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University students' participation and interaction in scripted collaborative learning – A case
study in Maker culture context

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Maker culture is a new movement adopted by the educational sector around the world. Such movement aroused the interest of researchers and educators to explore it. Within its environment, students can collaborate with others to solve problems or do some projects. However, collaboration does not occur naturally. From this problem, this research has flourished.

The research design of this study is a case study, following qualitative methodology entitled content analysis. The participants involved are twenty students in their 1st year of master studies. The aim of the current study is to explore collaborative learning in Maker culture to identify three aspects; 1) how it might affect the students' learning gain, 2) how the participation and collaborative interaction among the students are influenced, 3) how did the students perceive such collaborative script.

The researcher answered these questions by designing a macro collaborative script and implementing it in two separated sessions within the maker culture context. The data collection methods were pre and post-questionnaires in addition to video data and they were analyzed using QSR NVivo software. The findings of this study indicated that the students' learning gain was significant, yet the majority acquired a shallow level of knowledge and not a deep level of knowledge. As for the participation and collaborative interaction, although the students were on-task almost 57% of the duration of the sessions, interestingly the duration of collaborative interaction was only around 33% of their participation. Hence, it can be deduced that even if the students are participating in a collaborative task that does not mean they are collaboratively interacting; the reasons that might be behind such results are elaborated comprehensively in the study. Finally, the students had a positive attitude towards this type of collaboration script. The researcher recommends that collaborative interaction might be enhanced if the script was adaptive with more details, this might lead to a deeper level in cognitive learning gain and a higher percentage in collaborative interactions.

Keywords: collaborative learning, maker culture, collaborative script, collaborative interaction

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1 Introduction

Maker movement has attracted a lot of attention recently (Halverson & Sheridan, 2014). What makes it interesting is that it adopted children and adults, academics and non-academics; all together gathered with a common interest which is *making* and tinkering with your own hand and using different types of technologies. Such a wide scope of different people and expertise interested in this movement lead to the explosion of makerspaces; with more than 800 makerspaces reported around the world (Make:, 2019). This movement can be featured as a knowledge building community since it involves sharing, and collaboration among participants to co-construct knowledge and build things together (Martin, 2015) and nowadays it is being adopted widely in the educational sector (Hansen, McBeath & Harlow, 2019). Such a new environment is being adopted into K-12 education, has invited a vast number of researchers and educators to investigate its impact or the impact of some educational approaches implemented within its context (Chu, Quek, Bhangaonkar, Ging, Sridharamurthy, 2015; Martin, 2015; Eriksson, Heath, & Ljungstrand, 2018; Hansen et al., 2019; Halverson & Sheridan, 2014; Papavlasopoulou, Giannakos, & Jaccheri, 2017)

The need of this study stems from the fact that in makerspaces in educational contexts, the students or tinkerers might gather to solve a problem or build something collaboratively. Yet, putting students into a group does not mean they will collaborate successfully (Dillenbourg, 2002). Hence, it is essential to familiarize students with collaborative learning in this context. Collaborative learning is an umbrella term including diversity of group-based learning approaches (Smith & Macgregor, 1992) and a necessity in the 21st century global education (Aalst, 2013). Furthermore, it has been researched for more than twenty years (Damon & Phelps, 1989; Dillenbourg, 1999; Stahl, Koschmann & Suthers, 2005; Dillenbourg & Jermann, 2007; Webb, 2013; Laal & Ghodsi, 2012; Silvola, 2017). Nevertheless, collaborative learning and technology needs accurate design of the tools, the learning activities and the context in which these tools are being used (Dennen & Hoadley, 2013). With different studies about collaborative learning, it was scarcely investigated how to implement it in maker culture context. Hence, the need of this study appeared, and the researcher thought that this would have an additional value to the previous literature and might help the teachers who want to implement collaborative learning within Maker culture context. In addition, implementing collaborative learning effectively might lead to uniting the skills that might be acquired in collaborative

learning with the potentialities in maker culture and would produce a very fruitful outcome on the mentality and behavior of the students.

The research design of this study is a case study, following qualitative methodology entitled content analysis. The participants involved are twenty students in their 1st year of master studies. That aim of the current study is exploring scripting collaborative learning in Maker culture to identify three aspects; 1) how it might affect the level of students' cognitive learning gain, 2) how the participation and collaborative interaction among the students is influenced, 3) how did the students perceive such collaborative script.

