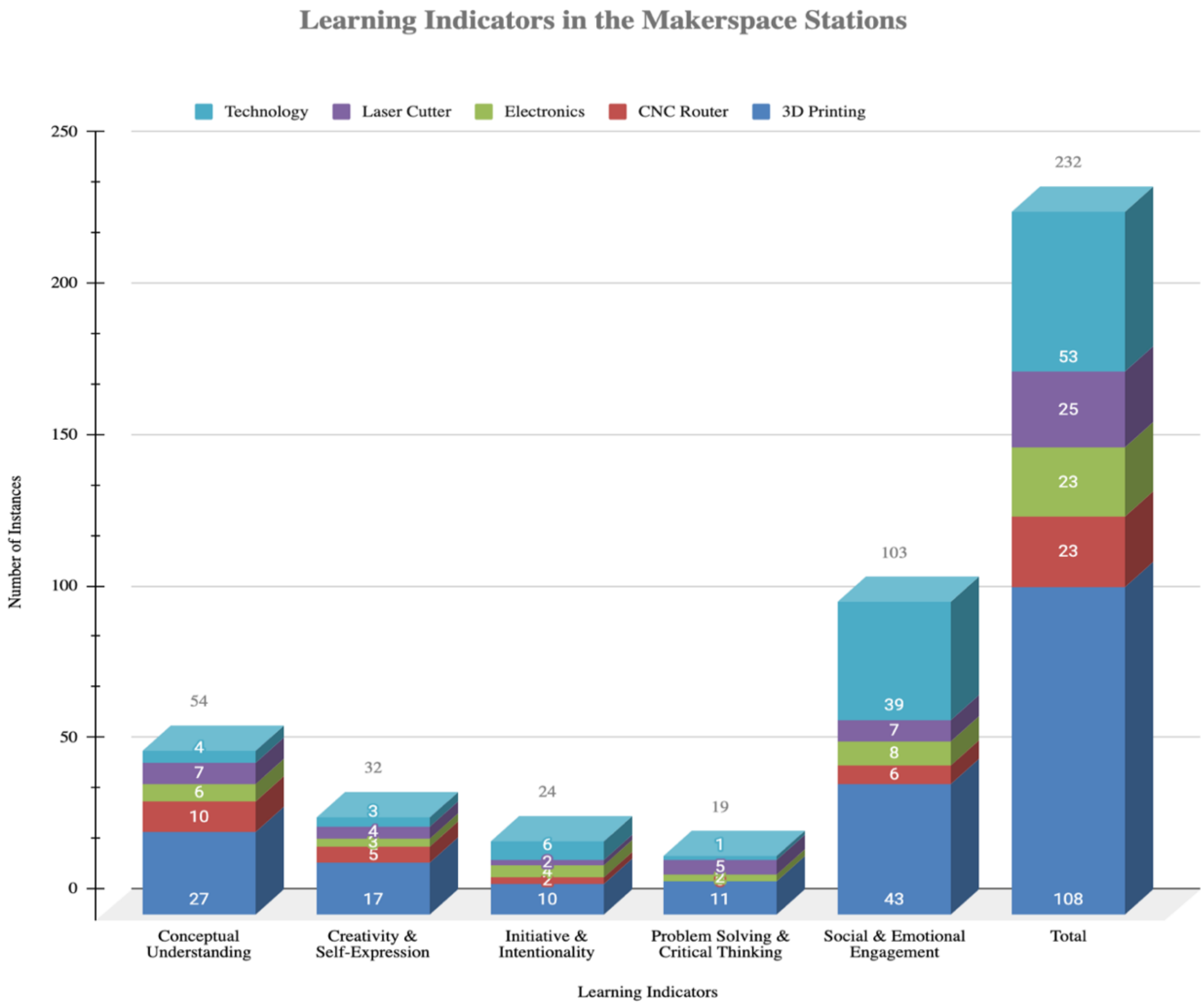

Figure 5.16 Number of Instances in All the Stations.

As each station had a different number of students, comparing the learning dimensions based on frequency would not be meaningful (see Figure 5.16). As a result, the number of dimensions for all stations was averaged (see Figure 5.17). The following section then discusses how many indicators are present in each dimension and how many are averaged across the stations.

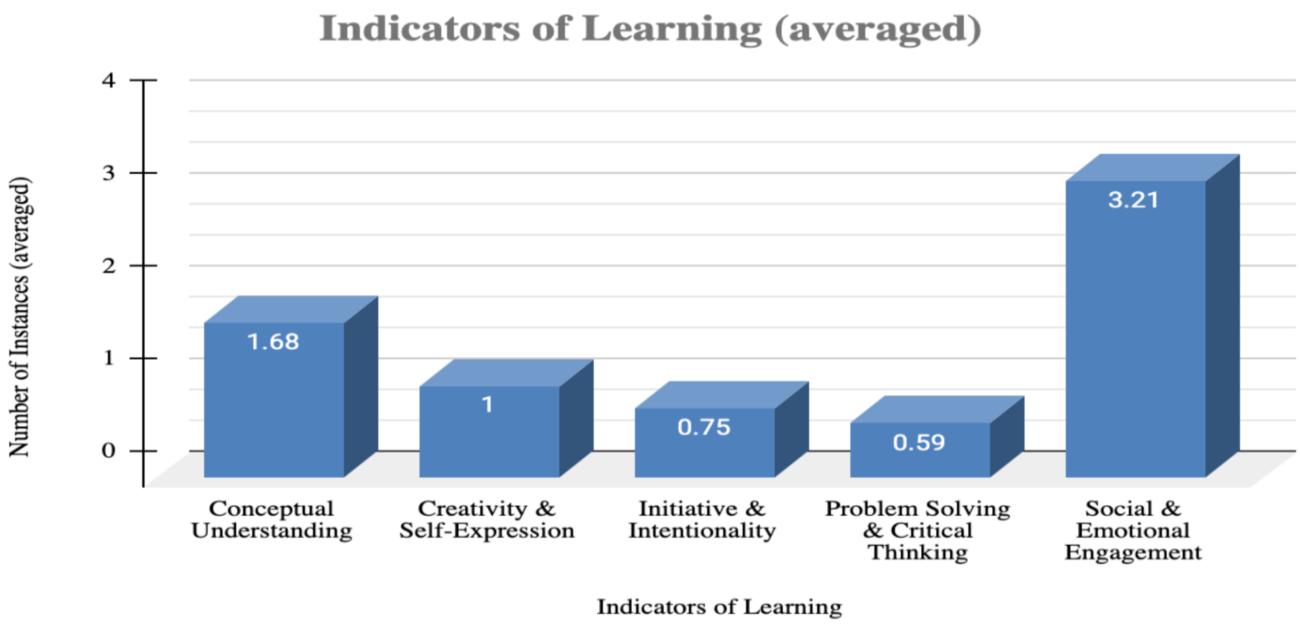

Figure 5.17 Average of the Indicators of Learning across All the Stations.

Conceptual Understanding

As shown in Table 5.7, *conceptual understanding* involves *making observations* and *asking questions, testing tentative ideas, constructing explanations*, and *applying solutions to new problems*. *Making observations, asking questions, and constructing explanations* were the most common of the five indicators within the *conceptual understanding* dimension. In all stations, the fourth indicator, testing tentative ideas, was invisible because the projects were structured, and no room was available for testing tentative ideas. Among the learning dimensions, *conceptual understanding* appeared in 54 instances, making it the second most prevalent dimension in the data. One student shared that:

> *Participant1(KOHC 3D printing station): Next time, if we encounter the same situation we faced during the creation of our model, we will avoid the problems we had while working.*

Station	Conceptual Understanding	Applying solutions to new problems	Constructing explanations	Making observations and asking questions	Testing tentative ideas
3D Printing	27	8	7	12	0
CNC Router	10	3	4	3	0
Electronics	6	1	4	1	0
Laser Cutter	7	1	3	3	0
Technology	4	1	0	3	0
Total	54	14	18	22	0

Table 5.7 Conceptual Understanding Learning Dimension across All the Stations.

Conceptual understanding was most evident in the CNC router (average 5) and 3D printing stations (average 2.7 instances) (see Figure 5.18). In contrast, it was least evident in the technology station (the interactive book project) with an average of 0.3 instances. These findings align with previous research showing that makerspaces can support students' conceptual understanding of the content (Vanderwerff, 2014).

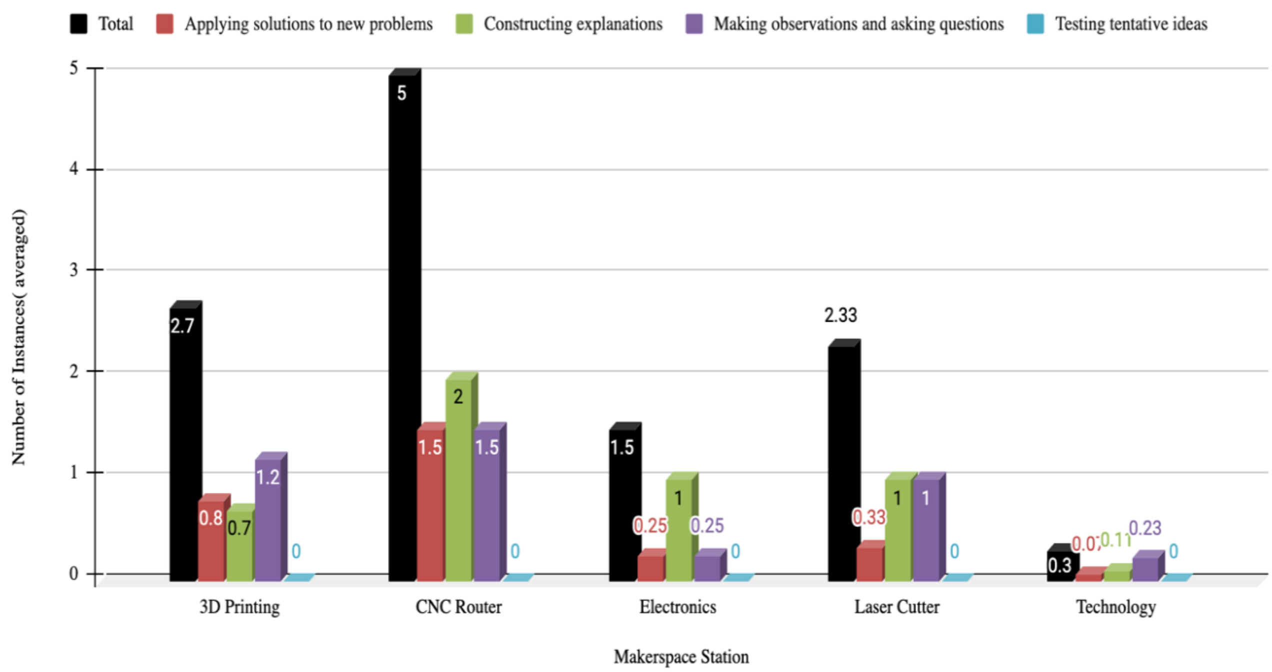

Figure 5.18 Conceptual Understanding Learning Dimension across All the Stations (averaged).

Creativity and Self-Expression

The learning dimension of *creativity and self-expression* was defined within the framework as a) *playfully exploring*, b) *responding aesthetically to materials and phenomena*, c) *connecting projects to personal interests and experiences, and* d) *using materials in novels*. This dimension was evidenced in all stations with a total of 32 instances, representing the third rank. With just two instances, *responding aesthetically to materials and phenomena* was the least reported (see Table 5.8).

Station	Creativity & Self-Expression	Connecting projects to personal interests and experiences	Playfully exploring	Responding aesthetically to materials and phenomena	Using materials in novel ways
3D Printing	17	10	4	1	2
CNC Router	5	2	2	1	0
Electronics	3	1	2	0	0
Laser Cutter	4	3	0	0	1
Technology	3	1	2	0	0
Total	32	17	10	2	3

Table 5.8 Creativity and Self-Expression Learning Dimension across All the Stations.

The most common indicators of *creativity and self-expression* dimension were *connecting projects to personal interests and experiences* with 17 cases, followed by *playfully exploring* with 10 cases. This dimension was most visible in the 3D printing station with 17 instances. *Using materials in novel ways* and *responding aesthetically to materials and phenomena* were invisible in some stations due to the nature of the project or station. For example, in the technology station, the students worked on a digital project, an “interactive math book”, and no physical material was involved. One student shared that:

> *Participant 1 (NN CNC Station): I would like to go into a major in the future that has to do with design and using software like Fusion 360.*

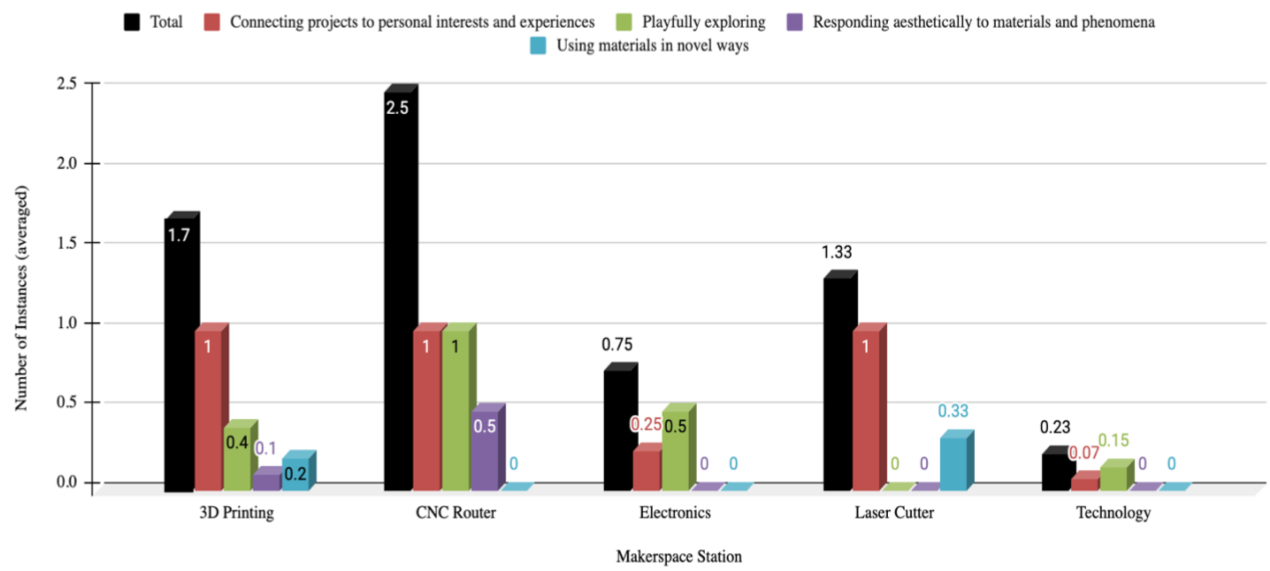

Figure 5.19 Creativity and Self-Expression Learning Dimension across All the Stations (averaged).

Figure 5.19 shows that *creativity and self-expression* were most evident in the CNC router (average of 2.5) and 3D printing stations (average of 1.7). The technology station indicated the lowest average (0.23).

Social and Emotional Engagement

A total of 103 instances of *social and emotional engagement* dimension across all stations were found within the data (see Table 5.9), which included *working in teams*, *teaching one another*, *expressing pride and ownership*, and *documenting and sharing ideas*. It is essential to note that this dimension is highly prevalent in school makerspace projects, which is an indication of how social the projects are. With 44 instances, *expressing pride and ownership* was the second most commonly occurring learning indicator. As an example of pride in their projects, the student participants in the reflective journals provided these thoughts:

> *Participant 1 (KOHC 3D Printing station): We are all satisfied with the result of our prototype.*

> *Participant 2 (ZHHC 3D Printing station): I am very proud of my group for that.*

Station	Social & Emotional Engagement	Documenting or sharing ideas with others	Expressing pride and ownership	Teaching and helping one another	Working in teams
3D Printing	43	3	19	12	9
CNC Router	6	0	3	2	1
Electronics	8	5	2	0	1
Laser Cutter	7	0	5	0	2
Technology	39	0	15	13	11
Total	103	9	44	27	24

Table 5.9 Social and Emotional Engagement Learning Dimension across All the Stations.

As shown in Table 5.9, the *social and emotional engagement* dimension was visible in all the stations. Approximately similar numbers were observed at other stations, but it was most noticeable at the 3D printing station. Despite the dimension having the largest number of instances, two indicators (*documenting and sharing ideas with others* and *teaching and helping one another*) were absent in some stations. Even though these indicators represent the social aspect of the dimension, there was no apparent reason for their absence. The reason could be that at some stations, such as the CNC, two students did not have the opportunity to help each other.

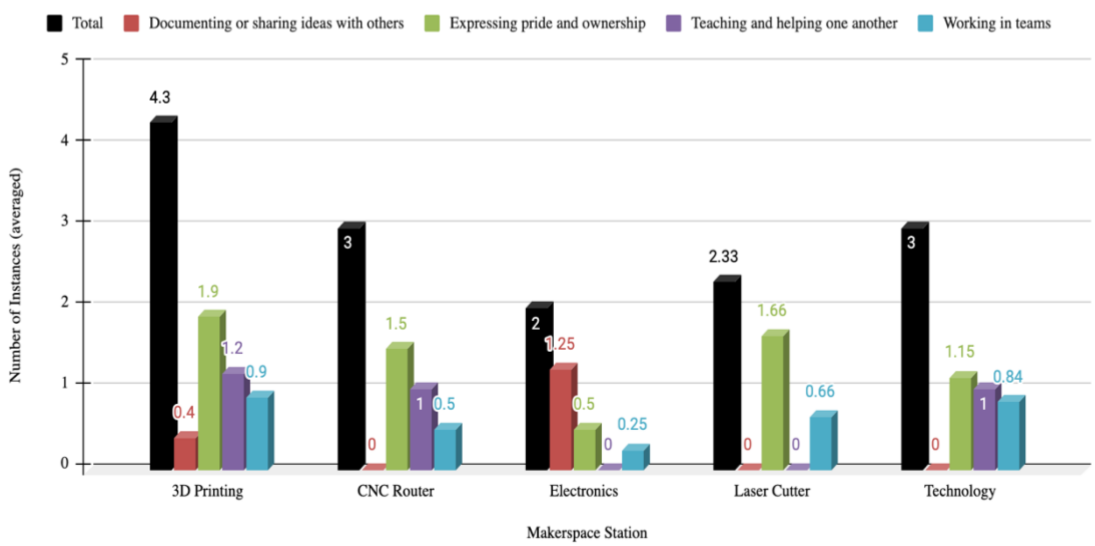

Figure 5.20 Social and Emotional Engagement Learning Dimension across All the Stations (averaged).

Figure 5.20 shows that *social and emotional engagement* was most evident in the 3D printing station, with an average of 4.3. The technology and CNC stations both showed an equal average (3).

Initiative and Intentionality

The learning dimension framework specifies four indicators within *initiative and intentionality:* a) *actively participating,* b) *setting one's own goals,* c) *taking intellectual and creative risks,* and d) *adjusting goals based on physical feedback and evidence*. The *initiative and intentionality* dimension was the fourth most frequently occurring learning dimension in the data with 30 instances (see Table 5.10). The students shared that:

> *Participant 1 (AAHC 3D printing): Our goal was to make the model perfect so that anyone can use it easily.*
>
> *Participant 2 (ZHHC 3D printing): Our goal was to help our community in any way we could, and this project satisfied our goal.*

Station	Initiative & Intentionality	Actively participating	Adjusting goals based on physical feedback	Setting one's own goals	Taking intellectual & creative risks
3D Printing	10	2	1	6	1
CNC Router	2	0	1	1	0
Electronics	4	0	0	4	0
Laser Cutter	2	0	0	2	0
Technology	6	0	0	6	0
Total	24	2	2	19	1

Table 5.10 Initiative and Intentionality Learning Dimension across All the Stations.

The *setting one's own goals indicator* appeared in most stations. The first most frequently occurring learning indicator within this dimension was *setting one's own goals* with 19 instances. The least frequently occurring learning indicator within this dimension was *taking intellectual and creative* *risks* with one instance only in the 3D printing station. Only one indicator was present in the projects with 19 instances, whereas the other three indicators were present in the data but at a lower frequency, with a total number of 5 instances (see Table 5.10).

Actively participating and *taking intellectual and creative risks* were not present in the two stations. The absence of *taking intellectual and creative risks* may be because the makerspace projects were structured with no room for taking risks. The absence of the *actively participating* indicator might be because some students faced problems during COVID-19. For example, in the laser cutter project students faced problems when using the software and asked for support during the pandemic as they could not install the software on their devices.

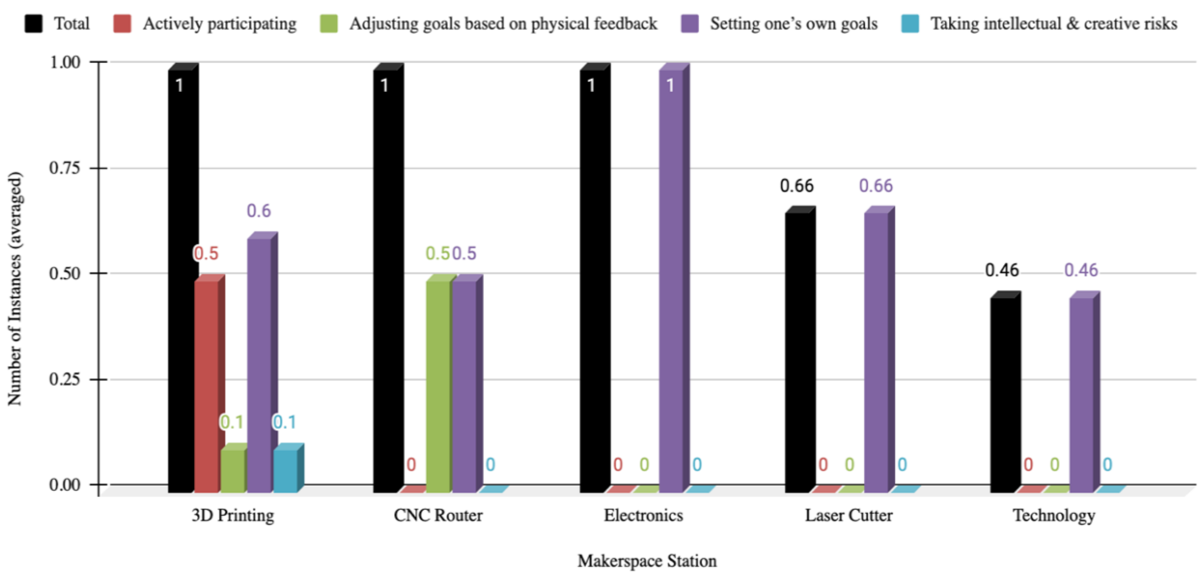

Figure 5.21 Initiative and Intentionality Indicators of Learning Dimension across All the Stations.

As shown in Figure 5.21, the *initiative and intentionality* learning indicators are the most evident in three stations (3D, CNC, and electronics) with the same average (1). In contrast, they are less evident in two stations (laser cutter and technology).

Problem-Solving and Critical Thinking

This dimension includes *troubleshooting through iterations*, *discussing the problem components*, *seeking ideas and tools, materials to solve the problem*, and *developing workarounds*. It had the lowest frequency across the data set with 19 instances arising.