2 Theoretical Framework

The theoretical framework forms the spinal cord of the study, that holds its parts together. How it is formulated depends on the study, what theories are relevant, the information needed to plan a unique piece of work. Hence, the researcher needs to pay attention to what he/she is including in her framework to avoid excess information that might mislead instead of helping to understand the study. The main pillars of this study are Maker Culture and Collaborative Learning (CL). Within CL, the theoretical conceptions behind it, definition, benefits, challenges, scripts in collaborative learning and finally collaborative interaction are all introduced to plan the complete picture of the study.

2.1 Maker Culture

Before elaborating about CL, there is a need to understand the environment that is nurturing it. Leading to building the solid foundation of this study. The expansion of technology all over the world, and the easy access to different sources of information about programming, electronics and 3D printing lead to the involvement of a large proportion of inexperts in the technology so they can prototype and produce things and participate in ‘do-it-yourself’ (DIY) activities (Chu, et al., 2015). Such activities were flourishing and happening all over the world and more people are joining it. Consequently, this became a new culture; the Maker culture. This Maker culture “represents a growing movement of hobbyists, tinkerers, engineers, hackers, and artists committed to creatively designing and building material objects for both playful and useful ends” (Martin, 2015, p.30). No matter what the background of the learner is, he/she can be involved, interact and learn within this specific culture through different activities. Albeit it is a new movement started with the release of the first issue of Make magazine in 2005 and the first Maker Faire in 2006 (Martin, 2015), yet it paved the path towards education successfully. In Montessori schools, an essential element for learning is that the children use different tools and materials to build their knowledge (Haskins, 2010; Montessori, 1912). This is what happens in maker culture, where children create by themselves pieces of artefacts from different materials or with different technologies. The interaction between the child and the surrounding environment, while he is trying to create an artefact by himself and encountering different experiences is in the heart of Piagetian learning theory (Piaget, 1980). Papert built on Piaget’s theory to develop the constructionism, which encourages students’ exploring to gain their knowledge that can be done by making processes. In addition, such maker environments can

nurture group working where different levels of experience might gather to work on a specific project, hence those who are less-experienced can benefit from those who are advanced, and this typically fits in Vygotskian zone of proximal development (Vygotsky, 1978). All these learning theories are deeply rooted in the Maker culture. Where the makers or the students are using different tools or methods to manufacture what they were designing in their mind or on a computer and try to reproduce it into a tangible product with trial and error which might lead to conceptual adaptation (Piaget, 1980). Such processes would encourage interaction and discussion among them, even some might help the others if they were more experienced leading to knowledge construction.

With such a deep connection with different theories of learning, this movement nowadays is being endorsed widely in the educational sector (Eriksson et al., 2018; Martin, 2015; Halverson & Sheridan, 2014; Papavlasopoulou et al., 2017), where the educators perceive it as a good opportunity to raise interest and engagement in science, technology, Engineering and mathematics (STEM) activities where it embodies STEM concepts (Martin, 2015; Bevan, 2017; Hansen, McBeath, & Harlow, 2019; Chu et al., 2015). Halverson and Sheridan (2014) identified three main components of the maker movement: first, the maker as identities, where Dougherty (2013) introduced the term maker mindset which is the growth mentality that nurtures the belief in the students, they can make anything they want. With such a mentality, the students change from consumers to makers. Second, *making* as a set of activities which the researcher will consider it in this study as the script that was designed to implement her case study, and these will be discussed comprehensively in section 2.2.4. Finally, maker *spaces* as communities, an example of such is Maker Fairs and fabrication (or fab) labs (Hansen et al., 2019). Fablabs are interdisciplinary learning environments (Joost, 2013), where tinkering, computation and engineering are fused together (Blikstein, 2013a). Digital fabrication can be practised within the premises of Fablabs. In their book chapter, Dittert and Krannich (2013) presented a practical example of implementing digital fabrication technology into the educational context. They also presented Neil Gershenfeld's (2005) work, where he connected between Papert's ideas about uniting the worlds of play and work, where tools and toys can be anticipated as the same for the invention and claimed that Fablabs might take this into the more advanced level, by increasing the transparency and the attractiveness of engineering and design. He elaborated that digital fabrication allows the digital fabricators to examine the feasibility and possibility of producing a practical description of a system into a physical form. Hence, virtual and real products are tightly connected to each other than earlier, leading to an increase

in creativity and giving the chance to concentrate on building ingenious artefacts. In maker spaces digital fabricators can work individually or form a group and work collaboratively, hence collaborative learning can be implemented in maker spaces.