Station	Problem-Solving & Critical Thinking	Developing workarounds	Dissecting the problem components	Seeking ideas, tools, and materials to solve the problem	Troubleshooting through iterations
3D Printing	11	4	1	3	3
CNC Router	0	0	0	0	0
Electronics	2	2	0	0	0
Laser Cutter	5	3	1	1	0
Technology	1	0	0	1	0
Total	19	9	2	5	3

Table 5.11 Problem-Solving and Critical Thinking Learning Dimension across All the Stations.

The most common indicator, *developing workarounds* with nine instances arising, represented the total of all instances in the *problem-solving and critical thinking* dimension (see Table 5.11). The overall frequency of *problem-solving and critical thinking* was lower throughout the data set, and the occurrences varied between the four indicators. There were no instances in the CNC router. The reflective journal supports the absence of indicators for the CNC router as the students indicated that they faced many problems during the COVID-19 period, and the machine was complicated. Additionally, one student expressed their desire to operate the physical machine:

> *Participant 1 (CNC router station): If I had more resources and time, I would like to learn more about the engine/motor part of the vehicle. If it were possible, we could also make the motor ourselves and work on the physical CNC router.*

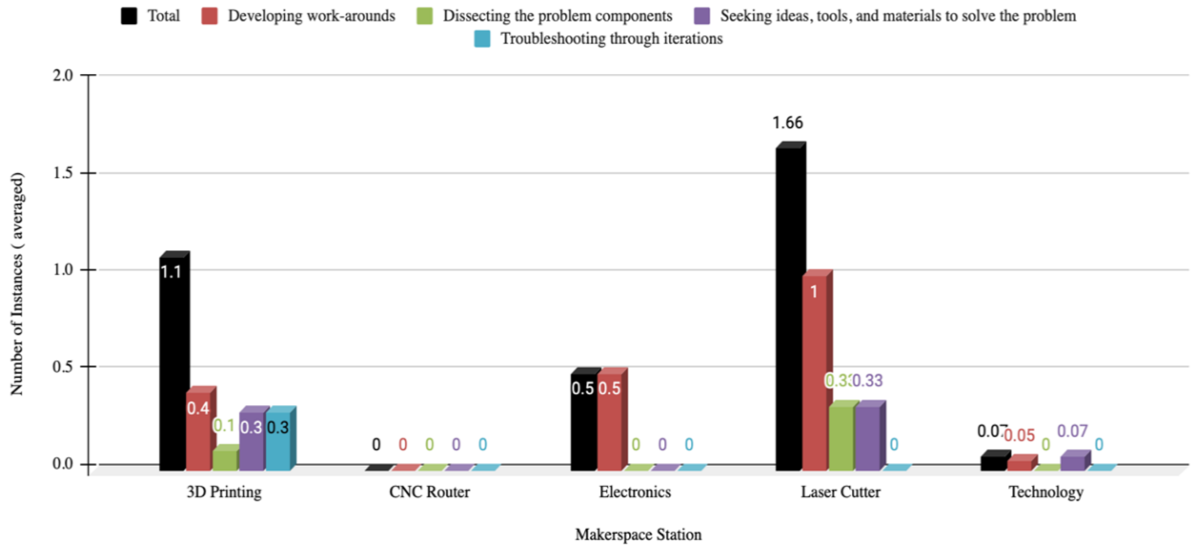

Figure 5.22 Problem-Solving and Critical Thinking Learning Dimension across All the Stations.

As shown in Figure 5.22, *problem-solving and critical thinking* was most evident in the laser cutter station with an average of 1.66 instances and in 3D printing with an average of 1.1 instances. It was less evident in the technology station with an average of 0.07 instances, while the CNC station had no occurrence of the dimension.

5.3.4.1 Summary

The students who worked in the 3D printing station revealed, on average, a higher level of learning indicators across all learning dimensions compared to the students who attended any of the other stations. All stations displayed learning dimensions but at different frequencies and the identifiable indicators of learners' learning varied by station. Although some students had negative experiences at their stations, as evidenced by their reflective notes, it was clear that they gained valuable skills. For example, in the 3D printing station, the students faced problems installing the 3D designing software. The students at the technology station were not happy because their work did not involve any hands-on projects. Overall, the researcher was able to identify how the students displayed their learning in the makerspace stations via the long-term projects through the learning indicators that appeared. This provided support for the researcher's argument that the students developed a wide variety of skills. Nine themes emerged from the observational notes analysis, which supports the claim that the pupils acquired a wide range of skills (see Figure 5.5). According to the findings, some students gained different skills and more than others. This will be discussed in the chapter that follows, along with the learning evidence and the value of the long-term projects.

To conclude, the most significant difference was apparent in the 3D printing and CNC stations (with the highest average) and the technology and electronics stations. On average, the students who worked on the 3D printing and CNC stations demonstrated 10.8 or 11.5 instances arising of learning indicators compared to 5.75 and 4 instances at the electronics and technology stations respectively (see Figure 5.23). Furthermore, as some students were inspired to buy 3D printers or open their 3D companies, the 3D printing station had the most (17) instances for the learning indicator of *connecting projects to personal interests and experiences*. In the next chapter, some of the factors contributing to this difference in the learning dimensions will be discussed, especially why the technology station had the lowest average (4) and the implications behind these results. The next chapter will also discuss the results through the lens of the makerspace quadrant and emergent themes to help explain the differences in the learning dimensions across the stations.

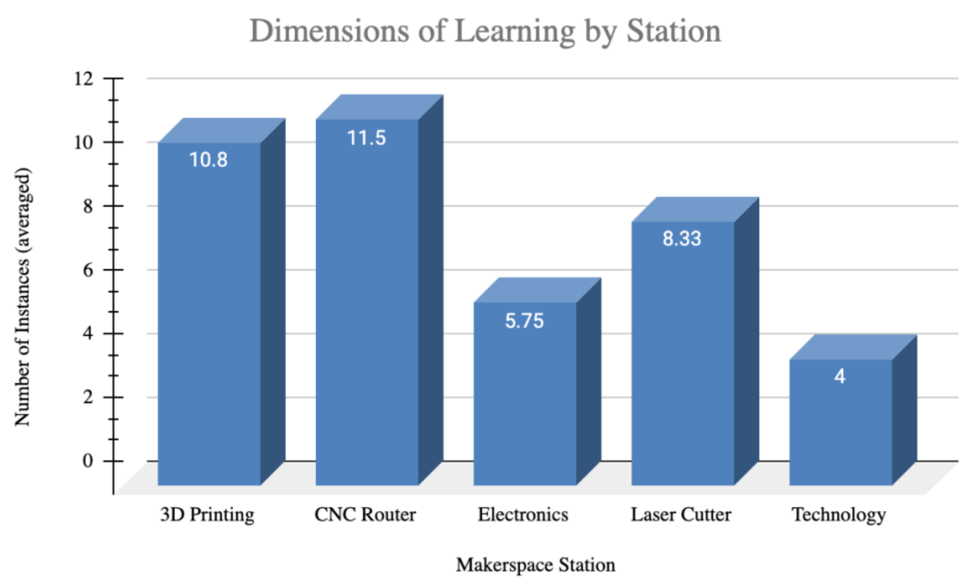

Figure 5.23 Dimensions of Learning by Stations Averaged across All the Stations.

5.3.5 Sub-question 5: How do different stations in a school makerspace contribute to learners' acquisition of life skills that could help them develop future career skills?

This sub-question was answered using an online survey to gain a deeper understanding of the students' perspectives on how a school makerspace contributes to their acquisition of life skills that could prepare them for future career skills. Additionally, the second part of the teachers' online survey contained questions related to career skills. This section contains two subsections: 1) the results from the students' survey; and 2) the results from the teachers' survey. Seventy-nine students participated in this survey (see Figure 5.24). The following subsection will reveal the results of each question in the survey across all stations.

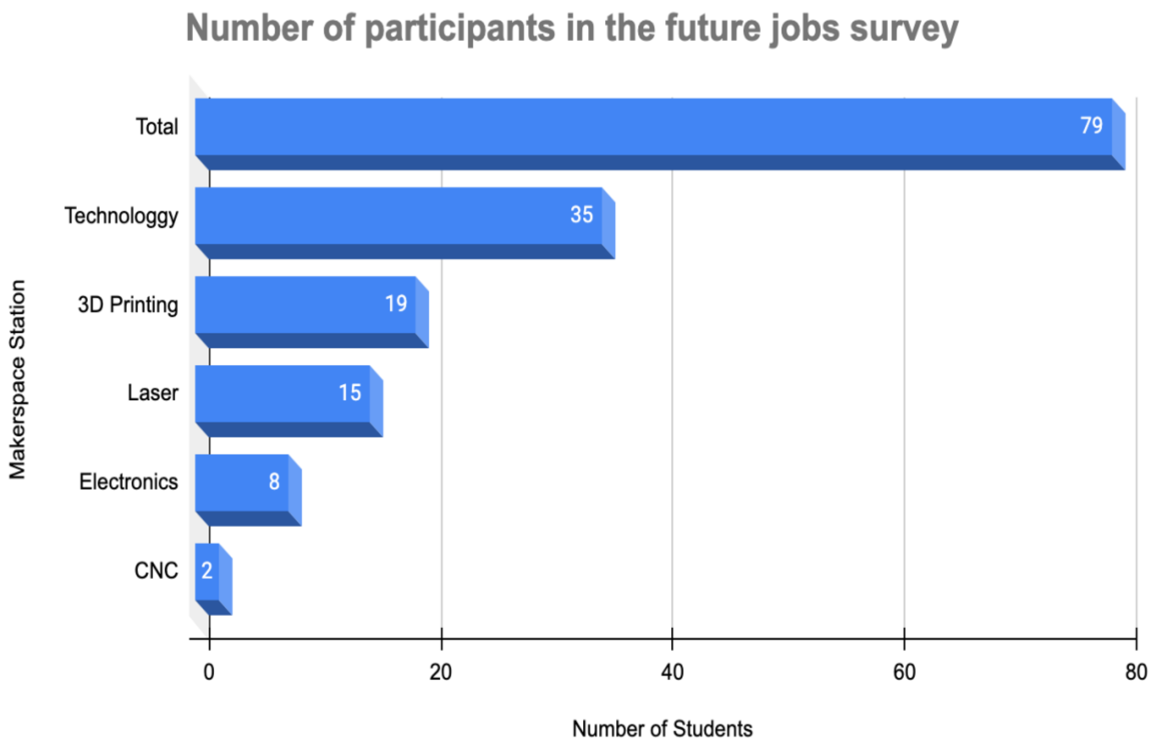

Figure 5.24 Number of Student Participants in the Future Jobs Survey.

5.3.5.1 Results from the Students' Survey

How have you changed? I am more aware of different careers

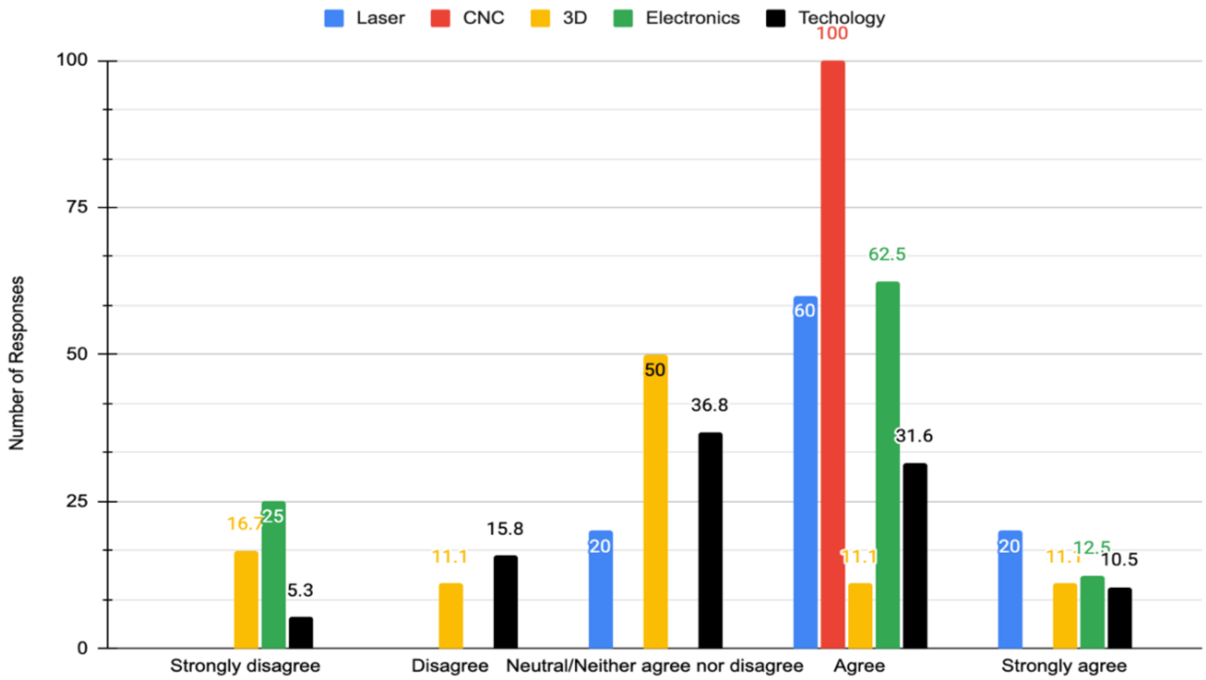

Figure 5.25 How have you changed? I am more aware of different careers

In Figure 5.25, all students (two students) in the CNC station agreed that working at these stations made them more aware of different careers. More than 60% of students (five) in the electronics station indicated that working in these stations made them more aware of different careers, while 60% (nine students) indicated the same for the laser cutter station. The highest percentage of students who strongly disagreed with the statement was from the electronics stations (25%, two students) and the 3D printing station (16.7 %, three students). The most interesting aspect of this graph was that only the two stations with heavy machines (laser and CNC) did not strongly disagree with the statement that the makerspace made them more aware of different careers. This might be interpreted due to the nature of the two stations, which include heavy machines that may open up awareness to different jobs. The observational notes confirm this result as one student stated that the project was useful if he or she wanted to pursue an engineering career.

I have more ideas about my future career

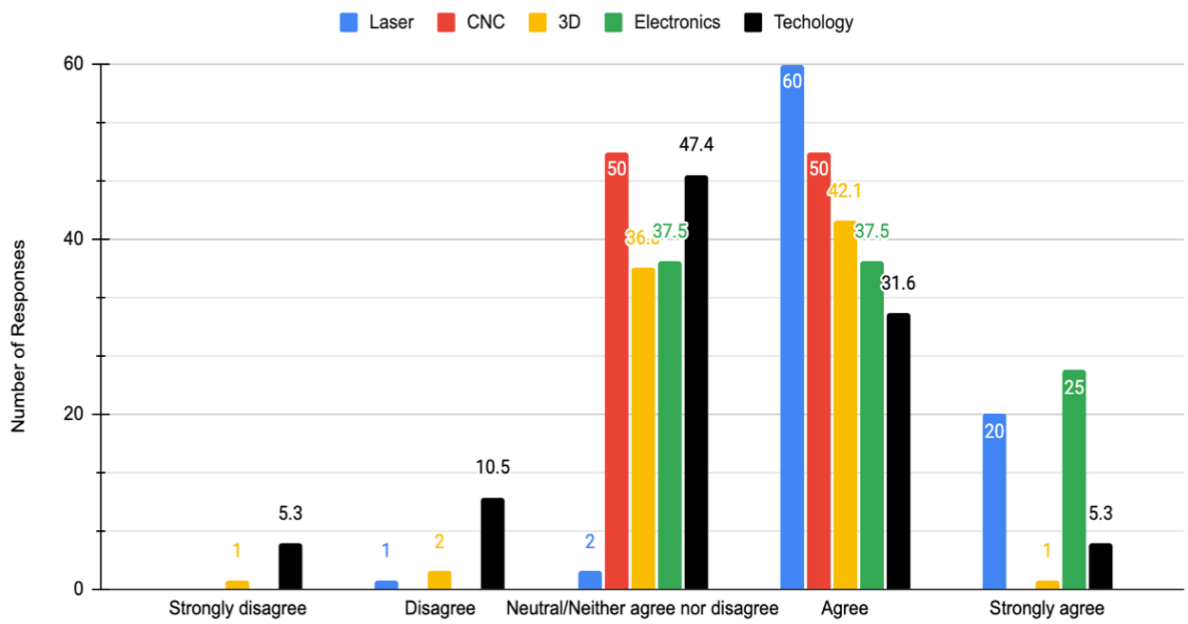

Figure 5.26 I have more ideas about my future career.

Figure 5.26 reveals that the students in all stations agreed that working in the makerspace gave them more ideas about their future careers. The highest percentage was evident in the laser cutter (60%, nine students), CNC (50%, two students), 3D (42.1%, eight students), and technology (47.4%, nine students) stations. Interestingly, the CNC and laser stations had no report of non-agreement regarding the students having more ideas about their future careers after working on the makerspace projects. One student shared the following:

> *In turn, this would relate to my community because it would benefit them if I pursued a career in Engineering or Design.*

I am clearer about what I need to do to achieve my ambitions

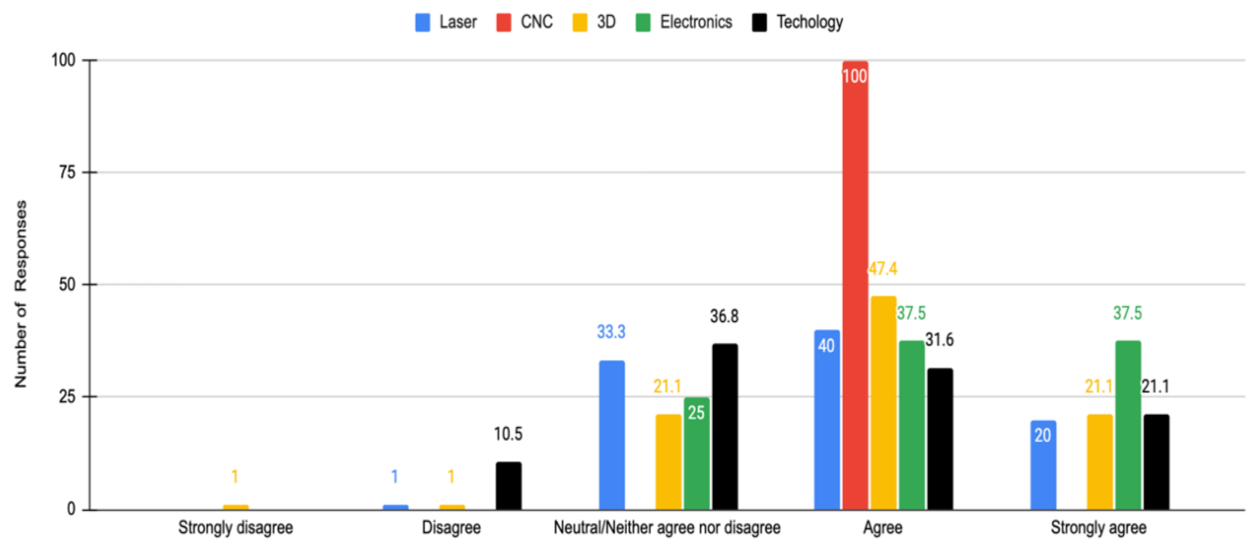

Figure 5.27 I am clearer about what I need to do to achieve my ambitions.

The data in Figure 5.27 indicates that all students who participated in the makerspace projects in the CNC station agreed that the projects helped them clarify what they needed to achieve their ambitions. Forty-seven point four per cent (nine students) from the 3D station and 40% of students (six students) from the laser station also agree with the statement. Only a total of 13.5% (five students) either disagreed or strongly disagreed that working on the makerspace projects helped clarify some of the needs related to achieving their ambitions, a large proportion of which were from the technology station (see Figure 5.25).

I know more people who can help me achieve my ambitions

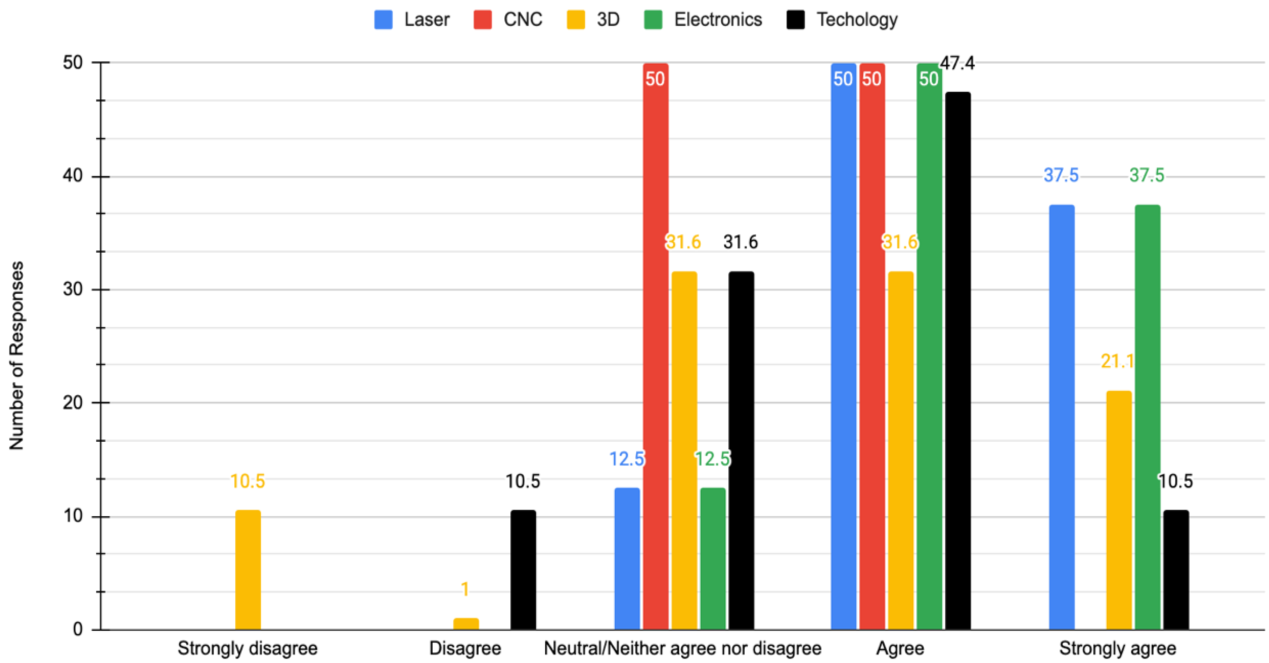

Figure 5.28 I know more people who can help me achieve my ambitions.

The students' agreement with knowing more people who could help them achieve their ambitions is present for all the stations (see Figure 5.28). However, more than 10.5% (two students) pooled from the technology station disagreed, which could be attributed to the digital nature of the technology station. Ten point five per cent (two students) from the 3D printing station strongly disagreed, which might signify students were not interested in these projects as they did not have the passion for working in 3D printing-related jobs or they had not decided on their jobs yet.