2.2 What is Collaborative Learning?

To understand what happened in this case study, there is a need to understand what Collaborative learning is at first. CL is an approach in learning that has been profoundly researched for over two decades. It was defined by a vast number of researchers, some of them are introduced in this study. Stahl et al., (2005) stated that “Collaborative learning involves individuals as group members, but also involves phenomena like the negotiation and sharing meanings—including the construction and maintenance of shared conceptions of tasks – that are accomplished interactively in group processes” (p. 411).

2.2.1 Defining Collaborative Learning

The need for engineering collaborative learning results from empirical studies on the effectiveness of collaborative learning. These studies show that “this effectiveness depends upon multiple conditions such as the group composition (size, age, gender, heterogeneity, etc.), the task features and communication media” (Dillenbourg & Jermann, 2007, p.276)

Collaborative learning resembles a situation among people preferably of similar status such as students, interacting while applying different learning mechanisms, for example, a negotiation that leads to an effect that can be demonstrated such as an achieved goal (Dillenbourg, 1999). Piagetian and Vygotskian theories provide a good infrastructure for understanding CL that concentrate on development (O’Donnell and Hmelo-Silver, 2013). Piaget (1980) developed the constructivist theory of cognitive development, which explains how the children build their cognition. Such intellectual growth happens through their interaction with their surroundings. While interacting, they might face new facts that contradict their own understanding, and this leads to disequilibrium in their cognitive system. Trying to balance this disequilibrium is what is called adaptation. This conceptual development occurs through the process of assimilation, which is how the person comprehends the new situation. and accommodation, that is “a process in which low-level schemas are transformed into higher level schemas” (O’ Donnell and Hmelo-Silver, 2013, p.6). During the collaboration, group members might disagree on a specific solution or problem; this disagreement might cause disequilibrium in their cognition.

However, through discussion and interaction, they might reach a common answer that would lead to the balance of their cognition again and that is adaptation.

O’ Donnell and Hmelo-Silver (2013) introduced Vygotskian perspective on development as it comprises both cultural-societal and individual factors. Although Piaget preferred that the group members have the same level of knowledge about the subject they are discussing, learning or solving. However, Vygotsky believed that inequality in the level of group members is beneficial especially to the weaker members, where they benefit from the knowledge of their more competent group members hence their cognition develops while interacting. Vygotsky introduced the term *zone of proximal development*. Vygotsky’s zone of proximal development is the level of capability on a task where the student cannot achieve it by his/her own, but he/she could do if the suitable help was presented to him/her from a more competent partner (O’Donnell and Hmelo-Silver, 2013). Such a phenomenon was highly witnessed in the current study and discussed in section 5.2. However, the competent partner needs to know what the less competent student has a deficiency in, to help him/her efficiently (Webb,1991). In addition, not every person could identify the needs of his/her group members, but such a skill can be taught for the student (Webb and Farivar, 1994).

2.2.2 Benefits of CL

One reason that motivated the researcher to investigate collaborative learning, is the benefits it has, and she has experienced some of it by herself too. This section provides some evidence of the positive impact of collaborative learning in different aspects. Laal and Ghodsi (2012) gathered all the advantages of CL that were mentioned in two comprehensive articles, then summarized and categorized them into four main categories; social, psychological, academic and assessment. In the social aspect, CL established learning communities, where a supportive social system is developed. Leading to a positive atmosphere and diversified understanding among the staff and the students while practising cooperation. As for the psychological advantages, CL apply student-centred instruction which in turn enhance students’ self-esteem. In addition, it establishes a positive mindset towards teachers. Furthermore, cooperation curtails anxiety. Next, is the academic advantages, while collaborating, the students get involved actively in the learning process and their critical thinking skills are enhanced. CL creates problem-solving techniques suitable for the students and it enhance classroom results. In addition, “large lectures can be personalized” (Laal & Ghodsi, 2012, p.487). Finally, the

teaching techniques applied in CL employ a diversity of assessment methods. Worth to note, that some studies has showed that the impact of CL does not occur only during the implementation only but it continues with the students (Berg, 1993; Rau, Bowman & Moore, 2017) where they internalize these skills and apply it in future courses; hence the positive impact of CL extended subsequently after ending the implementation and during conventional classes.

2.2.3 Challenges in CL

Identifying the challenges that faced the educational designers in the literature would help the researcher in raising her awareness about their existence, hence she can try to minimize the reasons that might trigger them while she is developing her design. In this CL process, the discussion is a vital element where students try to explain for each other and try to simplify the idea to proceed in their work and achieve their goal. According to Ploetzner, Dillenbourg, Preier and Traum (1999), “providing explanations to each other involve forms of collaborative learning” p.103. However, just putting three or four students into one group doesn’t mean that their collaboration and interaction is guaranteed or would provide learning (Burdett 2003, Cohen 1994, Dillenbourg, 2002; Järvenoja & Järvelä 2009; Rau, Bowman & Moore, 2017; Volet et al., 2009). In fact, CL as any teaching approach faces some challenges that the researchers and educators are continuously trying to solve. Webb (2013) had presented some debilitating processes of collaborative learning, such as failure to provide elaborated explanation, failure to seek and obtain effective help, suppressed participation, too little or too much cognitive conflict, lack of coordination, and negative socio-emotional processes. Furthermore, ensuring productive interaction is one of these challenges. Also, unequal participation, lack of motivation, unequal contribution can be considered as challenges too.

In a case study related to collaborative problem solving, a researcher tried to identify the applied strategies and challenges encountered by the students during a collaborative solving task. In his study, there were three challenges that faced the students; understanding the task, time management and lack of motivation (Rengifo, 2015). Since motivation strengthen learning by promoting students’ efforts, endurance in front of challenges, adoption of strategies for deep-level learning and self-regulation (Rogat, Linnenbrink-Garcia, & Didonato, 2013) then its lack might deeply affect the learning process. Another study was done by Silvola (2017), where she investigated the challenges that teacher students face in collaborative learning and how they

solved it. According to the qualitative video data analysis that was applied, she reported the following challenges that the students faced; mostly they had problems in understanding the task and maintaining their interest. She added that interaction between the teacher students, participation, organizing the work besides technological issues and external interruptions were also reported among the challenges.

Even though the potentiality of collaboration can happen when you group people together, but it is not guaranteed as mentioned earlier. Groups are often a source of annoyance for some individual members, causing loss of time and pessimistic feelings (Salomon & Globerson, 1989). The teacher needs to create some interaction that can promote learning, increase motivation and ideas sharing and discussing between the group members. Such planned interaction can be promoted by scripting.

2.2.4 What is a script?

As mentioned earlier, one attempt that teachers adopt to ensure an effective collaboration is scripting. A script can be considered as an educational contract between the teacher and the students (Dillenbourg, 2002) and a powerful approach when promoting collaborative learning (King, 2007). In addition, scripting interaction can develop the predetermined learning by prompting specific cognitive, socio-cognitive and metacognitive mechanisms through the pre-designed roles of participants, activities involved and sequencing the events (King, 2007). During the collaboration, the probability of knowledge productive interactions to occur is increased by scripts (Dillenbourg & Jermann, 2007). Scripts are activity programs intend to promote collaborative learning by framing the students' interaction through specifically arranged activities that are pre-assigned to different group members (Weinberger, Ertl, Fischer, & Mandl, 2005). However, not any script can be implemented in a collaborative learning situation to create collaboration, it needs to be a collaborative script. Hence, it needs to include some essential elements that were found crucial to obtain collaboration. Next section introduces shortly some types of scripts and emphasizes on collaboration script and later the elements of that type of script are displayed.

What are the types of Scripts?

Depending on the aim needed and the content of the subject, the designer chooses the type of the script needed for this specific goal. Throughout the literature, there were different scripts

that were vastly researched. O'Donnell and Dansereau (1992) are those who introduced the term scripting in an educational context, and they titled it "MURDER". They have created it to facilitate text comprehension. Kollar, Fischer and Hesse (2006) have written a comprehensive conceptual analysis related to collaboration scripts, where they introduced scripts that were meant for face to face learning and computer-mediated learning.