I am more motivated to work hard at school/college

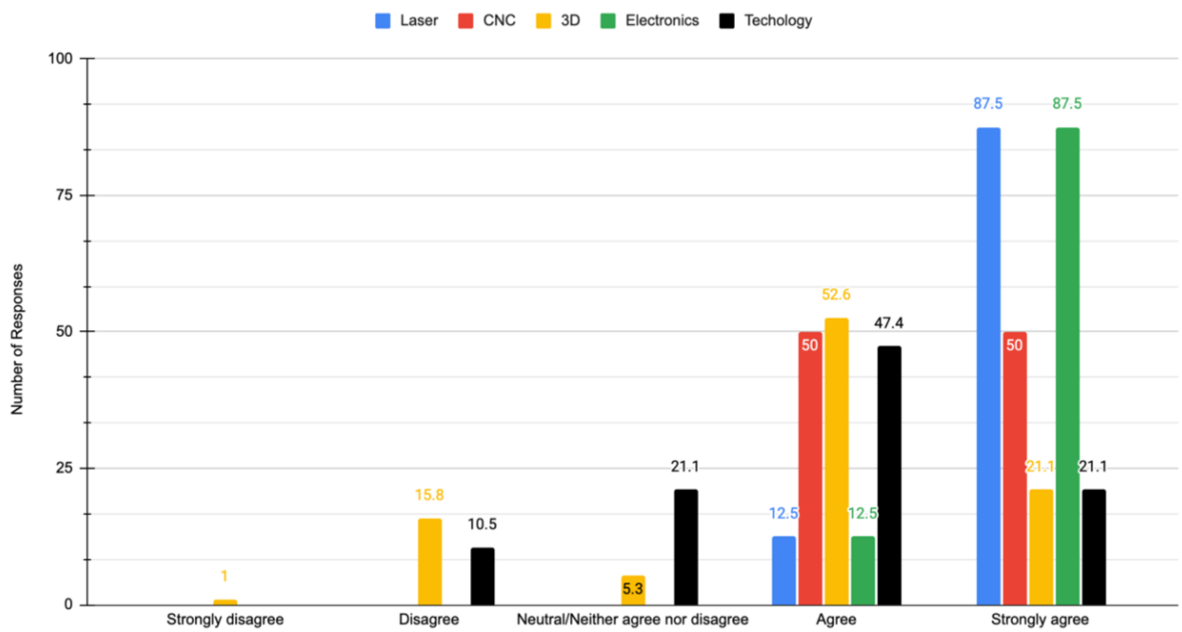

Figure 5.29 I am more motivated to work hard at school/college.

Most of the students agreed or strongly agreed that working on the makerspace projects motivated them to work hard at school or college. The highest percentage was evident in the electronics and laser cutter stations, with 100% each in total. Fifteen point eight per cent of students (three) in the 3D printing and 10.5% (two students) in the technology stations disagreed or strongly disagreed (see Figure 2.29). One of the student participants shared his experience:

> *I feel I have benefited a lot from this project, not only the knowledge of how and what to do in a design situation, but also vital life skills. I will be using these skills throughout not only my academic career, but throughout my life entirely.*

Careers readiness/decide what your ideal job would be

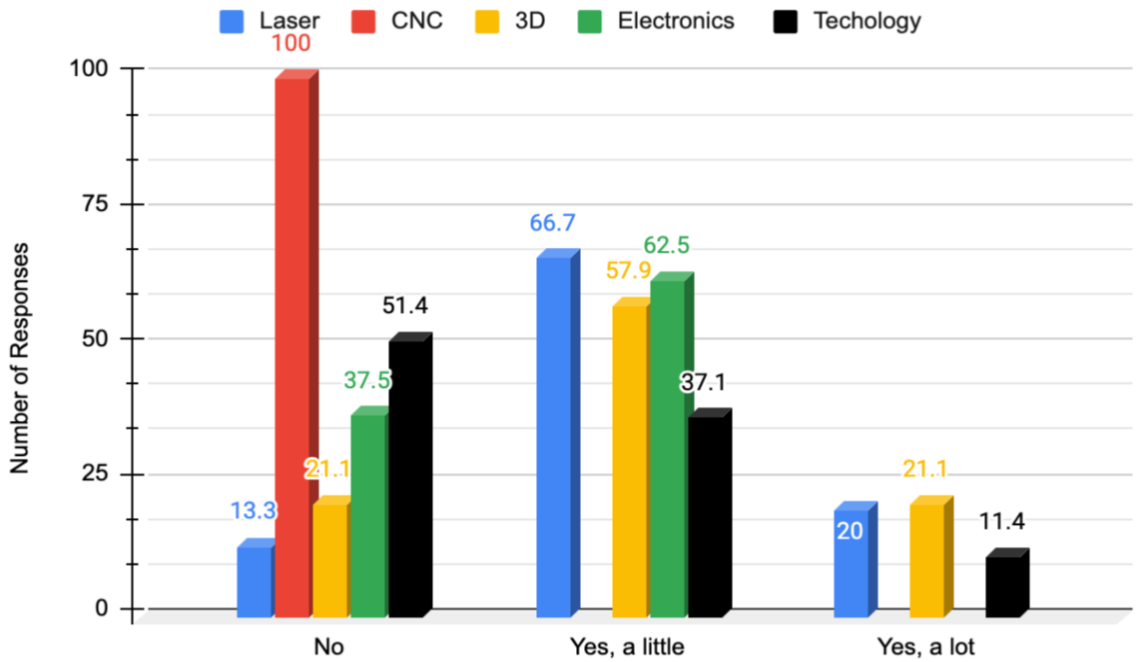

Figure 5.30 Decide what your ideal job would be.

Those who agreed that working in the makerspace helped them decide on their ideal job cut across all stations, except for the CNC station. All students in the CNC station disagreed that working there helped them decide on their ideal job (see Figure 5.30). The overall response to this question was not very positive as some students indicated that working in the makerspaces did not help them to decide what their ideal job would be or that it only helped a little. This result might be explained by the fact that the students were from different grades (9 and 10) and some of them had not yet started to think about their ideal job. The results might have been different if the students were from STEAM or science departments.

Assess your strengths and weaknesses

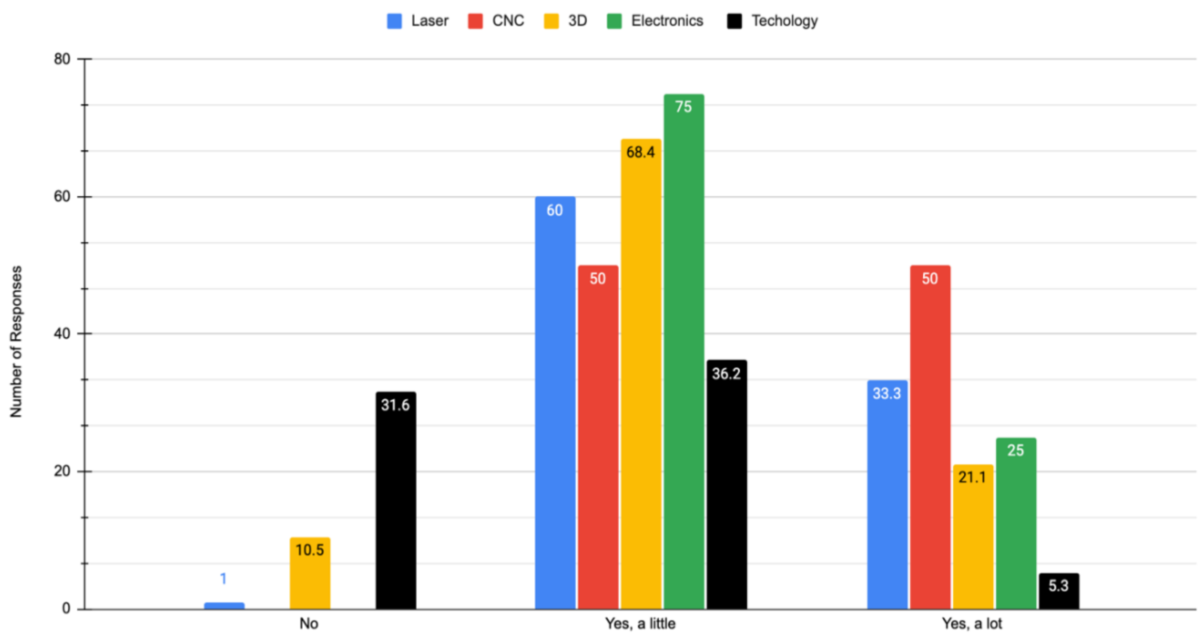

Figure 5.31 Assess your strengths and weaknesses.

The graph in Figure 5.31 reveals that students reported that working in the makerspace helped them assess their strengths and weaknesses, which was evident in all the stations, especially electronics, 3D printing, CNC and laser stations. There was evidence that less than 32 % of students (six) who worked in the technology station did not assess their weaknesses or strengths, including 10.5% (two students) in the 3D printing station.

Make a plan of your goals for the next five years

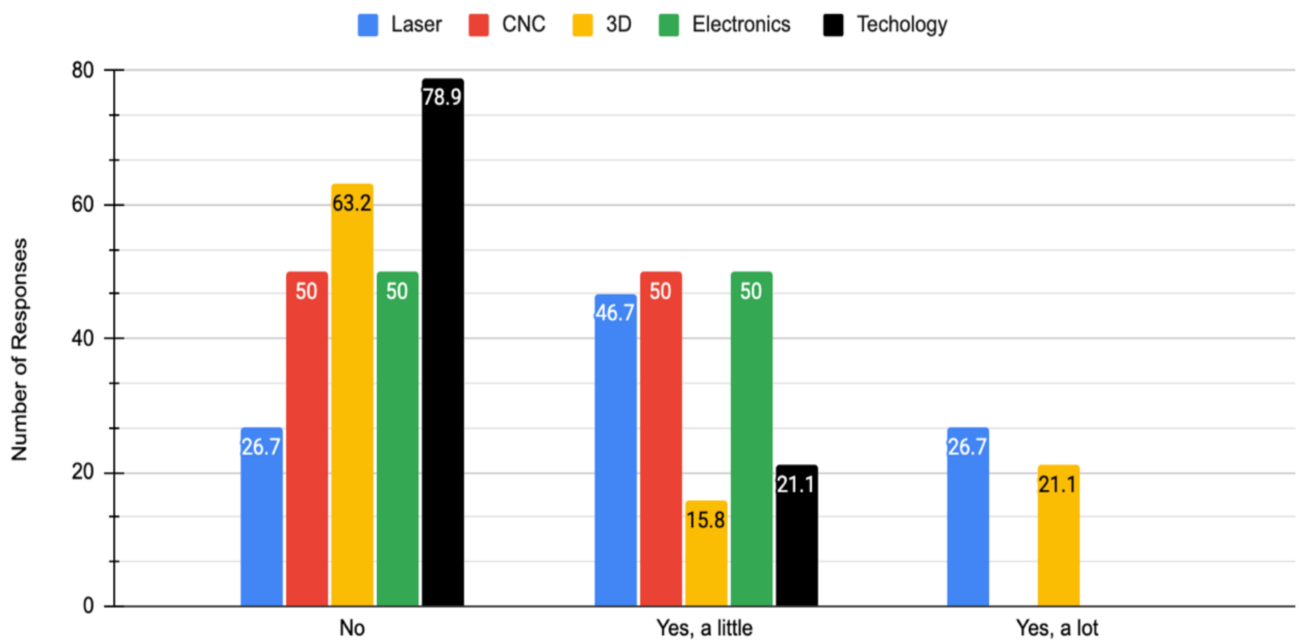

Figure 5.32 Make a plan of your goals for the next five years.

As shown in Figure 5.32, the findings indicated that around half of the students agreed that working in the makerspace helped them to make a plan of their goals for the next five years. The other half of the students disagreed; 78.9% (15 students), 63.2% (12 students), 50% (one student) and 50% (four students) and were in the technology, 3D, CNC, and electronics stations respectively. These findings should be read in context, as the researcher's school had no career counsellor who could help the students think about their future careers and make plans in relation to their goals.

Think about whether moving straight to work after school is right for you

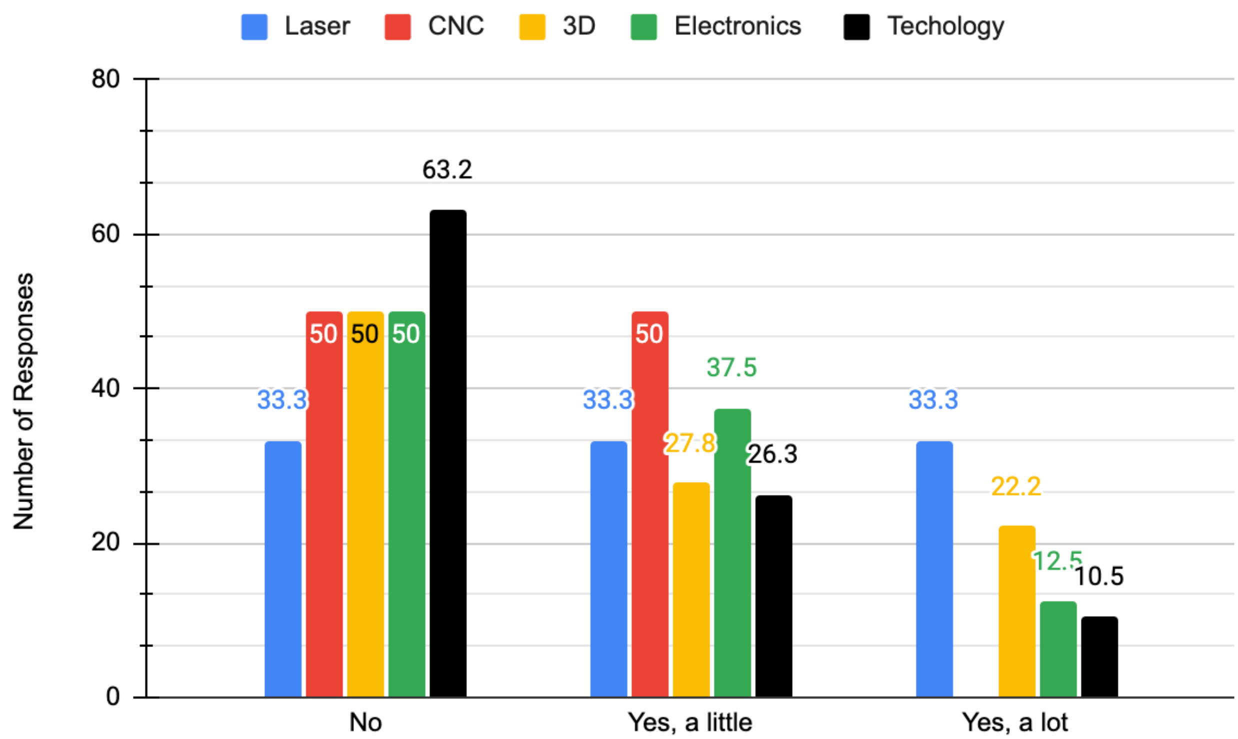

Figure 5.33 Think about whether moving straight to work after school is right for you.

The results from Figure 5.33 reveal that around 50% of respondents (around forty) in all stations disagreed that working in the makerspace let them think about whether moving straight to work after school was right for them. The findings reflect some of the cultural aspects of Kuwaiti students who are very wealthy and do not consider working until they graduate from university. Additionally, they do not do a great deal of work in their daily life, as they depend heavily on maids and drivers.

Think about whether further education is right for you

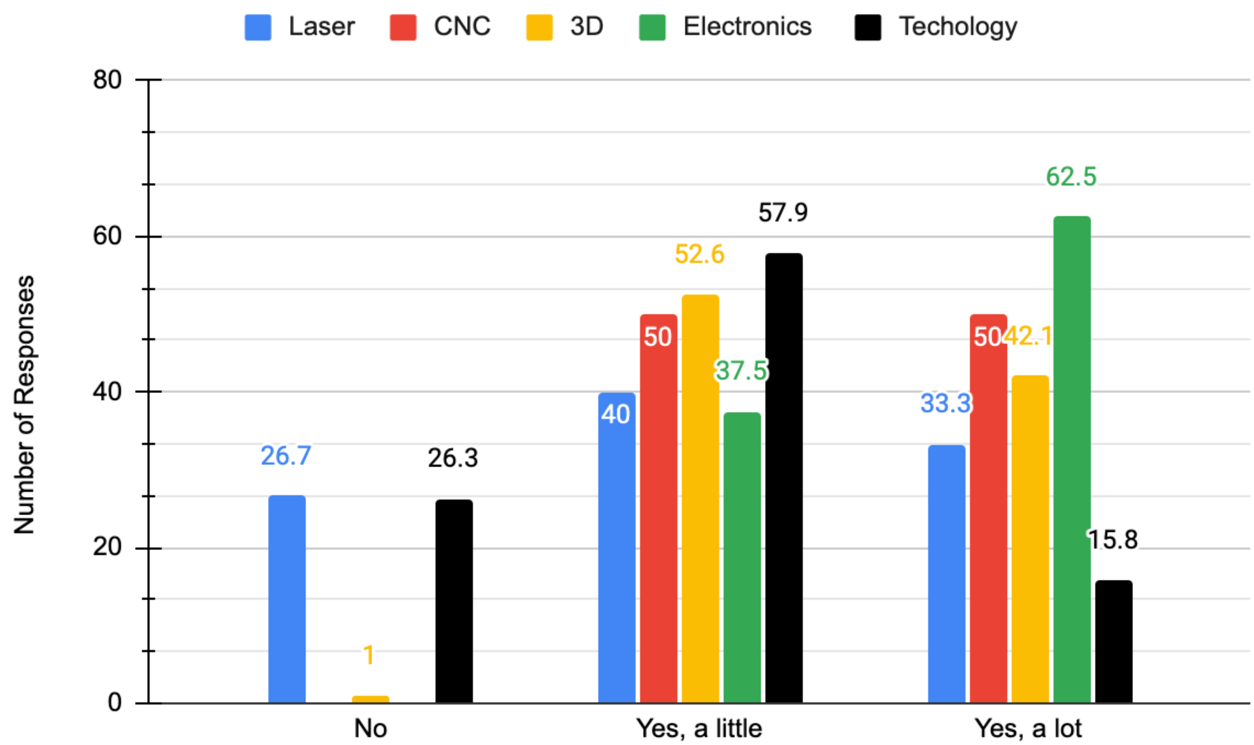

Figure 5.34 Think about whether further education is right for you.

As shown in Figure 5.34, most students agreed that working in the makerspace helped them think about whether further education is right for them. The highest percentage was evident in the electronics, CNC, and 3D printing stations. Two students in the electronics stations and 3D printing station asked their teachers to help them prepare a maker portfolio from their projects to use these in the admission process to their universities.

Seek help and support with your future education and career when you need it

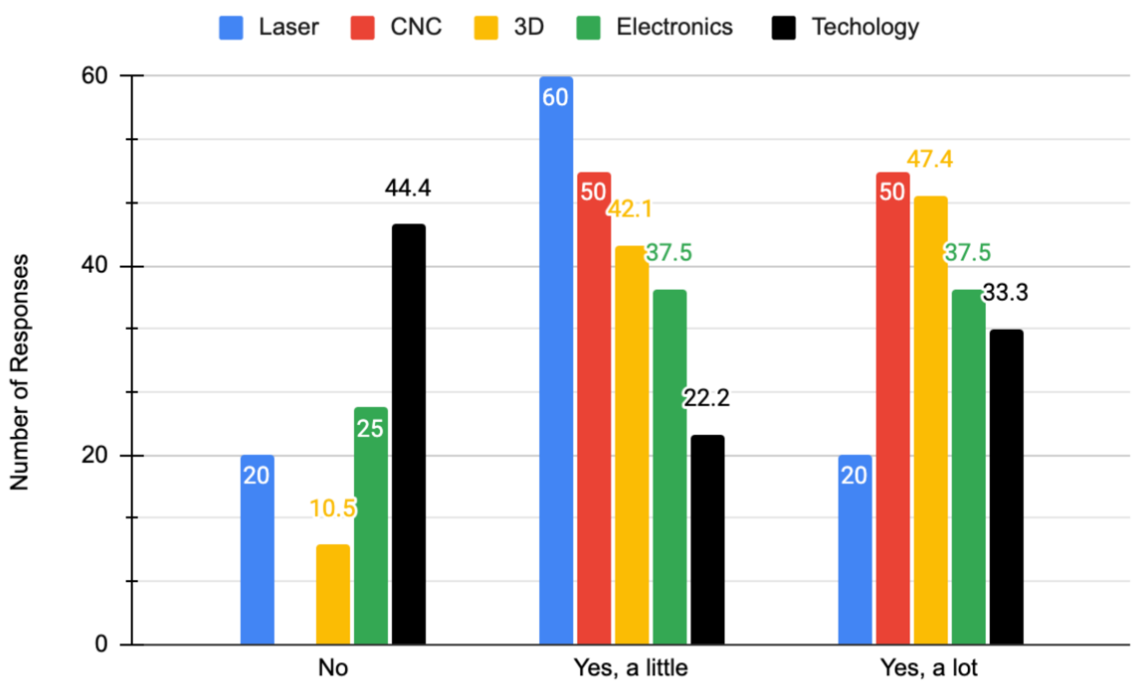

Figure 5.35 Seek help and support with your future education and career when you need it.

Most students indicated that working in the makerspace helped them to seek help and support with their future education and career when they needed it (see Figure 5.35). One of the activities that supports this finding is inviting an expert to introduce new topics. For example, the researcher's school hosted a speaker to talk about design thinking and its need for engineers.

5.3.5.1.1 Summary

In general, the survey results reveal that the students have changed after working on the projects in every station to varying degrees. The technology station, however, reported fewer signs of such change. As far as career readiness was concerned, this was evident in all stations to varying degrees. However, it was less visible and lower in the technology station. The results of this study are expected to reveal some of the emerging themes that might provide insights into how school makerspaces are designed and what the learners believe about learning. Based on these results, the students developed their career-oriented approach by working in the makerspace stations overall, except for the 3D printing and technology stations. This might be explained by the nature of each station. For example, with 3D printing, the students faced many problems when installing the 3D design software and in the technology station, the activity was fully digital and did not include any physical activity.

In comparison to the reflective journals, the results of the student survey suggest a significant difference between academic skills and career skills. For example, even though the 3D printing station had the highest number of learning indicators, it had one of the lowest reported frequencies regarding preparing students for their future careers, likely due to the limitations of 3D printing solutions and the problems that the students could face. Since it is said that many of today's school students will work in jobs that have not yet been invented, the next section outlines the benefits from a teacher's perspective, revealing how makerspace projects can help them prepare for their future careers.

5.3.5.2 Results from the teachers' survey

This subsection will present the findings of the second part of the teachers' survey, which focused on life and career skills. This section will cover adaptability, flexibility, initiative, and self-direction, working independently, and becoming self-directed learners.

Adaptability

Out of the seven teachers who participated in this survey, five teachers stated that their students worked effectively in a climate of ambiguity and changing priorities (see Figure 5.36). Two teachers reported that their students were able to work effectively in the face of ambiguity and shifting priorities. In the laser cutter station where the students designed a maze, the students expressed their ideas, which reflected how they were adaptable:

> *Our ideas for the maze are as follow:*
>
> *Using this maze for kids at school*
>
> *Selling it to kids as well.*
>
> *Birthday parties, so, they can benefit from it constantly*.

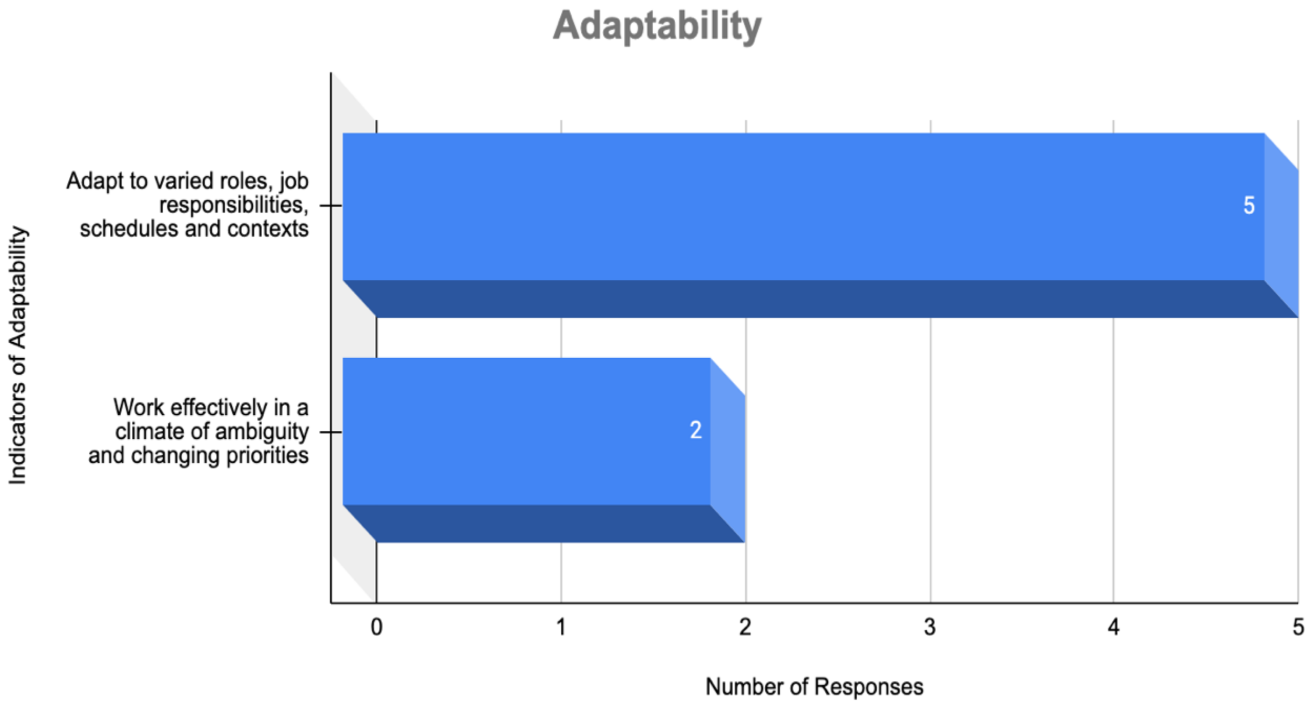

Figure 5.36 Adaptability.

Flexibility

Five teachers stated that their students incorporated feedback effectively and dealt positively with praise, setbacks, and criticism (see Figure 5.37). Four teachers indicated that their students understood, negotiated, and balanced diverse views and beliefs to reach workable solutions, particularly in multicultural environments.

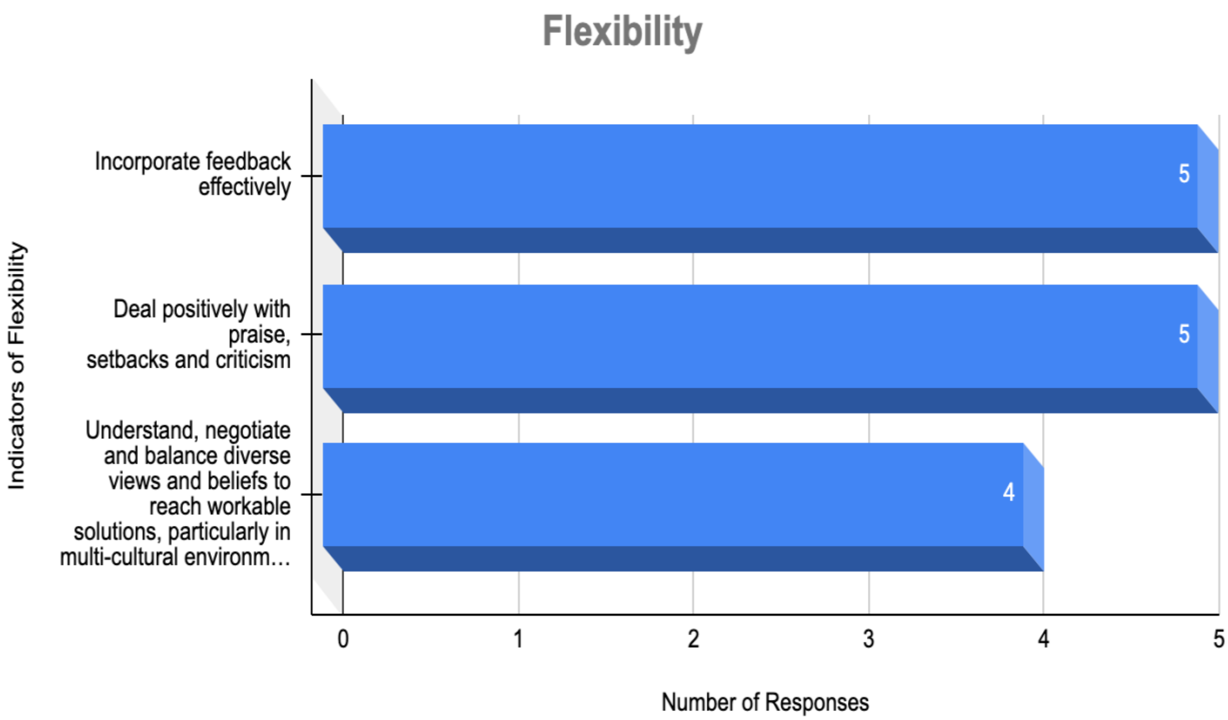

Figure 5.37 Flexibility.

Initiative and Self-Direction

Of all the survey participants, six of the seven teachers indicated that their students managed their goals and time, set goals with tangible and intangible success criteria, utilised their time and managed their workload efficiently. Five of them reported that their students developed balanced tactical (short-term) and strategic (long-term) goals (see Figure 5.38).

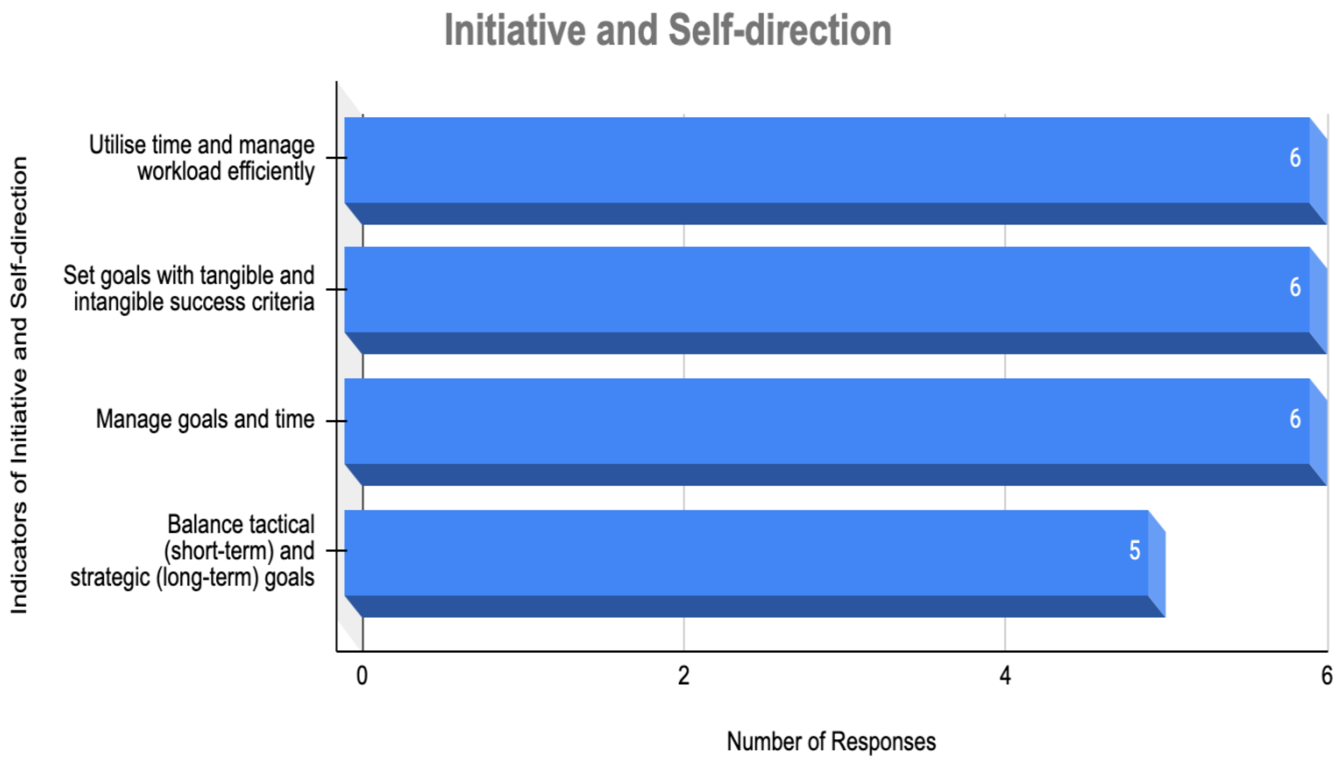

Figure 5.38 Initiative and Self-Direction.

Working Independently

All seven respondents indicated that their students monitored, defined, prioritised, and completed tasks without direct oversight (see Figure 5.39). These findings align with the nature of the makerspace projects, which were structured in their design. For example, in the laser cutter and 3D printing projects, the students watched a short video in each lesson on how to do specific tasks.

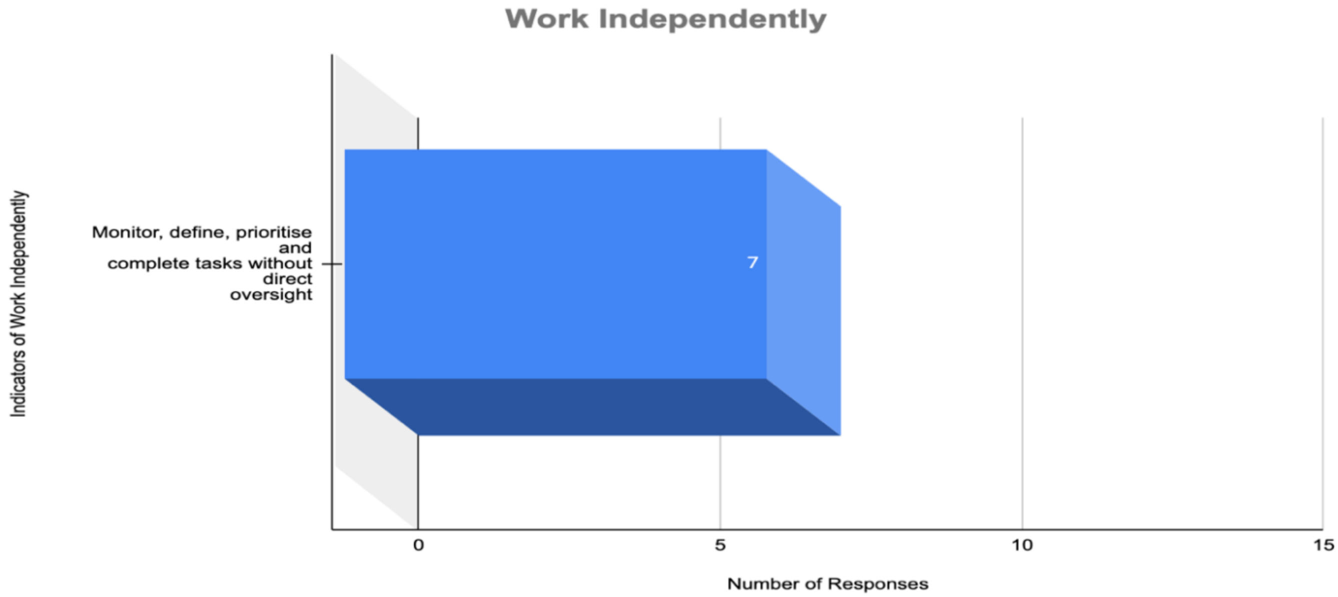

Figure 5.39 Work Independently.

Be Self-directed Learners

Half of the survey respondents indicated that their students were committed to learning as a lifelong process. Three teachers agreed on how their students did more than master the curriculum and skills; they explored and expanded their own learning and developed expertise. Only one teacher indicated that their students demonstrated a commitment to learning as a lifelong process (see Figure 5.40). According to Dale Dougherty, who is considered by many to be the father of the maker movement, the ability to figure out what to do is what differentiates a student who is directed to perform a task from one who is self-directed, as in the projects that take place in makerspaces (Dougherty, 2013).

One incident which supports how the makerspace project can support the students in becoming self-directed in their learning is the unique design of Ali's car. Ali did not follow the instructions from his teachers and created a different, unique design. Ali shared the following about his design:

> *I did not do the same design as the rest, which was wrong, I cannot say mine was better, but my design was made by me personally without a single help and I did not even watch a single video. I thought we would make our own designs, but I*

did not read them carefully. Even though it's not the same I still tried with my own creativity.

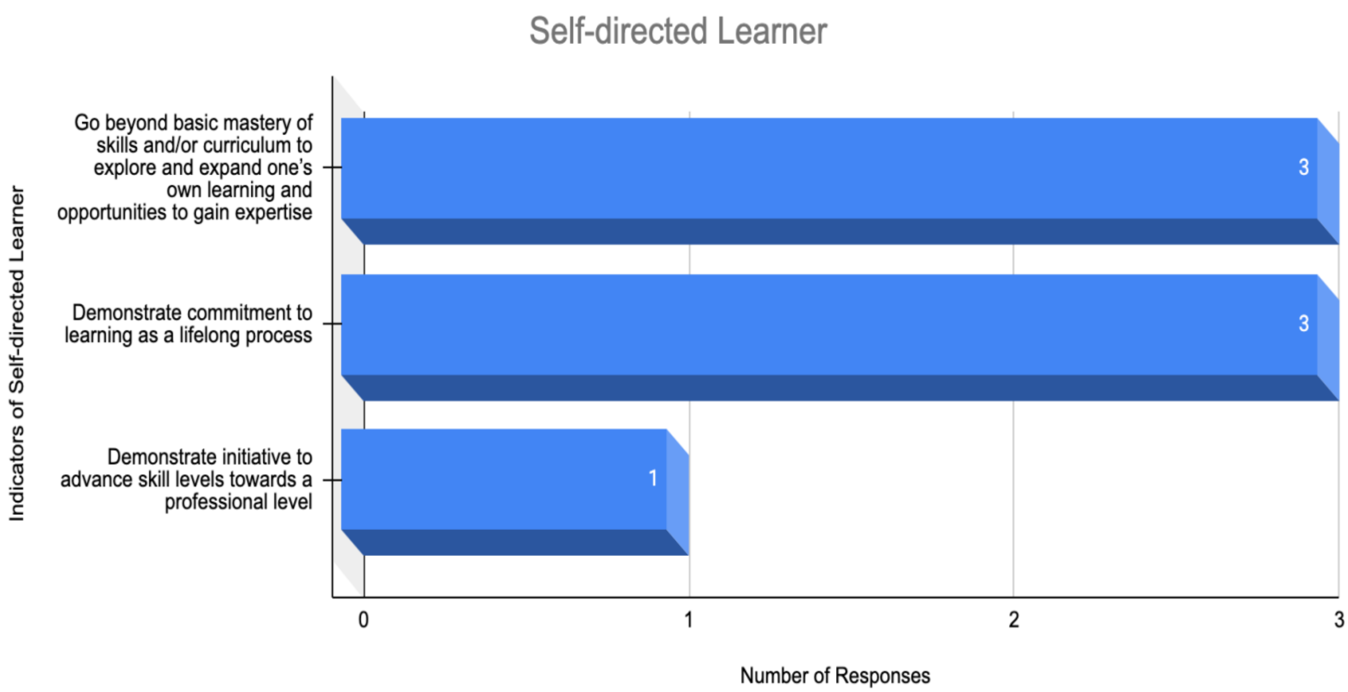

Figure 5.40 Be Self-directed Learners.

5.3.5.2.1 Summary

School makerspaces are supportive environments as students are not hindered by feelings of failure and tests. As a result, the students can become resilient, which is an essential skill for their future careers (Koul et al., 2021). Taking all of these findings into account, the findings reveal how school makerspaces can benefit students' lives in developing a career-oriented approach. For example, the teacher participants indicated that working on school makerspace projects helped many of the students become adaptable, flexible, and self-directed learners.

This result corroborates the prior subsection of the student survey which showed that makerspace projects helped many of the students develop their career skills and prepared them for life outside the classroom. Moreover, the results are consistent with the work of Nagel (2018) who reported that school administrators, teachers, and parents believe that students who complete project-based learning (PBL) in makerspaces are better prepared for college and career success. Similarly, Welbourn (2019) indicated that 'Any future job or career students consider will surely benefit from the necessary skills provided in the makerspace environment and transfer to future readiness in any job' (p. 32). The next section of this chapter will explore the results from the emergent themes, which include COVID-19, blended makerspace projects, and obstacles or challenges when using the makerspace in learning.

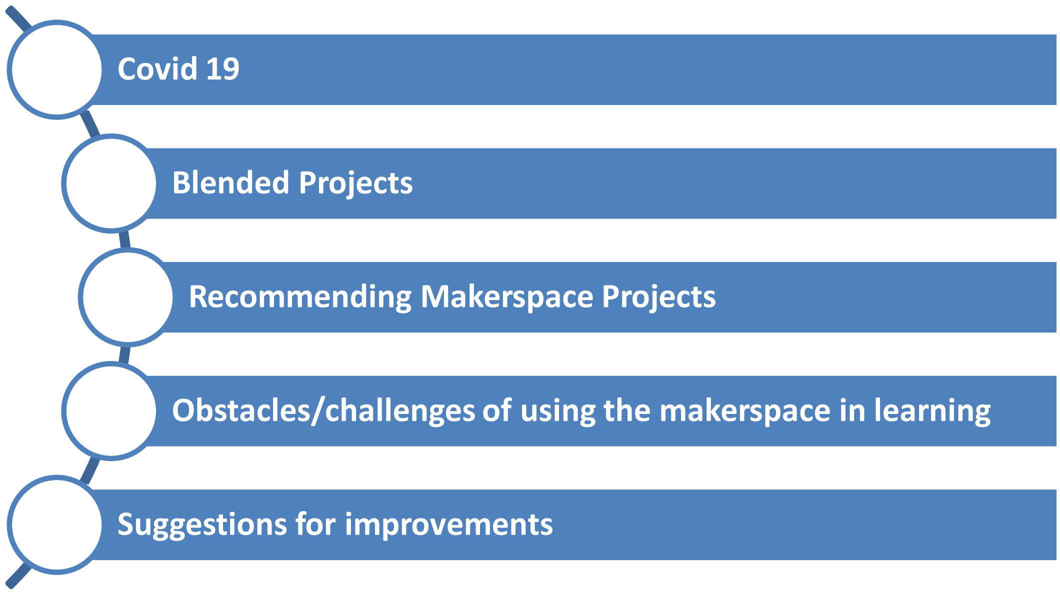

Figure 5.41 A List of Emergent Themes.

5.3.6 Other Emergent Themes from the Reflective Journals and Surveys

The findings in this section are reported as emergent themes, reflecting the major topics shared across the students' reflective journals and the comments in the teachers' surveys. As shown in Figure 5.41, five overarching themes emerged from analysing the reflective journals and surveys across the stations. The relationship of these themes with learning and teaching will be discussed in the next chapter.

COVID-19

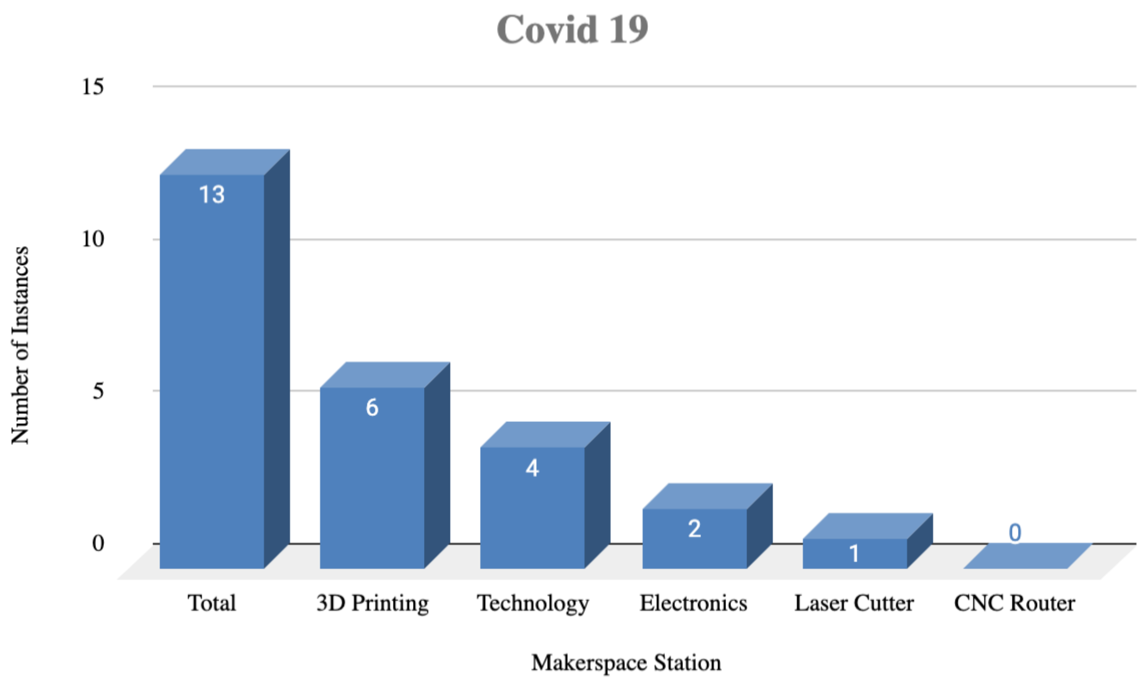

Figure 5.42 COVID-19 Instances.