It can be noticed that some types are more general than the others and can be considered as the main categories whereas the rest can fall under them. The umbrellas are internal and external. Schank and Abelson introduced the internal script (1977), who related it to the sequence of actions that a person does in a familiar situation, such as everyday situation and which the individual has formed it upon his prior knowledge and memory. While External script (Kollar et al.; 2007) was connected to "instructional approaches" (Wang, 2017, p.16). Then, Epistemic and social scripts (Weinberger et al., 2005). Later comes Micro- and Macro-script (Dillenbourg and Jermann, 2007), where micro-script aims at guiding the students' interaction directly, for example by providing specific details for role taking and task division. Whereas, the Macro-script affect the students' interaction indirectly, where it "promotes productive interaction by arranging basic conditions like the group size, the group task or the communication media rather than specific support" (Wang, 2017, p.16). Finally, social and epistemic scripts; epistemic script can be seen "as task strategy, which can be more or less specific to the domain and the learning task" (Weinberger et al., 2005, p.6) while social script intends to support learners' communication by knowledge constructing via sequenced interaction steps (Weinberger et al., 2005). The following figure (see Figure 1) represents some scripts categorized as the researcher was referring to.

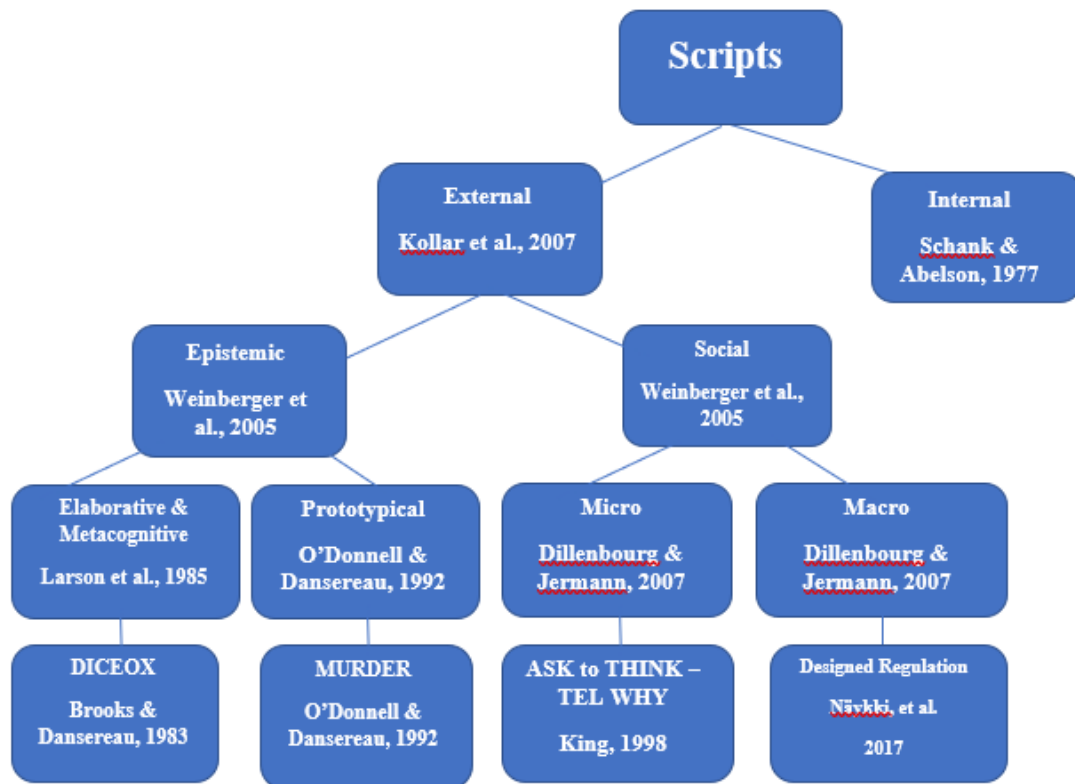


Figure 1: Types of scripts

Over-scripting might be a negative consequence if the script was too much detailed and that would lead learners' loss of freedom (Dillenbourg, 2002). However, it can be avoided by increasing the flexibility of the collaboration scripts (Fischer et al., 2013). Consequently, the researcher was keen to choose a collaborative script that would still leave for the group members a sense of freedom, that they need to continue effectively throughout the lesson. Hence, she chose the macro-script that stems from a pedagogical perspective (Häkkinen and Mäkitalo-Siegl 2007) and that would leave some space of control for the students. Since collaboration script was a main pillar in this study, the researcher chose to shed the lights only on it and not to go further in the other scripts.

What is Collaboration Script?