As this study was conducted during the COVID-19 pandemic, this was an emergent theme in the makerspace stations (see Figure 5.42) as it affected the makerspace projects and was mentioned several times in the reflective journals of the students. The COVID-19 theme was most evident in the 3D printing station with six instances reported. In the technology station, it was evident with four instances while only two instances were reported for the electronics station. The laser cutter station had only one instance reported. Although no instances were mentioned in the reflective journals for the CNC router, some instances were evident through the observational notes. The shared comments below illustrate how COVID-19 affected the students' work in the makerspace projects:

> *Participant 1 (AA Laser Cutter Station): I miss the excitement of going to school but unfortunately, we are in a global pandemic.*

> *Participant 2 (NH Technology Station): Everything was good except the internet, so we waited for it to restart and did it.*

Blended Projects

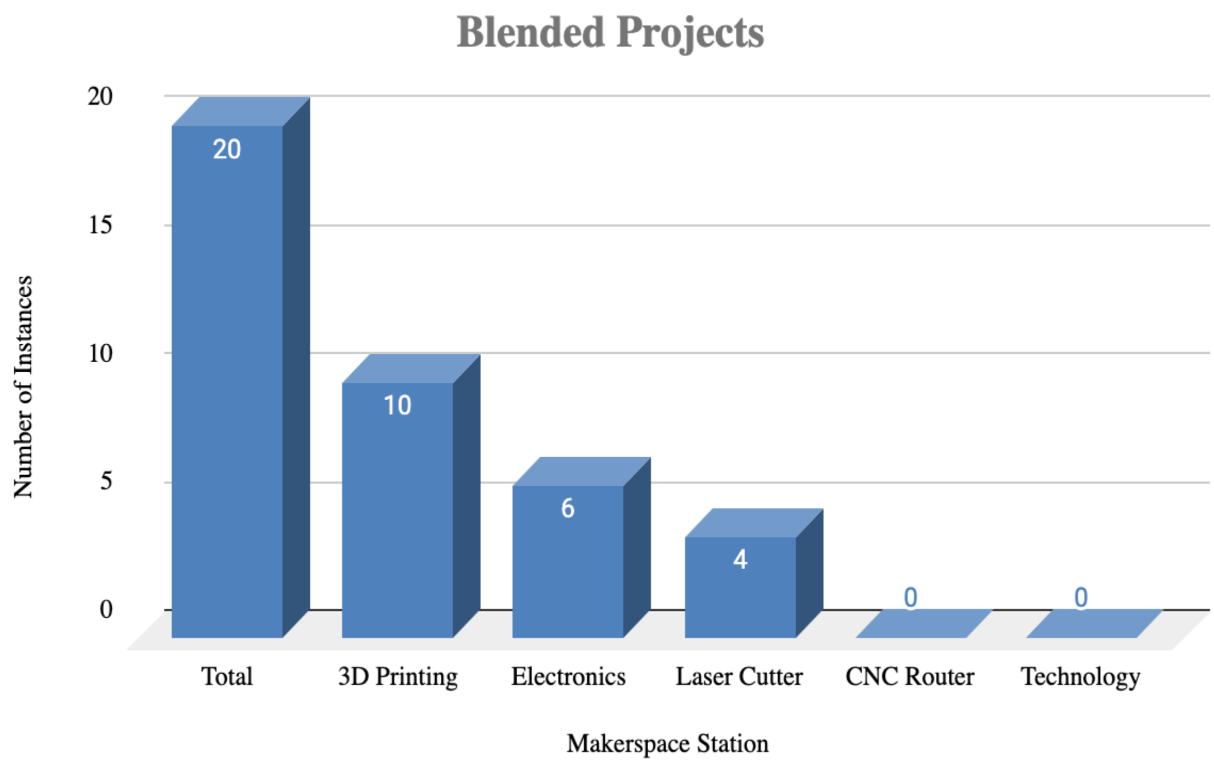

Figure 5.43 Blended Projects Instances.

Blended projects refer to makerspace projects that contain two components, specifically face-to-face and online. The blended project theme was one of the crucial themes in this current study, and it will be discussed in detail in the next chapter in terms of how the combination of face-to-face and online makerspace activities may help students (see Figure 5.43). It is most evident in the 3D printing station with 10 instances and the electronics station with six instances. These findings agree with the findings from the observational notes, which reported that the students were happy with the type of makerspace projects during the pandemic. It was also mentioned in the laser cutter station in four instances. In their reflective journals, one of the students noted the following:

> *Participant 1 (KOHC 3D Printing): It's a new experience for me and my colleagues working on such sophisticated machinery remotely from home.*

Recommending Makerspace Projects

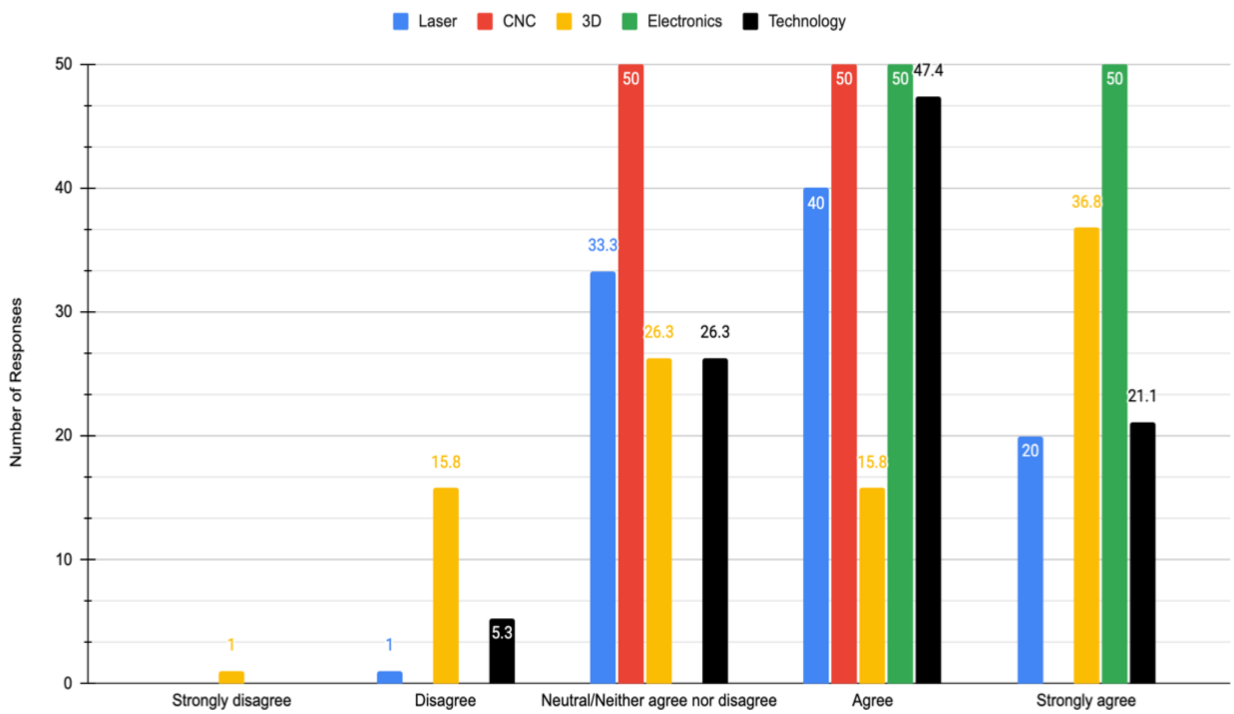

Figure 5.44 Recommending Makerspace Projects.

In all the stations, most students agreed or strongly agreed that the makerspace projects they worked on were worth recommending. It is worth noting that although the 3D printing station was the most favoured station by both students and teachers as it could be integrated with many projects, a minority of participants (three students) did not agree to recommend it (see Figure 5.44). This might be because the 3D designing process was done during the COVID-19 period when the students had no access to face-to-face support. In summary, these results show that most students in all stations agreed to recommend the makerspace projects.

Obstacles or Challenges when using School Makerspaces

Of the seven teachers who participated in the 21st-century online survey for teachers, several obstacles or challenges when using the school makerspaces in teaching and learning were indicated. The responses from the teachers can be categorised as follows:

1- Makerspace Tools and Staff

Participants 1 and 5 indicated that more staff were needed in the makerspace. Participant 2 indicated that the makerspace needed more than one device from each tool to serve more than one group at the same time. Participant 7 mentioned that some tools were hard to find. These findings agree with the observational notes which indicated that more tools were needed.

2- Professional Development and Curriculum

Participants 4 and 7 referred to the challenges to the curriculum, such as busy schedules, an absence of rubrics, and finding suitable activities. Participant 7 indicated that more training was needed for the staff, which aligns with the other studies where professional development for teachers is required to promote makerspace programmes (Heredia & Tan, 2021; Hughes & Dobos, 2022).

3- COVID-19

Participants 3 and 6 indicated that working on the makerspace projects was a challenge during COVID-19 as it limited the students' creativity, but that it was fun. The findings from the observational notes support these findings as they indicated that the students were happy, although they faced a lot of problems.

Suggestions for Improvements

Moving on from the difficulties of using the makerspace for learning, seven teachers who took part in the 21st-century online teacher survey made some suggestions for improving learning in the school makerspaces (see Appendix 13). The responses from the teachers' survey can be categorised as follows:

1- **Makerspace Environment**

Some teacher participants suggested getting more tools, a standalone makerspace for each division and a mobile makerspace. One participant suggested keeping the projects in a safe place in the makerspace.

2- **School Environment**

Some teacher participants suggested having flexible timetables, connecting the makerspace to the curriculum, having a library of video lessons, and focusing on long-term projects.

5.4 Summary of the Findings

This evaluative case study using mixed methods was carried out with the intention of investigating the learning that takes place at five different stations inside a school makerspace. In this chapter, a description of the case study as well as the findings of the thematic analysis of the data has been provided. The five research questions have been addressed using a within-case study analysis and cross case study analysis. This gained a better understanding of the type of learning that takes place in the makerspace and how the makerspace might help students prepare for future jobs.

The analysis of the data and comparison across the five stations revealed patterns and emerging themes that will be discussed in the following chapter. The findings show that many students and teachers believed that the makerspaces were beneficial to developing 21st-century skills, which are necessary to prepare students for employment. The quantitative and qualitative data from this mixed-method study also suggests that some indicators are visible in some stations, such as the 3D printing station. To help explain and understand the differences in the learning dimensions and the understanding among the stations, in the next chapter, these results are discussed through the lens of the makerspace quadrant. Also, Chapter 6 explores the relationship between the findings and prior research.

Chapter 6: Discussion

6.1 Overview

School makerspaces are hubs for learning that can help students learn a variety of life skills alongside subject matter (Dougherty, 2013). Peppler and Bender's (2013) view that the maker movement could reimagine education is consistent with the call for educators to establish innovative learning environments for 21st-century learning. Additionally, the increasing popularity of makerspaces in schools makes exploring their impact on students' learning a crucial topic for investigation. Thus, this mixed-methods study aimed to explore the effects of a makerspace on students' critical thinking, creativity, communication, collaboration, and career skills in a bilingual school in Kuwait.

Data were collected using reflective journals, online surveys, and observational notes. Data analysis yielded findings that supported the development of a new concept related to types of activities in the makerspace, varieties of makerspace stations and types of learning happening in school makerspaces. The study approach was in line with Eisenhardt's (1989) observation that building a theory from case study research is the most appropriate research approach when a topic is relatively new, as is the case with school makerspaces.

According to this study's findings, school makerspaces can help students develop the four Cs; furthermore, exposure and access to school makerspaces allowed some students to develop soft skills that can prepare them for their future careers (see Subsection 5.5.2). Consequently, makerspaces can present an opportunity to develop a variety of skills needed in future careers (Horton, 2017) and can help students build bridges to their future careers. Furthermore, data revealed that some identifiable indicators of learners' learning differed by makerspace station. The following discussion elaborates on various perspectives and interpretations of the current study's research outcomes. The learning outcomes of school makerspace projects are discussed through the lens of the makerspace quadrant model, advancing the argument for a blended makerspace approach based on the gathered evidence.

6.2 The Makerspace Quadrant Model and Study Findings

School makerspaces can provide physical learning spaces for project-, problem- and inquiry-based learning, as well as exploration, tinkering, and experimentation, as they are influenced by constructionist learning theories (Fleming, 2015). In this light, makerspaces can be hubs for project-based learning, innovation, and STEAM in schools. This approach aligns well with constructionist pedagogy, which is founded on the idea that students are not passive recipients of information but rather active creators of knowledge (Papert, 1993).

As stated in Chapter 3, the makerspace quadrant model (Vuorikari et al., 2019) outlines makerspaces within four scenarios that accommodate both the intentional–incidental and makerspace–maker programme continuums. This model enables educators to choose the design of their makerspace and the kind of learning that will occur in the designated space (Koul et al., 2021). A review of any quadrant reveals several features that describe and distinguish it from the other quadrants.

Within a makerspace, learning can take two forms on the continuum of the quadrant model. At one end of this continuum is intentional learning, which is highly structured and has definite aims; at the other, there is incidental learning, a more organic process that is directed by the learner but does not have set outcomes. Figure 6.1 presents an illustration of the relationships between the learning modes and types of making. The making space itself can be thought of as a continuum in the quadrant model, with one end hosting a structured makerspace programme and the other representing a more flexible space that constantly changes (Vuorikari et al., 2019).

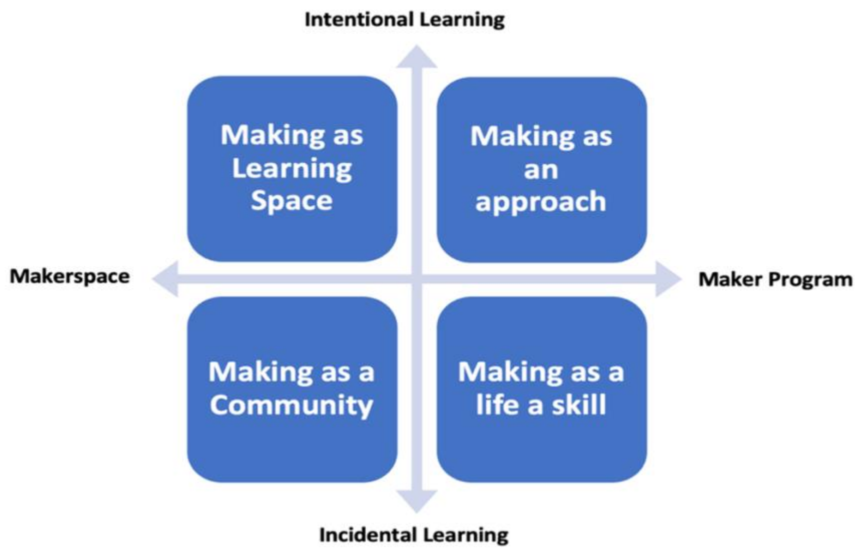

Figure 6.1 The Makerspace Four-Quadrant Model (Vuorikari et al., 2019).

Some scholars have emphasised the differences between makerspaces and maker programmes (Blackley et al., 2018). In the context of school makerspaces, in my view, there is no need for distinction between maker programmes and school makerspaces, as a maker programme can be a part of a school makerspace (see Section 3.4). In contrast to the setting of the current study, Blackley et al. (2018) and other researchers (including Anderson, 2017) discussed makerspaces from the perspective of a makerspace located in a library or other public facility. The following reasons undergird my belief that school makerspaces differ from the model that Blackley et al. (2018) presented. First, a school makerspace can be a physical place for teaching and learning, a type of location differing from museums and libraries that may fulfil purposes other than learning. Second, a school makerspace can accommodate or support many programmes in schools, such as supporting students in preparing for their future employment. Additionally, school makerspaces have permanent customers (i.e., students) rather than drop-in visitors who stay for a few hours, as in a museum or library makerspace. Based on my school makerspace experience, some activities require students to use their material and supplies to spark their interest in innovating. In other structured projects, students can use ready-made materials, such as ready-made kits. Additionally, the school makerspace studied here offers many types of making, such as makerspace projects that are designed to support curriculum, after-school clubs, and makerspace carts. For all these reasons, the distinctions that Blackley et al. (2018) previously defined between makerspaces and maker programmes cannot be generalised to school makerspaces.

Although I have defined a school makerspace as a factory inside a school, my experience indicates that it is more than a factory, following Koul et al.'s (2021) observation, 'Unlike a factory where all the items are the same, these items were unique and belonged solely to the individual' (p. 19). In specific terms, Vuorikari et al. (2019) described four types of making. The first and second types – making in a learning space and making as a community as illustrated in Figure 6.1– both are part of the category of makerspaces. The third and fourth types of making – making as a methodology and making as a life skill – comprise the category of maker programmes. The previous categories, between makerspaces and maker programmes, as the findings of this study suggest, the first and second types do not perfectly describe school makerspaces, as the makerspace quadrant focus was on formal education (from early childhood education through obligatory, VET and university education) and not school makerspaces. As a result, I contend that the school makerspace can be connected to all four types of making instead of only two, as suggested by the makerspace quadrant.

My focus in this discussion is on standalone school makerspaces, excluding other forms of makerspace since making in schools can take more than one form (e.g., maker classrooms, library makerspaces or STEAM laboratories). According to the current study's findings centred around one standalone makerspace, some students who learned in the space in five makerspace stations developed the four Cs and career skills; thus, I believe that implementing a standalone makerspace in schools can contribute to the quality of learning, allowing students to take their projects to a more advanced or innovative level. One reason that school makerspaces can support innovation, as in the context of the current study, is the availability of machines and materials, which can provide students with many opportunities to develop a project from scratch and manufacture different artefacts. Additionally, the ample space in a makerspace sets it apart from a traditional classroom. An example from the makerspace studied here that supports this belief is the story of a student who did not follow the instructions for a project and created a distinct unique design.

The following section will discuss the study's findings through the lens of the four types of making in the makerspace quadrant model as displayed in Figure 6.1. Vuorikari et al. (2019) posited that school makerspaces might correspond to two contexts: the top left-hand corner of the diagram shown in Figure 6.1, "Making as a Learning Space", or the bottom left-hand corner, which represents "Making as a Community". In contrast to Vuorikari et al. (2019), the findings of this study suggest that school makerspaces can match all four contexts of the makerspace quadrant. The following subsections present more details to explain how the current study's findings support this claim.

6.2.1 Making as a Learning Space

Makerspace projects require assessment methods that differ from the traditional tools used to assess classroom activities, such as tests and quizzes. According to Hughes and Dobos (2022), one of the key differences between the modern maker movement and the home economics or shop classes of the 1970s and 1980s is 'the emphasis on the design and making process, rather than on the product' (p. 3). Assessing learning in school makerspaces, along with assessing makerspace projects, should focus on the process rather than the final models or products. In particular, process-focused assessments can enable teachers to identify the skills that students have developed and how students took different routes to achieve their goals (Mersand, 2019). One method for evaluating student progress in school makerspaces is through use of the tinkering learning dimensions framework (TLD; Bevan et al., 2020). The results of this study are in line with Hansen (2018) in showing that the TLD, although designed for museum makerspaces, helped examine learning in school makerspaces; nevertheless, the framework requires modification to make it more suitable for assessing school makerspaces. For example, it does not have a section about employability skills. Therefore, a fourth indicator, called life skills, can be added to encompass the following aspects:

- Connecting the activity to real life
- Connecting the activity to employability skills

In the same vein, during the data analysis process, assessing innovation based on the TLD was not easy. Therefore, I suggest adding an innovation component to this framework, as none of the innovation indicators in the TLD could be found while analysing the reflective journals. Although the innovation dimension was included in one of the draft versions of this framework, the researchers who developed it ultimately excluded innovation and viewed this aspect as "understanding", considering students' status as drop-in visitors in the museum makerspace context (Bevan et al., 2018). However, I believe that innovation should be included because the school makerspace context differs from the museum makerspace context.

6.2.2 Making as a Community

The study findings revealed that the *social and emotional engagement* indicator of learning was the most visible across the stations, with 103 instances reported (see Table 5.20). This outcome aligns with the reviewed literature indicating that makerspaces have many potential social benefits. As discussed in Chapter 3, Litts (2015) asserted that makerspaces require a community element and tools do not make makerspaces; rather, the people who share, help, and interact with each other inside them do, meaning that teamwork is essential in the makerspace. In the same vein, Kurti et al. (2014) described "a makerspace without makers" as "just a workshop full of lonely tools" (p. 9). Maintaining a sense of community is one of the strongest hallmarks of school makerspaces, which aligns with Burke's (2014) contention that makerspaces are examples of communities that emphasise collaboration, teaching, learning and the sharing of ideas.

This study's findings regarding the social environment of a school makerspace are consistent with the maker movement's theoretical foundations, as discussed in Chapter 3 (see Section 3.3). For instance, they are consistent with constructionist learning, which contends that students develop knowledge via the creation and sharing of artefacts with their peers and the public (Papert, 1993). Similarly, Wools's (2013) comparison of three makerspaces to identify different types of support involved in established makerspaces resulted in the researcher's emphasis on the importance of social support in the three makerspaces. Additionally, the social environment of a school makerspace is consistent with Vygotsky (1943), who theorised learning as a collective social activity, as well as Lave and Wenger's (1991) conception of learning as participation in a community of practice. Lave and Wenger also asserted that to learn is to engage in the process of transforming the self. In the context of this study, this process occurs through "maker-centred learning", which involves moving from "newcomer" to "old-timer" in a practising community "school makerspace" that reflects a strong focus on community. As mentioned earlier in the literature review (see Subsection 3.3.2), the community in a makerspace is reflected in the participatory culture theory, as makerspaces offer a form of participatory learning wherein students work together to achieve their dreams in a playful environment.

Furthermore, the nature of school makerspace projects depends on collaboration among students, which entails providing opportunities for all students to grow and learn. In this study, the *documenting or sharing ideas with others* indicator was visible, with nine instances occurring (see Subsection 5.2.4). This outcome indicates that collaboration, which mimics how work is accomplished in real workplace situations, is essential in education (Koul et al., 2021). Conversely, traditional instruction results in two scenarios: one student passes and another student struggles (Otieno, 2022). In addition, teachers expect students to work independently and discourage them from sharing ideas.

The current study's findings agree with Wools (2018), who noted that students not only make and create but also share their work with others when engaged in makerspace projects. This idea is also found in Ching and Kafai's (2008) concept of "peer pedagogy", a style of learning built on student collaboration to support one another's transitions during projects. In this study, in particular, peer pedagogy was evident when students who were knowledgeable or skilled in particular aspects of some areas of the project guided other students to complete their projects.

As explained in Chapter 4, collaboration, an essential element in makerspaces, is sometimes viewed as a constraint in school makerspaces. This problem can be attributed to schools' traditional emphasis on autonomous work and individual grades, making it difficult to assign and analyse collaborative activities (McLean & Rowsell, 2020). In the same vein, although cooperation has been associated with innovation, for various reasons, it may appear harmful (Merchant, 2011) or dangerous – for example, a teacher might encounter the difficulty of knowing whom to praise and whom to blame or whether there is too much talking and not enough doing.

According to the current study's findings, socialisation in the makerspace – in other words, developing a collaborative makerspace learning environment – is a feature of the makerspace that makes it a unique learning environment. Additionally, the findings underscore the importance of collaboration as a skill in terms of the effectiveness of makerspace projects (see Subsection 5.2.1). According to Mersand (2019), making activities in the makerspace are undertaken collaboratively; rather than happening in isolation; they comprise a social way for students to learn with their peers about the world around them. As mentioned in Chapter 3, Litts (2015) contended that 'interdisciplinary learning is demonstrated through naturalistic engagement in makerspaces' (p. 192); similarly, working in makerspaces can contribute to the development of a collaborative makerspace culture for teachers and students. Such collaborative spaces entail making unities and inspiring a community of people who work on projects to design solutions to problems or make things for fun (Honey & Kanter, 2013). The current study's results included identifying the *teaching and helping one another* indicator in 27 instances across all the stations; by comparison, the *working in a team* indicator occurred in 24 instances. These findings are consistent with the third core principle of participatory learning: that working in makerspaces can lead to engagement through meaningful play (see Subsection 2.2.1).

The results of this study echo Collins's (2017) finding that 'the social environment promotes a safe environment that encourages innovative ideas and risk-taking' (p. 11) – for example, the story of the student who took a different approach to design a racing car, as mentioned in Chapter 5 (see Subsection 5.2.1). Furthermore, the current study's findings support the claim that makerspaces differ from traditional classrooms in requiring students to work together and learn from each other (see Table 5.20). Finally, the study findings support Brubaker et al.'s (2019) assertion that school makerspaces can be viewed as social worlds. All these findings support my belief that they can be a gym for students' minds and a place for building communities.

6.2.3 Making as a Life Skill

In *Learning in the Making*, Gerstein (2019) contended that making is essential to the human experience. Accordingly, school makerspace projects should focus on improving life and the world around oneself by solving problems to make life better for people and guiding the development of the individual. The current study's results demonstrate that school makerspaces can have a positive impact on students' future careers by helping them develop various life and career skills, such as adaptability and flexibility (see Subsection 5.1.4.2). For example, some students decided to buy 3D printers or open their own 3D printing companies One teacher participant shared the following thoughts:

> During a psychology class with high school students in the middle of work, one of the students suddenly said: 'Do you know, Ms. Daliah, that my mom was happy yesterday because I could sew my ripped shirt, and I feel what I am doing right now with you is more beneficial than the subject itself. At least I can fix my clothes now if it gets ripped one day. I want you to teach us how we can stitch buttons (see Descriptive Note 18).

Another story that reflects the capacity of school makerspaces to promote the development of life skills was shared by another teacher participant. After students finished making their smart lamps at the electronics station, the teacher said that the students made the lamp perfectly and better than he could, as they worked as a team to learn from each other; furthermore, one of the students even made another lamp at home. According to Washor and Mojkowski (2013), making can provide opportunities to develop entrepreneurial and scientific abilities as students use their hands and minds. The findings of this study show that school makerspaces are an example of connecting learning in schools with real life, as noted in the student's explanation of how he changed his opinion of the school makerspace after he finished his project and how he considered working in a school makerspace a way to develop life skills (see Subsection 5.2.2).

6.2.4 Making as an Approach

Although I concur with Dewey (1897) that school must represent the student's present life, it should also extend the present life and focus on the future life. When students work in a makerspace, they can apply skills in all three learning domains – affective, cognitive, and psychomotor – as they work together to design solutions, make prototypes and solve problems related to their personal interests and local communities (Mersand, 2019). The literature about makerspaces similarly illustrates how making creates learning through making as an approach via offering different tools for making, such as makerspaces, maker carts and maker classes. Additionally, my findings reveal the need to offer long-term projects and after-school activities in the makerspace (see Subsection 5.1.6). Accordingly, making should be a school culture; moreover, the makerspace should be the hub of this culture. Making or maker-centred learning, in other words, should be invisible in the sense that it should be used throughout the school and is "something that should happen across content and curriculum" (Gerstein, 2019, p. 55). In the following subsections, I will discuss three elements that define the makerspace as an approach and could assist schools in using maker-centred learning as a culture.

6.2.4.1 Blended Makerspace Activities

Because technology evolves quickly, educators are encouraged to find ways to stay up-to-date on technological developments to integrate technology into their curricula. This requirement is similar to the process of finding ways to speak a language that students can understand. According to Kamaruzaman et al. (2021), 'Technological advancement opens up the possibility for global design collaboration that crosses the boundaries of culture and nation' (p. 5). Makerspaces deal with different types of technology, ranging from machines and devices to software used in designing digital prototypes. In this context, an educator's role is to use suitable tools in the makerspace to meet students' needs.

It seemed providential to conduct this case study during the COVID-19 period of online learning. Working online with students and teachers on different projects for approximately an academic year sparked the researcher's interest in finding ways to adapt to the pandemic situation. Specifically, the COVID-19 pandemic made it necessary to adapt to distant and blended learning. Data drawn from the reflective journals revealed that the blended makerspace project's theme was evident in some of the stations (see Figure 5.44 and Figure 5.43) as the majority of students agreed or strongly agreed that their makerspace projects conducted in this study were worth recommending. The observational notes provided additional insights into the blended makerspace projects, as some students reflected on how they were happy to work on such projects remotely as well as to receive their final models from their school. Long-term projects and makerspace blended projects were identified as central themes of the makerspace during data collection in the five stations, resulting in the coining of the term *blended makerspace projects* and *long-term projects* as a new approach in maker pedagogy.

In this light, I propose a new type of activity that I call "*blended makerspace activities"*, meaning makerspace activities with two elements: (a) face-to-face learning or interaction and (b) online learning. Figure 6.2 demonstrates the interlocking relationships between the elements and activities. The highest number of frequencies of the *expressing the pride and ownership* indicator provides evidence of the educational value of the proposed model and how teachers' and students' satisfaction levels emerged while working through it (see Table 5.8). The following details pertaining to each of the three types of learning are intended to clarify the terms used to describe these novel makerspace activities:

- **Online learning.** Students can listen to online instructions or work online in groups to discuss topics related to their projects.
- **Face-to-face learning.** Students come to the makerspace to print or make something using the different tools in the makerspace.
- **Blended learning.** Students have access to the makerspace tools and can print their designs. Teachers can send the designs home, or students can come to collect them.

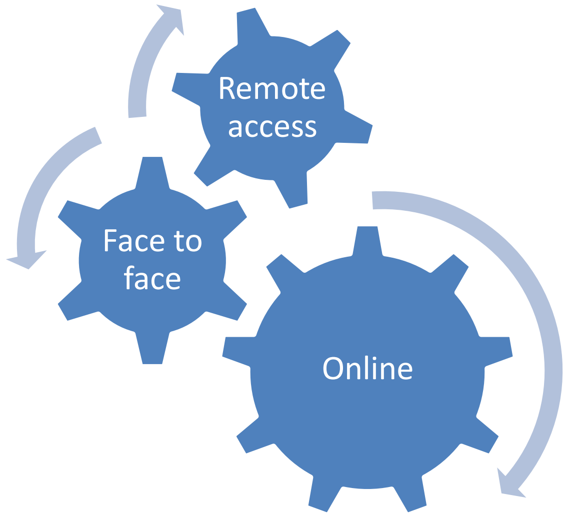

Figure 6.2 Elements of Blended Makerspace Activities.

6.2.4.1.1 Benefits of Blended Makerspace Activities

Blended makerspace activities can be used in schools that do not have makerspaces or that have limited resources. Schools that can find a nearby public makerspace can collaborate with the latter facility to use its devices and machines. Furthermore, this model could offer a solution in times of war or pandemics. Table 6.1 summarises the differences between physical and blended makerspace activities.

Element	Physical activities	Blended activities
Collaboration	Occurs in a dedicated space	Occurs in breakout rooms
Process	Face-to-face	Online and face-to-face
	Sense of community	Online community
	Individual and collaborative projects	Individual and collaborative projects
Skills	Focus on hands-on skills	Focus on technology-related skills
Artefacts	Students create artefacts in the makerspace	Students make artefacts remotely or simulate them

Table 6.1 Differences between Physical and Blended Makerspace Activities.

Although teacher participants in this study highlighted that working online during the COVID-19 pandemic had some limitations, the comments they shared about the projects conducted in the makerspace (blended makerspace activities) indicated that the students developed a variety of skills and enjoyed the activities. Some of the teachers' observations about the new type of projects delivered during the study are reflected in the following comments (see Appendix 13):

- The experience of having students work remotely was a real challenge, but the students have enjoyed it because they were able to collect their models to feel and touch what they have designed and worked on for a long time.
- Being online limits students' creativity to a certain extent, as they are not able to come to the makerspace as often as they would like to.
- It was great using some of the makerspace tools and technology and integrating that into the curriculum. Students had fun and enjoyed the learning experience.
- I am glad to use the makerspace. It is such a great opportunity for teachers and students during the COVID-19 period.

As evidenced by this feedback from the teacher participants, students and teachers faced challenges in working in the makerspace during the COVID-19 pandemic; nevertheless, the students enjoyed working on the newly proposed activity type (blended makerspace projects). Although I entered this study with the aim of exploring learning, I exited it by proposing a new model. I also implemented the same approach in this study when students were asked to work online. In this context, they used the machines remotely to make their artefacts and collected a ready-made kit from the school to work on their projects at home. As a result, there was a connection between the online and in-person components, which allowed them to remotely experience, feel and touch what they designed.

The proposed type of makerspace activities is similar to the idea of virtual makerspaces, which are designed to enable students to create, build and invent models using only digital tools, as described by Cuizon (2020). Such activities can be useful when adapting to remote and hybrid learning as a necessity in the event of disruptions in in-person learning, for example, pandemics or wars. Alternatively, students working in a blended makerspace context have a chance to interact with the machines online or physically, while virtual makerspaces confine their users to simulations. The two concepts are alike in their scope of learning, as makers can work and share their ideas in either a physical or a digital environment. Additionally, these activities are similar to additive innovation, as discussed in the literature review chapter (Jordan & Lande, 2016).

The first attempt to incorporate online components in makerspace projects might have been made by McCue (2017), who implemented a flipped, active learning teaching technique in an academic makerspace. This approach moves the majority of the training into online modules to be finished before the session begins and devotes face-to-face workshop time to hands-on activities. One of the advantages of using online tutorials before the hands-on session in the makerspace is the ability to reduce the amount of lecture time and focus on hands-on work. Furthermore, McCue (2017) highlighted the additional advantage of time-savings, observing that ‘in the experience of the University of Victoria Libraries makerspace, a 90-minute workshop can typically become a 60-minute workshop by moving to a ‘flipped’ pedagogy or teaching method’ (p. 5). Consequently, flipped pedagogy in school makerspaces can accommodate many classes by focusing on hands-on projects and presenting the associated tutorials about machines, software and instructions online.

Although the flipped method and the blended makerspace approach are similar, they can differ in three ways. First, compared to video tutorials, the blended makerspace approach may rely on more tools, such as simulators. Second, students may control the equipment remotely during an online class (as in this study), allowing them to watch their model being printed or engraved (see Figure 6.3). Lastly, students may have their model made at a nearby makerspace by sending their digital files electronically.

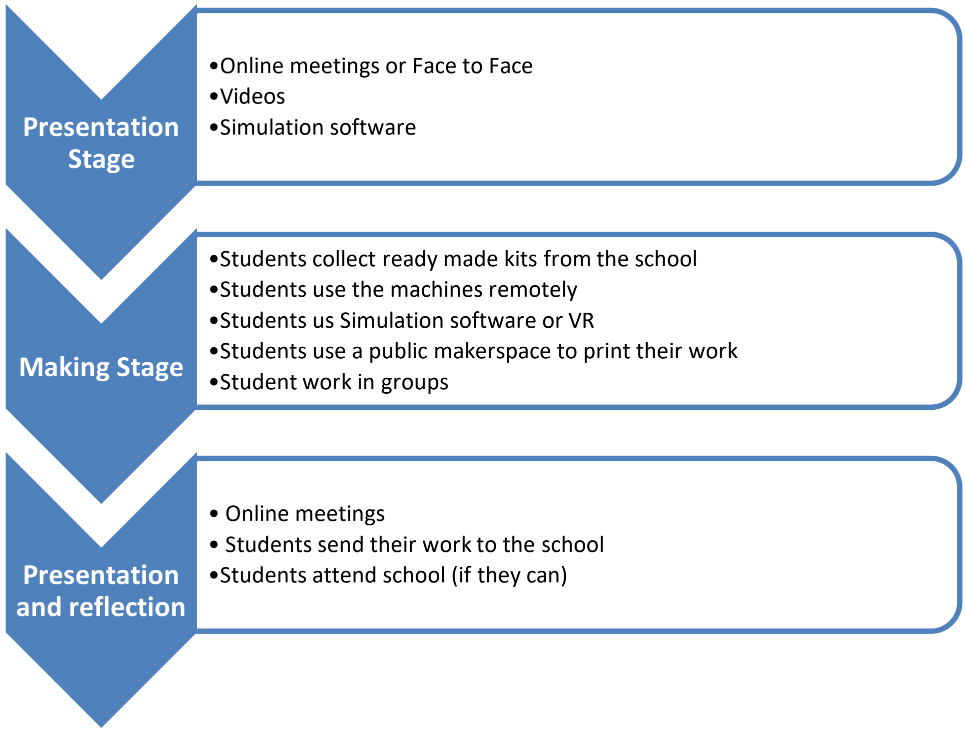

Figure 6.3 The Author's Blended Makerspace Approach.

Figure 6.3 depicts the concept of blended learning within the context of the makerspace environment. It illustrates how students have access to makerspace tools and how they can utilise them to create their designs. Additionally, it highlights the flexibility of the learning process, where teachers can either send the designs digitally for students to print at home or arrange for students to collect their printed designs from the makerspace. The figure is based on the analysis of survey responses, participant observations, and student journals, which provided valuable insights into the experiences and perceptions of learners and teachers in the makerspace environment. By incorporating both digital and hands-on activities, makerspaces can offer opportunities for learners to engage in creative, experiential, and interdisciplinary learning experiences.

6.2.4.2 Long-Term Projects

School makerspaces typically feature two different types of projects: (a) short projects that last no more than four weeks; and (b) long-term projects that last more than four weeks and up to an entire semester or more. The study's findings emphasise the importance of long-term projects in a variety of subjects (see Figure 5.20). For example, one teacher participant recommended long-term projects because they enhance students' abilities to develop many skills. Another teacher indicated that students had fun and enjoyed learning in the makerspace. Lastly, a third teacher reflected that he was happy with the makerspace and found it an excellent opportunity for teachers and students while working on long-term projects (see Appendix 13). Students can learn by doing in the form of construction-based tasks during long-term projects, and they can engage in minds-on learning by using technology or digital tools to reflect on what they have learned (Chee & Keat, 2018).

Educators should consistently seek the most appropriate methods to accommodate students' ever-changing needs in school makerspaces. As indicated in the previous chapter, most of the students commended the long-term projects (see Figure 5.42). Consequently, long-term projects, as proposed by this study, can be useful in the makerspace because they offer students enough time to develop soft skills along with technical skills (see Figure 5.20).

Most of the teachers who participated in this study indicated that their students monitored, defined, prioritised, and completed tasks without direct oversight (see Figure 5.37). According to this observation, long-term projects that were highly structured helped students be self-directed. Thus, this study's findings support the claim that long-term projects provide a starting point for acquiring technical and life skills, as noted in the literature review (see Subsection 2.5.2). One feature of a long-term project is the co-teaching model, where a teacher and makerspace teacher work together to merge the subject content with the maker skills. However, long-term projects can cause some issues in the makerspace. For example, as indicated by Collins (2017), they might prevent other teachers from scheduling lessons in the makerspace since it will already be fully booked.

6.2.4.3 Hands-on Activities or Digital Activities

According to Riskowski et al. (2009), students who participate in hands-on activities like those provided in makerspaces are more likely to understand complicated ideas than those who learn in more traditional contexts. The results of this study revealed more learning dimensions in the hands-on projects than in the technology projects. For example, students who worked on the 3D printing and CNC stations demonstrated, on average, 10.8 or 11.5 instances of learning indicators compared with 4 instances at the technology station (see Figure 5.23), suggesting that more forms of learning took place in hands-on activities (3D printing) than technology activities (digital). Technology activities are projects that depend on fully digital tools and do not require any physical work on any physical tools or devices in the makerspace, such as making interactive books or designing a website. Undeniably, technology has become a key influencer and driver in everyday life, as evidenced by the prevalence of software, web and mobile applications and artificial intelligence. Additionally, students' overwhelming dependence on technological tools, especially during the COVID-19 period, underscores an urgent need to achieve a balance between hands-on and technology activities. Some scholars have distinguished between hands-on and technology activities by using the terms "hands-on" as opposed to "minds-on" (Carin, 1997). A blended learning approach can support educators in maintaining this balance in their teaching, as it can equip students with technological, technical and life skills alike. The results of this study and previous studies show that students who engage in hands-on projects, including makerspace projects, are more likely to develop the skills of critical thinkers and collaborative workers who can design innovative solutions to real problems (Novak, 2019).

Bringing together the findings about the differences between hands-on activities and digital activities exemplifies the dichotomies related to pedagogy that previous studies have identified. The combination of hands-on and digital approaches to making has been called the maker movement (Martin, 2015). Some studies have suggested that involving students in hands-on projects, bearing similarities to teachers' function in the makerspace, can increase students' motivation, engagement, and interdisciplinary awareness, as well as bring other benefits (Smith et al., 2015). The integration of the mind and hands in projects can also increase students' achievement and transform how they learn and construct knowledge (Ateş & Eryilmaz, 2011). Other studies have confirmed that hands-on activities encourage creativity and problem-solving skills (Staver & Small, 1990) and engage children's natural curiosity (Yannier et al., 2021). The benefits resulting from hands-on and minds-on activities "as what is providing" is the most obvious illustration of the advantages of using a makerspace in teaching and learning.

Because the makerspace movement 'draws upon the innately human need to generate things using our hands and our minds' (Fleming, 2015, p. 2), school makerspaces may boost students' engagement, creativity, and curiosity. Hands-on or making activities can connect learning to real life and mimic the activities that students do in their daily lives. For example, if students want to learn to fly a drone, they are better served by buying a drone to practice flying than by reading a textbook about flying a drone. The value of making becomes evident when teachers decide to take this activity to the next level by helping students make a drone and then use it to learn the basics of flying. Additionally, technology can enhance hands-on activities for students in two respects in terms of allowing them to use the information literacy skills they learn and helping them become content creators (Koole et al., 2017). This finding is consistent with Uno's beliefs (Rasinen et al., 2010) about including hands-on activities in learning, as illustrated in the literature.

In conclusion, according to the current study's findings, projects should include technological and physical elements to give students the opportunity to work with their hands and minds. The benefits of learning and working with one's hands cannot be overemphasised, particularly as students are developing fine motor skills. Otieno (2022) highlighted the need to include both hands-on and minds-on activities in students' learning processes. Another scholar observed that children who built things with their hands in a fun environment could remember educational content better and retain the information longer (Martin, 2020). Having hands-on and minds-on elements in makerspace activities also aligns with Brubaker et al.'s (2019) conclusion that 'makerspaces are where minds meet hands, designing meets making, and creativity meets physical reality' (p. 2). Taken together, the literature and the findings of this study suggest that involving students in makerspace projects with hands-on and minds-on elements can engage each student's mind and hands.

6.3 Relationship Between Study Findings and Prior Research

Despite the growing popularity of makerspaces, little research has been undertaken on standalone school makerspaces detailing the various stations inside such makerspaces and exploring their impacts on teaching and learning. This study adds to the growing corpus of research examining how makerspaces in schools might help teaching and learning. In addition, this investigation is the first to evaluate Bevan et al.'s (2020) dimensions of learning in a standalone school makerspace environment, incorporating the voices of instructors and students. Due to the fact that Bevan et al.'s (2017) framework was designed for museum makerspaces instead of school makerspaces, it may be necessary to revise some aspects of this framework. Accordingly, this research suggests a modified version of Bevan et al.'s (2020) aspects of learning for school makerspaces (see Subsection 6.1.1.1)

The findings in this thesis also echo Abdurrahman's (2019) recommendation that 'makerspace could be used in fostering students' creative thinking, critical thinking skills and problem-solving skills in physics by promoting and utilising higher-order thinking skills' (p. 6). In the same vein, the current study's findings are in line with Martin's (2015) assertion that makerspaces support the development of the four Cs, as well as Collins's (2017) conclusion that learning can be demonstrated through social interaction using a highly collaborative approach. Finally, this study revealed the potential for school makerspaces to impact perceptions of both teachers' and students' learning concerning students' future jobs.

This study's most significant contribution may be revealing the importance of connecting school makerspaces to students' everyday lives and future academic studies. In a study that reported similar findings to those of the current research endeavour, Horton (2017) wrote that students showed pride in working in the makerspace, sustaining their motivation to return. In this study, this pride and enthusiasm encouraged some students to think about buying 3D printers, opening their own 3D printing companies or attending an engineering college (see Subsection 5.1.2). One participant was even inspired to become an architect. Students described these connections in glowing terms. For example, one student (DR TECH) said, 'I think if we were to get jobs that required skills from things from the makerspace, then, of course, the makerspace would have a positive impact on our future careers.' Meanwhile, another student (KM TECH) predicted, 'Makerspace could influence me to take a more creative career in the future because of the creative nature of makerspace'.

Online makerspaces or virtual makerspaces offer an approach that is comparable to the blended makerspace approach (see Subsection 2.4). Koul et al. (2021) described a virtual makerspace as 'a one-stop, web-based space where users may access digital tools for engaging in online maker-style activities' (p. 291). Games and simulations are two examples of activities that can be done in the virtual makerspaces – while in a physical makerspace, students may learn how to code and fly drones, in virtual makerspaces, they will learn how to code and fly using a simulator, such as DroneBlocks. Khadri (2022), who investigated the possible futures of makerspaces as an essential fundamental component of K–12 education, characterised students' uses of the virtual makerspace as a learning environment that enabled them to use a network of numerous new digital technologies and resources without being constrained by the time and location restrictions of traditional physical makerspace environments. In other words, students can make use of a wider variety of technologies and resources than they would be able to access in a traditional physical makerspace.

Another study that supports and complements the blended makerspace concept is Shu and Huang's (2021) study on the use of virtual reality (VR) in makerspaces in the context of the COVID-19 pandemic. When lockdowns made it difficult to learn machine operation skills in makerspaces, the authors found that VR could simulate the process of operation training while reducing the risk of operation in the makerspace and allowing students to learn remotely. The blended makerspace approach is more closely related to learning by making because it employs online platforms while still requiring students to create a physical model. This approach allows students to touch and feel the things they have designed and serves as a framework for transforming the makerspace into an environment for students to acquire 21st-century skills.

6.4 Summary

In summary, the quantitative and qualitative data that emerged in this mixed-methods study concur with previous literature indicating that students who work on makerspace projects tend to develop a variety of skills (Novak, 2019), as illustrated by the makerspace quadrant model. The newly proposed project type (blended makerspace projects**)** can enable students to develop soft and academic skills. Furthermore, blended makerspace projects support the claim that school makerspaces provide a feasible solution for adapting to remote or hybrid learning when needed – for example, during pandemics and wars or in developing countries. This study's findings about hands-on and digital projects can be understood in terms of factors contributing to this difference in learning dimensions. Finally, this study and previous related research suggest that school makerspaces can encourage the four Cs, representing essential skills for students in their future professions (Vongkulluksn et al., 2018).

Based on the current study's findings, the makerspace could be redefined as follows: a school makerspace is a unique place where students are provided with a space where they can develop transversal skills, ignite their capacity for innovation and creativity, make mistakes, prepare for their future employment, build up communities and work with their minds and hands. This concept fits well with Gerstein's (2019) contention: 'It's not just a matter of what you know; it's a matter of taking risks and failing and learning from those failures. It's a matter of being open to exploring new possibilities and developing your full potential' (p. 43). The following chapter details the study's conclusions, contributions, recommendations, and limitations.

Chapter 7: Conclusions

7.1 Overview

This case study aimed to explore learning in a school makerspace at a bilingual school in Kuwait with a focus on what career skills students may develop. The following sections provide an overview of the study, the conclusions that can be drawn from the study and how the identifiable indicators of learners' learning differed by station, recommendations for teachers and policymakers in creating maker-learning environments, contributions, recommendations for future research, and the limitations of the study.

7.2 Overview of the Study

Makerspaces are spreading in schools and are seen as an innovative means of reimagining teaching and learning (Fleming, 2015). Therefore, researchers and practitioners need to develop a deeper understanding of makerspaces in schools as learning settings and how to re-envision teaching and learning through a new lens of 21st-century skills. As Lindsey and DeCillis (2017) indicate, 'currently, our research-based understanding of making is still far behind the growing enthusiasm for making in the educational world, and with it, the ongoing spread and scaling of making to formal and informal learning environments' (p. 9).

Previous research has recognised the value of makerspaces in maker empowerment (Clapp et al., 2017), creativity, innovation, and entrepreneurship (Fleming, 2015), and STEAM integration (Collins, 2017). However, little is known about the impact of standalone school makerspaces in K–12 educational settings and how they contribute to teaching and learning to prepare students for their future jobs, especially in Middle Eastern schools. This research employed an exploratory case study to explore how high school teachers and students describe and perceive the skills that students developed over the course of a number of projects and how these skills can help prepare them for their future careers. In total, 79 students and seven teacher participants from the high school division worked in five makerspace stations on different projects. The classes that participated in the projects were selected from different disciplines, including life skills and economics. All projects started in November 2019 and were completed in May 2020. Due to the emergent and developing nature of school makerspaces, a mixed-methods approach was selected for this study to answer the research questions because of its ability to confirm findings from different data sources and collect reflections from both teachers and students (Creswell, 2003).

To address the aim of this study, online surveys, reflective journals, and observational notes were used to collect data from teachers and students. The TLD, the 21st-century skills frameworks and the makerspace quadrant were used as frameworks to guide this study when designing the data collection tools and in discussing the findings. Additionally, this study was guided by the following central research question:

What educational benefits and indicators of learning are identifiable among students who use the different stations in the makerspace, and how could makerspaces help them develop their future career skills?

In the following subsections, the study's conclusions, and original contributions to knowledge are discussed.

7.3 Conclusions

The study's conclusions are discussed in accordance with answers to the following sub-research questions:

1- **How do high school teachers perceive the educational benefits of the various stations of a school makerspace?**

From teachers' perspectives, the makerspace offers a space for students to develop the four Cs and the skills required for their future careers (see Subsection 5.1.1.1).

2- **How do high school students perceive the educational benefits of the various stations of a school makerspace?**

This study's results suggest that students can benefit from working in school makerspaces, through connecting makerspace projects to career skills, life, university, and learning from mistakes (see Subsection 5.1.2).

3- **What indicators of learning are identifiable among the students using the various stations in the makerspace?**

All five learning dimensions of the TLD framework– conceptual understanding, creativity and self-expression, social and emotional engagement, initiative and intentionality, problem-solving and critical thinking – were visible to varying degrees in students' reflective journals and in observational notes. The social and emotional engagement and conceptual understanding indicators were the most visible learning dimensions reported, reflecting the collaborative nature of the projects in school makerspaces. As discussed earlier, the findings reveal that the social aspect of the makerspace is the most reported element (see Subsection 5.1.4).

4- How do the identifiable indicators of learners' learning differ by station?

Overall**,** students who worked at the 3D printing station had greater learning indicators across all learning dimensions than students who worked at other stations. The technology station showed the least number of indicators, as it perhaps did not involve any hands-on work or creation of physical artefacts (see Subsection 5.1.4.1).

5- How do different stations in a school makerspace contribute to learners' acquisition of life skills that could help them develop future career skills?

The findings of the current study revealed that some students practised life skills required for their future careers. Some of them decided to buy devices, such as 3D printers to start preparing for their future jobs or were inspired to start their own businesses (see Subsection 5.1.5). This possibility is supported by Chivukula (2019), who stated that the maker movement not only has benefits for education but can also bring economic benefits by encouraging inventors and entrepreneurs.

7.4 Original Contribution to Knowledge

It appears that establishing makerspaces in schools can assist in reshaping education in light of the lessons learned from the COVID-19 epidemic and contribute to fulfilling the changing demands of 21st-century students. The original contributions to knowledge include proposing a new type of activity (blended makerspace projects), introducing the concept of long-term projects and suggesting changes to the TLD. The proposed model can take physical makerspaces to the next level by combining face-to-face and online activities in K–12 education and enhancing educators' grasp of a future of school makerspaces.

During the COVID-19 period, using blended makerspace activities suggested in this study gave access to a plethora of data and enabled exploration of learning in a school makerspace. I found it useful to contrast activities that incorporated hands-on components with those that were entirely digital, such as the interactive book project at the technology station. This study echoes the results of previous studies showing that students who worked in a school makerspace or school library makerspace gained specific learning outcomes (Bieraugel & Neill, 2017; Blikstein et al., 2013; Collins, 2017; Oates, 2015). The significance of this study arises from its investigation of the details (see Figure 5.16) related to the different stations inside the makerspace rather than viewing the makerspace as one entity, as previous studies have done (Lacy, 2016). Additionally, using reflective journals in data collection enabled me to include students' voices, which have sometimes been overlooked in previous studies (Hansen, 2018).

The makerspace in this study evidenced learning in five stations (3D printing, laser cutter, CNC, electronics, and technology). Additionally, students who participated in the projects evidenced a range of skills that mapped to the TLD framework. The resulting data offer evidence that school makerspaces can help students gain skills that can prepare them for their future jobs. The findings of this study add evidence to the literature regarding the impact of long-term projects and blended makerspace projects.

In the same vein, this study supports the Horizon Report: 2017 K–12 Edition (Freeman et al., 2017), which aimed to identify technology likely to impact teaching, learning and creativity and noted that 'makerspace enthusiasts in education highlight the benefit of engaging learners in creative, higher-order problem-solving through hands-on design, construction, and iterations' (p. 21). Furthermore, makerspaces, according to Otieno (2022), are transforming how educators approach teaching and learning in schools. Makerspaces are more than just buzzwords; they can link what students do at school with their everyday lives and future careers. This study takes this notion forward, creating the concept of proposed blended makerspace projects and long-term projects.

This thesis seeks to envision for educators and other members of the community a view that school makerspaces should be perceived not only from an education perspective but also as a tool that can affect society and the world at large. In other words, not only can school makerspaces enhance specific learning outcomes in schools, but they can also improve countries' economies by encouraging students to establish their own enterprises and shifting society from one that values consumption to one that values production (see Subsection 5.1.5). Nesta's report on makerspaces in

China, for example, which examined the trends driving the maker movement in China based on a survey of nearly 100 makerspaces, found that makerspaces transformed China from a manufacturing to an innovating country by integrating makerspaces into China's design and development ecosystem (Sanders & Kingsley, 2016).

Taking into account all that the student participants shared in their reflective journals, the comments from teachers in this study and the previous research, it can be concluded that a school makerspace offers students a unique space for learning in which they can develop technical and future-ready skills that can help them be better prepared for their future careers. Similarly, school makerspaces are student-centred environments that show the promise of being an exemplar for innovation and a place for fostering students' four Cs skills development. Additionally, it can be concluded that the value of a school makerspace is visible when learning is connected to the local community and real life. This thesis seeks to encourage proposed long-term projects and blended makerspace activities to help educators use school makerspaces to impact teaching, learning and the wider world.

To conclude, this study indicates that school makerspaces can contribute to redesigning teaching and learning by developing the connection between makerspace projects and learning in everyday life, academic studies and the local community and promoting interaction among learners. Finally, this study brings attention to the 'maker gap', a term used by the researcher to refer to schools that do not have makerspaces, which can be supported by implementing blended makerspace projects. As Khadri (2022) has indicated, not all school makerspaces and activities are created equal, and some schools cannot afford to buy expensive equipment. In a nutshell, this study contributes to the research literature on bridging the gap between the informal learning emphasis of makerspaces and the formal educational emphasis of school makerspaces, with a particular emphasis on the possible development of career-oriented skills.

7.5 Implications

This research has many implications that may aid students, teachers, and school leaders. In the following subsection, I discuss these implications in line with the research questions.

7.5.1 Implications of the Findings for RQ1 and RQ2

As school makerspaces enable students to explore topics, tweak, fail, and try again, bounce ideas off one another, and collaborate to construct something, schools are encouraged to promote makerspace learning by establishing a maker culture (Catherine, 2020). Maker education should be embedded; for example, there should be a makerspace, maker classroom zone, and maker carts in schools.

Practitioners can use the proposed blended makerspace activities to assist them in designing maker programmes to help learners learn deeper and more meaningfully by developing the four Cs. The proposed blended makerspace activities and long-term projects discussed in the previous chapter can be adopted by other makerspace teachers to help them use tools and devices that do not exist in their school makerspace.

7.5.2 Implications of the Findings for RQ3 and RQ4

The findings of this study provide guidance for school leaders and support in determining which stations or tools should be included in a makerspace. The findings suggest that more focus should be given to 3D printing and other stations that include machines, such as CNCs and laser cutters. Makerspaces can help schools design programmes and activities to increase students' engagement in learning. Additionally, makerspaces can help schools promote events to encourage social and community interaction among students.

7.5.3 Implications of the Findings for RQ 5

The findings of this study provide guidance for students to use makerspaces to prepare them for their future jobs, especially through developing soft skills, which are increasingly required today. As school makerspaces can promote entrepreneurship, schools should prepare personalised plans for each student to connect students' interests with the types of projects in the makerspace.

7.6 Recommendations

To further enrich maker pedagogy in schools and effectively address the needs of the new generation, the following recommendations are provided. These recommendations are tailored to the local context of the study while considering the broader field of makerspaces:

7.6.1 Recommendations for Schools

Given the findings of this study, schools can promote the culture of maker-centred learning by establishing additional makerspaces or exploring alternative approaches to accommodate the scheduling challenges faced by teachers. Schools should consider implementing stand-alone makerspaces, mobile makerspaces, and creating makerspaces in available classrooms to ensure equal opportunities for all students. Furthermore, encouraging students to connect their makerspace projects with the local community will help foster their development as future leaders.

To provide valuable opportunities for students in school makerspaces, educators and curriculum managers should collaborate to develop interdisciplinary approaches that seamlessly integrate maker-centred activities into curricula (for example, designing a project where students use both science and art skills to create a drone show). This requires reshaping the curriculum as a flexible framework that embraces student voice, agency, inquiry-based learning, and project-based assessments as shown by previous research and the findings presented in this thesis. By aligning the curriculum and school makerspaces, incorporating maker pedagogies and leveraging the resources and tools available in school makerspaces, students can actively engage in hands-on exploration and develop essential 21st-century skills and competencies.

7.6.2 Recommendations for School Leaders

School leaders play a crucial role in implementing successful makerspaces. It is recommended that school leaders develop strategic plans for the implementation of makerspaces and allocate appropriate resources to support their establishment and maintenance (Otieno, 2017). To support teachers, continuous professional development opportunities should be provided to keep them abreast of the latest trends and research in makerspace education. Additionally, integrating makerspaces into faculties of education and student teachers' preparation programmes can ensure that future educators are well-equipped to incorporate maker-centred approaches. School leaders should also consider the potential of 3D printing technology as an important component of makerspaces. Lastly, makerspaces should be seen as integral tools to support society, aligning with broader visions of where countries seek to stimulate economic growth and encourage individuals to become producers and creators rather than solely consumers (Gerstein, 2019).

7.6.3 Recommendations for Future Research

To expand the knowledge and understanding of makerspaces, future research should focus on the impact of various makerspace initiatives on teaching and learning outcomes. Exploring additional tools and stations, such as vacuum forming machines, gaming, drones, and heat presses, can provide valuable insights into their potential contributions to students' learning experiences. Furthermore, examining the design and layout of makerspaces and their influence on learning outcomes can inform practitioners and guide decision-making regarding the arrangement of stations and devices. Conducting a comprehensive census of school makerspaces in different countries would provide a broader perspective on the prevalence and characteristics of such spaces. Additionally, replicating this research in different demographic regions could offer comparative insights and enrich the existing knowledge base.

Countries without school makerspaces could explore the possibility of introducing blended makerspace activities, as this thesis proposes, by cooperating with a public makerspace or a public library or even by connecting a school to makerspaces in another country. For example, a school in one country could design digital models and ask someone in the local market or a different country to print or manufacture the models and send them via a postal service. Schools that do not have makerspaces can partner with places (with different types of makerspaces) that offer makerspace services. According to surveys of the literature, Bevan (2017) shows that many making programmes have been largely based in private schools, museums, and higher institutions. The approach that is recommended for school makerspaces based on this study is to help decrease the 'making gap', a term referring to those schools that do not have makerspaces due to a lack of funding and other resources.

Further research could also explore the role of school makerspaces in developing future employability skills and career opportunities for students. Designing activities that support specific skills and offering entrepreneurial opportunities within makerspaces might then contribute to students' career development, particularly in fields such as engineering.

In conclusion, these recommendations seek to enhance the implementation and impact of school makerspaces while considering the local context of the study and the wider field of makerspace education.

7.7 Limitations of the Study

The following limitations should be acknowledged when interpreting the results of this research. First, this study was limited to a single school makerspace. Examining more school makerspaces and expanding the number of participants might make this research more comprehensive in terms of broader generalisation potential. Furthermore, the use of case study methodology limited the scope of this research in terms of population size, demographic data, and other factors. Working with students and teachers in one school also entailed some challenges in collecting data due to teachers' overloaded schedules and possible changes in the school schedule as a result of the COVID-19 pandemic.

Another limitation of this study is that the researcher works as a makerspace specialist and has a strong passion for spreading the culture of school makerspaces more broadly, which may have led to bias. To combat this bias, a second coder was involved to validate or question the thematic coding, and multiple sources of data were employed. In addition, a mixed-methods study approach that included qualitative and quantitative data was employed.

Furthermore, this study does not include the whole spectrum of makerspace experiences; it represents innovation centres or open-space makerspaces that enable working with different types of materials and tools, such as robotics, technology, and woodworking. The low number of students who participated in the study in some zones, especially the CNC project, is another limitation. Additionally, it was not possible to include many STEAM projects or other subjects; as a result, the evidence does not account for the wider variety of activities that take place in these areas.

Makerspaces are recognised as innovative learning environments fostering innovation, critical thinking, and problem-solving skills. However, it is crucial to consider their accessibility and equity implications, particularly for less advantaged children and schools. One limitation of the context explored in this research is its focus on the context of affluent children and a school with resources to afford expensive equipment and materials for makerspaces. This raises concerns about potentially exacerbating existing educational inequalities.

Additionally, this research did not take into account the gender of the student participants, their culture, or any other demographic factors that could have influenced the results. This limitation can be addressed by conducting further research with expanded data gathering and analysis. Lastly, there was no control group or a comparison group against which the results could be compared.

7.8 Summary

This chapter has provided an overview of the study, conclusions drawn from the study, recommendations for educators and policymakers to create maker-learning environments, recommendations for future research and an overview of the study's limitations. Additionally, original contributions to knowledge were discussed, as were the implications of the study.

As makerspaces become more prevalent in schools, educators and policymakers are attempting to comprehend the importance of these areas and develop ways to enable teachers to use them in teaching and learning. As teachers, makerspace specialists and other educators are committed to implementing 21st-century skills, they work together to implement makerspace programmes to empower learners to be more prepared for life, universities and jobs that do not yet exist (Kitagawa et al., 2018). Pedagogy today seeks to consider all the skills needed by students and requires teachers to include a variety of methods; makerspaces can fit this need and support this type of pedagogy or maker-centred learning. This research contributes to our understanding of the kinds of learning that take place in school makerspaces. By conducting a case study of a school makerspace and using two frameworks to analyse data, the research explored the nature of learning in a makerspace in a bilingual school in Kuwait. This study contributes to the literature on how learning in school makerspaces can take place during crises, such as wars and pandemics. Schools may follow proposed blended projects to enable students to enjoy makerspace projects while they study at home. The findings of this research reveal that school makerspaces can serve as a context for developing 21st-century skills and as hubs for exploring many career pathways and real-life linkages.

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Appendix 1. Battelle for Kids Permission

RE: BFK Contact Us Request #11599869

LB [redacted]@battelleforkids.org>

To: You

Cc: [redacted]

Sat 27/03/2021 01:04 AM

Battelle for Kids gives you permission to use the frameworks (located here on our website) in for educational purposes, with proper attribution given to BFK.

Please abide by all requirements on the website above as well as the following guidelines:

- Prominently display the BFK copyright (including url) on every page where the Materials are displayed:

  Example: ©2020, Battelle for Kids. All Rights Reserved. www.bfk.org

- Do not remove the BFK copyright from underneath any graphics.
- Prominently display the BFK logo, where applicable
- Content may be used solely for educational purposes and must remain unchanged.
- Do not represent yourself in a manner that can be interpreted as implying that you are officially certified or endorsed by Battelle for Kids.

BFK retains exclusive right, title and interest in the proprietary materials. Use of any other BFK proprietary materials requires the written permission of BFK.

Thank you,
L.

[redacted]

Senior Specialist I **Battelle for Kids** I [redacted]
www.bfk.org I twitter.com/BattelleforKids
30 questions to prepare your school system to be ready and resilient for re-opening schools. Read the Conversation & Action Guide.

Appendix 2. Teachers' Survey (Battelle for Kids, n.d.)

I hope you've been having a lot of fun at the makerspace. Please take a few minutes to complete this survey. I would like to know your thoughts about the makerspace projects made by your students. There are no right or wrong answers, but please be honest. Your answers are important to identify any learning or skills that students have gained in the makerspace.
This survey will take approximately 15 minutes to complete.
Your answers will be submitted through an anonymous Google survey and personally identifiable data will not be collected. Thank you for your support. If you have any questions, please contact Sayed Mahmoud at alis13@lancaster.ac.uk
Your answers to the survey will not be saved until you click the "Submit" button on the last page. To make sure you don't lose any of your answers, please do not close this survey or your browser window before then. By completing this survey, you are agreeing to take part.

Choose the skills that your students developed while working in the makerspace:

CREATIVITY AND INNOVATION

- Use a wide range of idea creation techniques
- Create new and worthwhile ideas
- Elaborate, refine, analyse and evaluate their own ideas
- Develop, implement and communicate new ideas to others effectively
- Be open and responsive to new and diverse perspectives
- Demonstrate originality and inventiveness and understand the real-world limits to adopting new ideas
- View failure as an opportunity to learn
- Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur

CRITICAL THINKING AND PROBLEM SOLVING

- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation
- Analyse how parts of a whole interact with each other to produce overall outcomes in complex systems
- Effectively analyse and evaluate evidence, arguments, claims and beliefs
- Analyse and evaluate major alternative points of view
- Synthesise and make connections between information and arguments
- Interpret information and draw conclusions based on the best analysis
- Reflect critically on learning experiences and processes
- Solve different kinds of non-familiar problems in both conventional and innovative ways
- Identify and ask significant questions that clarify various points of view and lead to better solutions

COMMUNICATION

- Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts
- Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions
- Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade)

- Utilise multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact
- Communicate effectively in diverse environments

COLLABORATION

- Demonstrate ability to work effectively and respectfully with diverse teams
- Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal
- Assume shared responsibility for collaborative work, and value the individual contributions made by each team member

LIFE & CAREER SKILLS

Choose the skills that your students develop while working in the makerspace which help them to be well-prepared for the future and for career adaptability:

ADAPTABILITY

- Adapt to varied roles, job responsibilities, schedules and contexts
- Work effectively in a climate of ambiguity and changing priorities

FLEXIBILITY

- Incorporate feedback effectively
- Deal positively with praise, setbacks and criticism
- Understand, negotiate and balance diverse views and beliefs to reach workable solutions, particularly in multi-cultural environments

INITIATIVE AND SELF-DIRECTION

- Manage Goals and Time
- Set goals with tangible and intangible success criteria
- Balance tactical (short-term) and strategic (long-term) goals
- Utilise time and manage workload efficiently

Work Independently

- Monitor, define, prioritise and complete tasks without direct oversight

Other:

Be Self-directed Learners

- Go beyond basic mastery of skills and/or curriculum to explore and expand one’s own learning and opportunities to gain expertise
- Demonstrate initiative to advance skill levels towards a professional level
- Demonstrate commitment to learning as a lifelong process

Other life skills (You can suggest other skills that were not mentioned above)

…………………………….

Makerspace Stations/Obstacles / Suggestions

What are the current obstacles/ challenges of using the makerspace in learning?

…………………………………

Suggestions for improvement

…………………………………

Appendix 3. Permission from the Careers Enterprise Company

From: Research <Research@careersandenterprise.co.uk>
Sent: Wednesday, October 7, 2020 11:14 AM
To: Ali, Sayed (Student) <s.ali20@lancaster.ac.uk>
Subject: [External] RE: The Future Skills Questionnaire

This email originated outside the University. Check before clicking links or attachments.

Hi Sayed,

Please accept my apologies for the delay in my response. Yes, we'd be happy for you to use the Future Skills Questionnaire. We're currently piloting a revised version of the questionnaire, this likely won't be available in the public domain until 2021 but you're welcome to use the previous versions (attached).

Please let me know if you have any questions.

Best wishes,

[redacted]

THE CAREERS & ENTERPRISE COMPANY

Research

t: 0207 5663400
2-7 Clerkenwell Green, London, EC1R 0DE
www.careersandenterprise.co.uk
Email Policy

Appendix 4. Future Skills Survey (The Careers and Enterprise Company, 2019)

This survey is customised from The Careers and Enterprise Company Future Skills Questionnaire. The Careers and Enterprise Company works across England to help young people make good choices about their futures. Please take a few minutes to complete this survey. I would like to know your thoughts about the makerspace projects. There are no right or wrong answers, but please be honest. Your answers are important to identify any learning or skills you gained in the makerspace. This survey will take approximately 15 minutes to complete.

Your answers will be submitted through an anonymous Google survey and personally identifiable data will not be collected. Thank you for your support. If you have any questions, please contact Sayed Mahmoud at alis13@lancaster.ac.uk

Your answers to the survey will not be saved until you click the "Submit" button on the last page. To make sure you don't lose any of your answers, please do not close this survey or your browser window before then.

By completing this survey, you are agreeing to take part.

Career Activities

How have you changed?

How far do you agree or disagree that the activity has had the following results?

I am more aware of different careers

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

I have more ideas about my future career

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

I am clearer about what I need to do to achieve my ambitions

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

I know more people who can help me to achieve my ambitions

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

I am more motivated to work hard at school/college

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

I would recommend this makerspace project to other students

Strongly disagree

Disagree

Neutral/Neither agree nor disagree

Agree

Strongly agree

Career readiness

Has the activity helped you …

Decide what your ideal job would be?

No

Yes, a little

Yes, a lot.

Assess your strengths and weaknesses?

No

Yes, a little

Yes, a lot.

Make a plan of your goals for the next five years?

No

Yes, a little

Yes, a lot.

Think about whether moving straight to work after school is right for you?

No

Yes, a little

Yes, a lot.

Think about whether further education is right for you?

No

Yes, a little

Yes, a lot.

Seek help and support with your future education and career when you need it?

No

Yes, a little

Yes, a lot.

You can add your comments here:

……………………………………

Thank you for your time.

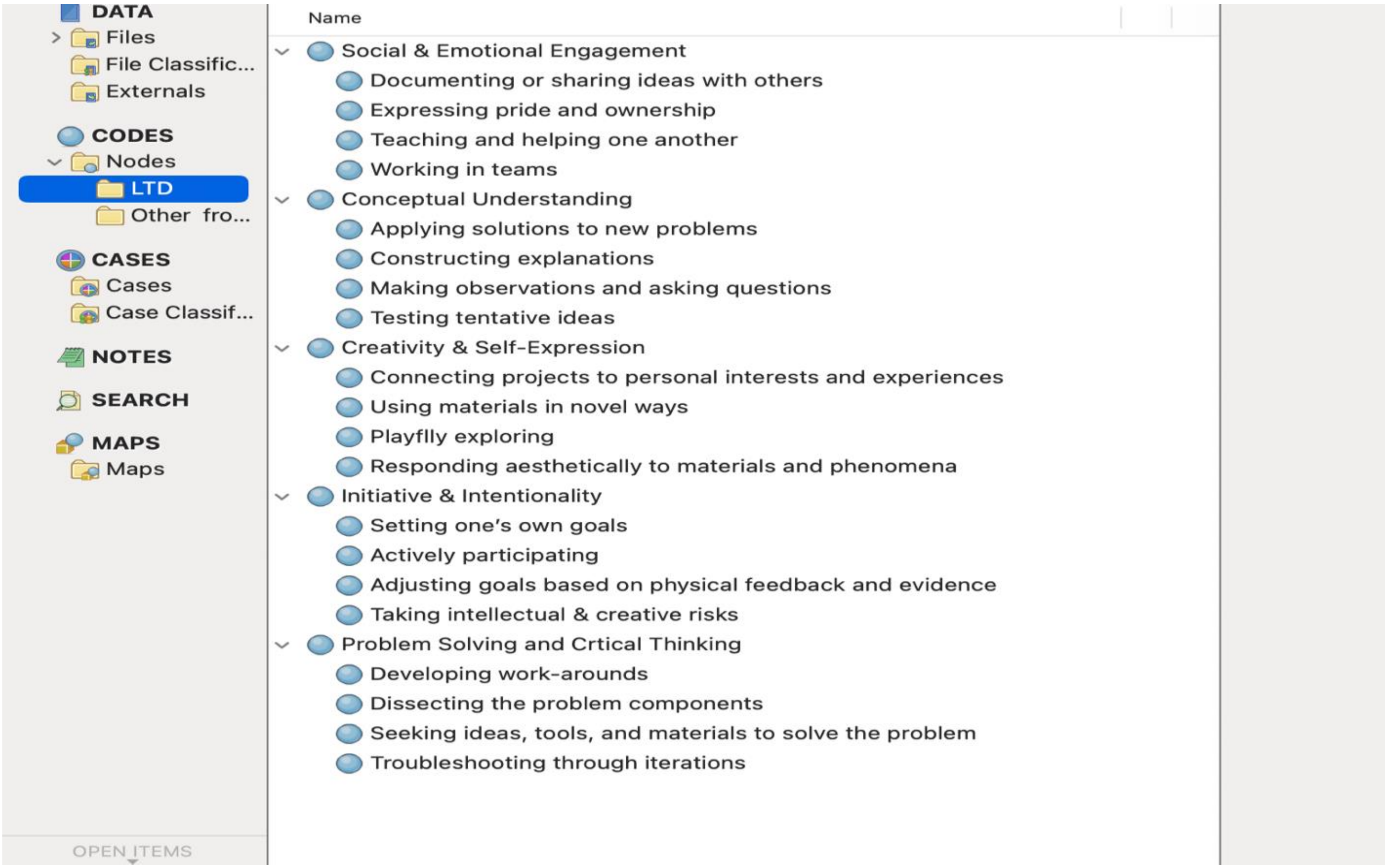
Appendix 5. Reflective Journals Sample

	Group: Date: Project:
Description	What is your project? Tell me about your goals What happened during classes? What role did you play in class? What is the coolest thing you've made during this project? What role did your classmates play?
Feelings	How did you feel during this week's classes? How did your feelings change? What were your goals for making your model? Did you adjust your goals?
Evaluation	What was good about this week? Why? What was bad about this week? Why? What was challenging to you during this week? Have you learnt from any failures? Tell me about a moment you got stuck while working on your project and you decided to give up. How did you deal with it? Any work-arounds? Who/what/ how helped you?
Analysis	What could you have done to improve your work? Assess the impact of this week on you and your future steps of your project or other projects.
Conclusion	Are there any skills you learnt? What are they? Any life skills? Did you help or receive help from others? Tell your story about this. Which design stances did you follow? playful/functional/pragmatics/commercial - or other please write here……….

	Are you happy with the plan/ideas prototype? Is there any connection between what you designed and your personal experience or interests? Do you think there are some aspects that you might change? What is your favourite makerspace station? What's your favourite thing about it? Did you use any new tools or materials while making it? Is there any future impact of the makerspace in your future life/careers? Do you plan to get any tools such as 3D printers at your home?
Action plan	How are you going to do things differently next time to avoid any problems/mistakes you faced this week? Will you use the iterations in the same way

Appendix 6. The Final Coding Scheme Based on the LTD

Reflective Journals were coded using a deductive/inductive approach. The first step was to break up each journal into paragraphs and classify related paragraphs into one of the two general themes (TLD learning indicators). Using the deductive approach, I created all the relevant instances, which represent the learning indicators in five stations of the makerspace (see the figure below produced by NVivo software).

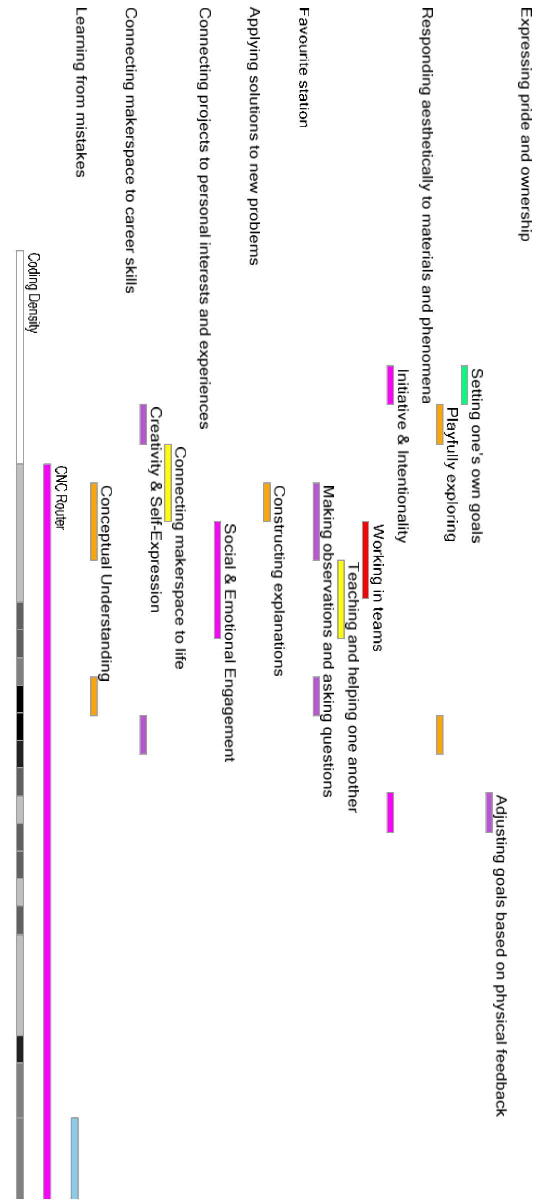


Appendix 7. An Example of Coding Strips of CNC Router Station

Name: NN CNC

Created On: 08/01/2022 12:45:49 ص
Created By: MA

Our project was to create an F1 car model in a computer software. The software I used was Fusion 360 along with a few people in my class, then the rest of the class used TinkerCad. During class we made our models on our computer following a set of measurements premade to our project. We also made a presentation following the project to reflect and to show off our models. The role Iplayed in class was that I helped myself get over obstacles faced throughout the project. The coolest thing we made throughout our time using Fusion 360 was our model of course, but I think the whole process of us learning to use Fusion 360 is cool. It is cool because it not only helps us in the future, but it also helps us with design thinking , and it gives us a new creative outlet. The role my classmates played was giving good feedback and advice when asked. I think the atmosphere with my classmates was very helpful in all of us achieving what we have. At the beginning of this project, I felt overwhelmed because I thought this project consisted of too much tedious work. My feelings changed throughout the project because I saw how much it not only benefits me, but is also fun. My goals were to create a fully functioning vehicle with a motor and be able to detail the exterior like a normal car would have been. I adjusted my goals because of the lack of resources and time, and because of virtual learning it limited us as well. My adjusted goals were to create a model correct in measurements and in parts.



What was good about the time we spent on this project was that we learnedso much. We learned things like design thinking and the LAUNCH cycle as well as a multitude of life skills like time management, patience, and defeating my beast. My beast was that I was overwhelmed in the beginning and didn't like the idea of too much tedious work. Throughout this process there were bumps in the road, and one of them was having to redo the project because the measurement

Appendix 8. Consent Form Sample

CONSENT FORM

Lancaster University

Project Title: How State-of-the-Art Makerspace Stations Contribute to Differences in Students' Learning: A Case Study of a Bilingual High School in Kuwait

Name of Researcher: Sayed Mahmoud
Email: alis13@lancaster.ac.uk

Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily	☑
2. I understand that my participation is voluntary and that I am free to withdraw before the last week of projects related to this study in the makerspace, for any reason.	☑
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher, but my personal information will not be included and all reasonable steps will be taken to protect the anonymity of the participants involved in this project.	☑
4. I understand that my name/my organisation's name will not appear in any reports, articles or presentation without my consent.	☑
5. I understand that data will be protected on encrypted devices and kept secure.	☑
6. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study.	☑
7. I agree to take part in the above study.	☑

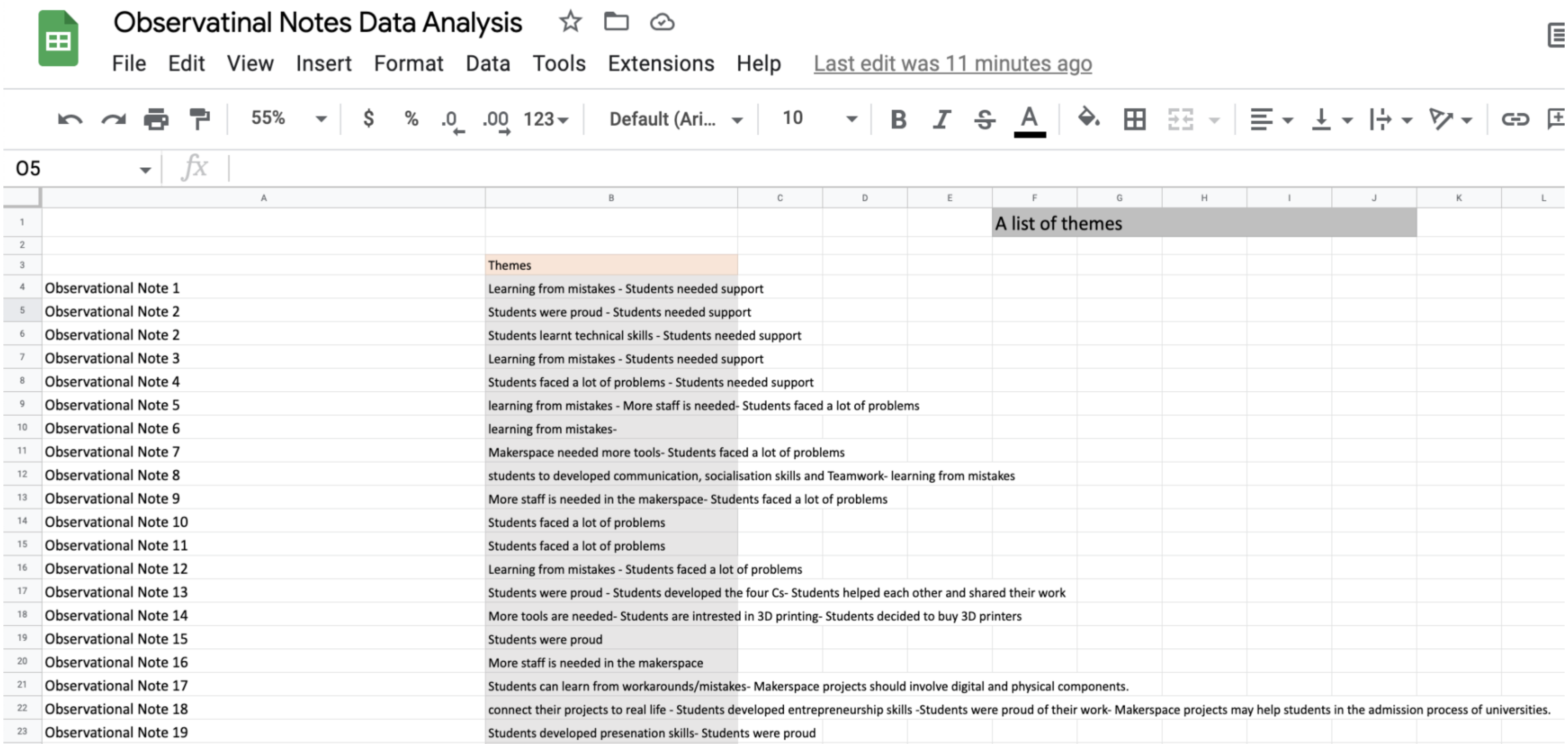
[redacted] March 20, 2021 [redacted]
Name of Participant Date Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent Sayed Mahmoud Date 20-3-2021 Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

Appendix 9. Analysis of Observational Notes



Observatinal Notes Data Analysis

File Edit View Insert Format Data Tools Extensions Help Last edit was 11 minutes ago

	A	B	F
1			A list of themes
2			
3		Themes	
4	Observational Note 1	Learning from mistakes - Students needed support	
5	Observational Note 2	Students were proud - Students needed support	
6	Observational Note 2	Students learnt technical skills - Students needed support	
7	Observational Note 3	Learning from mistakes - Students needed support	
8	Observational Note 4	Students faced a lot of problems - Students needed support	
9	Observational Note 5	learning from mistakes - More staff is needed- Students faced a lot of problems	
10	Observational Note 6	learning from mistakes-	
11	Observational Note 7	Makerspace needed more tools- Students faced a lot of problems	
12	Observational Note 8	students to developed communication, socialisation skills and Teamwork- learning from mistakes	
13	Observational Note 9	More staff is needed in the makerspace- Students faced a lot of problems	
14	Observational Note 10	Students faced a lot of problems	
15	Observational Note 11	Students faced a lot of problems	
16	Observational Note 12	Learning from mistakes - Students faced a lot of problems	
17	Observational Note 13	Students were proud - Students developed the four Cs- Students helped each other and shared their work	
18	Observational Note 14	More tools are needed- Students are intrested in 3D printing- Students decided to buy 3D printers	
19	Observational Note 15	Students were proud	
20	Observational Note 16	More staff is needed in the makerspace	
21	Observational Note 17	Students can learn from workarounds/mistakes- Makerspace projects should involve digital and physical components.	
22	Observational Note 18	connect their projects to real life - Students developed entrepreneurship skills -Students were proud of their work- Makerspace projects may help students in the admission process of universities.	
23	Observational Note 19	Students developed presenation skills- Students were proud	

Observational Note 20	Teachers and students can relate projects to their life
Observational Note 21	Students developed communication skills
Observational Note 22	Students know how they can implement their project in their life
Observational Note 23	Students learnt from their mistakes
Observational Note 24	Students developed Creativity/innovation skills
Observational Note 25	Students faced a lot of problems during COVID-19-Students enjoyed long-term projects
Observational Note 26	Students connected the projects to their universities and Students connected the projects to their universities future jobs
Observational Note 27	Students were proud of their functional model
Observational Note 28	Students developed communication skills
Observational Note 29	Students were happy about the long-term projects- Student relate projects to their life and future jobs
Observational Note 30	Few students were unhappy about the projects in the makerspace- Students developed time management skills
Observational Note 31	Students developed emotional intelligence
Observational Note 32	Students developed problem solving skills

Theme	**Number**
Learn from mistakes	8
Students developed the four Cs skills	10
Students connected the projects to their universities	2
Students were proud	5
Students faced problems	7
Long term projects	2
Teachers and students can relate projects to their life	3
Students needed support	6
Student relate projects to future jobs	4

Appendix 10. An example of an Analysis of Surveys

Compare

	Laser	CNC	3D	Electronics	Techology
I am more aware of different careers					
Strongly disagree			16.7	25	5.3
Disagree			11.1		15.8
Neutral/Neither agree nor disagree	20		50		36.8
Agree	60	100	11.1	62.5	31.6
Strongly agree	20		11.1	12.5	10.5
I have more ideas about my future career	**Laser**	**CNC**	**3D**	**Electronics**	**Techology**
Strongly disagree			1		5.3
Disagree	1		2		10.5
Neutral/Neither agree nor disagree	2	50	36.8	37.5	47.4
Agree	60	50	42.1	37.5	31.6
Strongly agree	20		1	25	5.3
I am clearer about what I need to do to achieve my ambitions	**Laser**	**CNC**	**3D**	**Electronics**	**Techology**
Strongly disagree			1		
Disagree	1		1		10.5

Appendix 11. Examples of Instances

A code was given for each participant. Codes indicate the type of the project, such as 3D printing.

Learning from mistakes

AAHC 3D Printing

We failed a couple of times but tried multiple times till we reached the results that we wanted

AAHC3D printing

Fear! Fear has helped me push my limits and face the challenges. Fear is a good thing

AWHC 3D printing

We learnt from the failure and quickly got back to our account to view the project.

AA CAR

I've failed many times, but I learned from them and redid the assignment.

FA Car

I have learnt from failures to be honest and am trying to push myself to do stuff before they are due.

UD Car

Happiness does not come from doing easy work. It comes from the afterglow of satisfaction after the achievement of a difficult task that demands your best.

Appendix 12. Examples of Descriptive and Reflective Notes

Observational notes were divided into descriptive and reflective notes. Reflective notes interpret or describe the descriptive ones.

<u>Descriptive Note 1</u>

1- Some devices were infected with viruses.

I discovered the issue of viruses through my efforts to help a student. After many attempts to help this student, she could not install Fusion 360. The only solution was to ask her to bring her laptop to my home to fix it during the weekend. Her father brought the device and I promised to fix it within two days. When I start the process, I discovered that the issue was that the student installed hacked software. The software caused many problems to the device and prevent the student from installing Fusion 360. I formatted the device and could successfully install fusion 360. I told the parent and the student about the issue and advised them not to install any hacked software in the future. The student described this incident in the following paragraph:

> I have faced lots and lots and lots of problems with fusion 360 throughout the entire semester. At first, I couldn’t get a license, then I wasn't able to download the app, after that, the app refused to open leading to a lot of viruses and complications on my laptop. I informed Mr. Sayed about the problems in the app, so he tried to fix it by using the share screen feature on zoom unfortunately it did not work. We tried several other ways, and still got the same outcome. After that, Mr Sayed contacted by father, and he took my laptop on winter break so he can fix it, he did install fusion, and everything in my laptop got erased as well in hoped for the app to work this time, but it did not. So, for the last time Mr. Sayed made an after school 40 zoom session to try to solve the problem, but fusion still did not work. This is where Mr. Sayed decided that he make me and the class to have the option of working in a other website called Tinkercad.

Reflective Note 1

- Students faced a lot of problems in their makerspace projects during the pandemic.
- Students needed a lot of support from the makerspace staff.
- Makerspace staff should have plan B when they plan for makerspace projects.

<u>Descriptive Note 2</u>

- I discovered that one of the student's models had a problem (no holes for the wheels).
- When we asked her if she was happy with it, she said that she was busy and she had a lot of work during the pandemic, and it was difficult for her to find time to work on it.
- One student was astonished when he realised that it was the real model of what other colleagues designed and was **enthusiastic** (is it our model / wow! I cannot believe it)
- One student was very happy when I told him "You can get a motor from an old toy and connect the model".
- I printed only two models.
- The teachers used Zoom to show the students how they could operate the 3D printer and

students were happy.

Reflective Note 2

Students faced a lot of problems in their makerspace projects during the pandemic

Students were happy when they saw the 3D printed model of their work.

Students were interested in taking take their projects to the next level and improve them

Appendix 13. Examples of Comments and Themes from Teachers' Survey

I analysed the qualitative data in the teachers' survey which included three parts (obstacles, suggestions, and other comments). I grouped all quotes that were clearly identified as belonging to each theme and relative to the interests of study (what students can learn in the makerspace stations). I created the main list of codes from the comments of teachers. Sub-codes, such as long-term projects, were then generated from the text using open coding, and codes were sorted into comparable concepts using constant comparisons.

What are the current obstacles/ challenges of using the makerspace in learning? The following table summarises the results:

Participant 1	The makerspace needs more staff to work in
Participant 2	The makerspace needs more than one device from each tool to serve more than one group at the same time
Participant 3	The experience of having students work remotely was a real challenge, but the students have enjoyed it because they were able to collect their models to feel and touch what they have designed and worked on for a long time.
Participant 4	Busy timetable
Participant 5	1- I believe it might be how to have all the students working together, at the same time, with the help of the teacher and the makerspace specialist (maybe more staff is needed if all groups are working together). 2- making sure everyone is adhering to the safety procedures. 3- keeping track of tools, avoiding loss or misuse.
Participant 6	Being online limits students' creativity to a certain extent as they are not able to come to the maker space as often as they would like to.

Participant 7	Curriculum and pacing. Finding suitable activities. The limited time per department-the lack of teachers PD-the absence of rubrics of blinded learning. Some supplies are hard to find or not available

Other Comments

One teacher recommended long term-projects because it enhances the abilities of the students to develop many skills. Another teacher indicated that students had fun and enjoyed learning with the makerspace. Finally, one teacher stated that he was happy with the makerspace, and it was a great opportunity for teachers and students.

The experience of having students work remotely was a real challenge, but the students have enjoyed it because they were able to collect their models to feel and touch what they have designed and worked on for a long time.

Being online limits students' creativity to a certain extent, as they are not able to come to the makerspace as often as they would like to…….

It was great using some of the makerspace tools and technology and integrating that into the curriculum. Students had fun and enjoyed the learning experience.

I am glad to use the makerspace. It is such a great opportunity for teachers and students during the COVID-19 period.

Students got a sense of what it would be like to go out there and deal with the real world and find solutions to problems as well as conflict resolution skills and how to overcome problems while working in a group with different points of view and ways of doing things. Students learned how to overcome personal differences and do what's best for the group and project they are working on

What are your Suggestions?

Makerspace Tools and Staff

Participant 1 and 5 indicated that more staff is needed in the makerspace. Participant 2 indicated that the makerspace needs more than one device from each tool to serve more than one group at the same time and participant 7 mentioned that some tools are hard to find.

PD and Curriculum

Participant 4 and 7 referred to challenges to the curriculum, such as busy schedules, the absence of rubrics and finding suitable activities. Participant 7 indicated more training is needed for the staff.

Covid 19

Participant 3 and 6 indicated that working on makerspace projects was a challenge as it limited the students' creativity, but it was fun.

Suggestions for Improvement

To get more tools.
To make training for teachers and students, as the students are not aware enough of the importance of the makerspace to improve their life-skills.
To have a stand-alone makerspace allocated to serve high school students only.
More flexible timetable
Having more staff in the maker space, assigning different sections for different classes, and having a safe place to keep the projects the students are working on

It would be great to allow students to come in more often to work with their hands during the making process.
Design the curriculum by adding more activities.
Mobile stations-providing PD for teachers-create a library of ideas with their rubrics.
Bring more supplies are commonly used

Themes

Three themes were generated from the above table

1- Makerspace Environment

Some teacher participants suggested getting more tools, a stand-alone makerspace and mobile makerspaces. One participant suggested keeping the projects in a safe place in the makerspace.

2- School Environment

Some teacher participants suggested having flexible timetables, connecting makerspace to the curriculum and having a library of video lessons.

3-Long-term Projects