Since this type of script is the one to be implemented in the study, it is a necessity to go back in literature to know exactly what it is, so the researcher could design and implement it appropriately. Collaboration script is a collection of tasks that shows how the interaction and collaboration between group members should occur in order to solve a problem (O'Donnell & Dansereau, 1992). It was also described as “an instructional means that provides collaborators with instructions for task-related interactions, that can be represented in different ways, and that

can be directed at specific learning objectives” (Kollar, Fischer and Hesse, 2006, p.162-163). With these definitions and many more, collaboration script had been researched vastly in the previous years (Dennen & Hoadley, 2013; Diziol, Rummel, Spada, & McLaren, 2007; Fischer et al., 2013; Kobbe et al., 2007; Kollar, 2006; Rummel, Mullins, & Spada, 2012; Tsompanoudi, Satratzemi, & Xinogalos, 2015; Tsovaltzi, et al., 2010; Wang, 2017). Yet how such a script would be or would affect maker culture is something that was scarcely discussed.

Since the sequence as well as the occurrences of events is known, the students’ progress throughout the collaborative task is enhanced (Weinberger, Ertl, Fischer, & Mandl, 2005), and this would help the individuals to tolerate the different steps, expects the tasks and roles of the participants and commemorate the procedures to be followed (Schank & Abelson, 1977). In addition, scripts are helpful in lightening the cognitive load, hence, the participants can concentrate better on their thinking on what is significant in the context and the interaction (Dansereau, 1988).

Collaboration script was applied in different domains, such as mathematics, chemistry, computer science, medical field and many others. Reading about those implementations had enlightened the researcher about different experiences and how they went and what they faced. A study by Rummel, Mullins and Spada (2012) aimed at developing students’ mathematics learning, using a computer-based tutoring system for high school mathematics called Cognitive Tutor Algebra (CTA) in collaborative settings. Also, a collaboration script was meant to promote students’ interaction was investigated too. They compared three conditions: scripted collaborative learning, unscripted collaborative learning and individual learning. The results showed a positive impact of the script on students’ interaction and problem-solving during scripted interaction and in subsequent unscripted interaction. However, they were not able to identify a general learning effect in students’ performance because of the loss of some data. Another research was done by Tsompanoudi, Satratzemi and Xinogalos (2014) to investigate the impact of implementing collaboration script in distributed pair programming system to teach computer programming for students in Computer Science. Forty-eight students took part in this study. The results showed that students had a positive attitude towards distributed pair programming, and that this way of programming supported by collaboration script eased problem-solving better than normal programming tasks. In addition, learning objectives among pairs were equally distributed. A new study was executed by Zottman, Dieckmann, Taraszow, Rall and Fischer (2018) also examined the impact of the collaborative script but this time in medical field. Where it was implemented in the observational phases of simulation-based

training for medical students, in an attempt to produce more active participants even if they are observing the simulations. The collaboration scripts were implemented in four courses and acquiring Crises Resource Management CRM heuristics was one of the learning goals, and the classes were divided into control and experimental groups where the independent variable was the existence of collaborative script. The assessments were on the individual and collaborative level. Learning processes were evaluated via pre and post-self-assessments of CRM skills and a brief video-based CRM skills test at the end of the course. The study results present a positive impact of the collaborative script on the individual and collaborative learning processes, leading to elevated collaborative activity of scripted learner and elevated focus on heuristic strategies.

What are the elements of Collaboration Script?

Identifying the elements of collaboration script would help in designing the lesson plan according to them, to make sure that it would meet all the criteria needed for a good collaborative learning. Hence, any missing criterion would have a negative impact on the lesson plan, leading to a deficiency in the coherency of the collaborative work within the structure of the lesson. In their comprehensive conceptual analysis of collaboration scripts, Kollar, Fischer and Hesse (2006) investigated script in cognitive psychology and educational psychology, they have concluded five common conceptual components in collaborative scripts; “(a) learning objectives, (b) type of activities, (c) sequencing, (d) role distribution, and (e) type of representation” p.160. The researcher was very keen that all these elements were included in her lesson while designing this collaborative learning situation. The script in order to be collaborative must have a learning objective that will be achieved at the end of the lesson where the students would work collectively to achieve it. This collective work is based on specific activities that were chosen and designed specifically for the sake of this collaborative work and these activities needs to be in a specific consequence too, sometimes skipping a step would be problematic, since they are all meant to build on each other in order to form the targeted knowledge. Sequencing the activities would improve the learners’ interaction among each other (Weinberger, Ertl, Fischer, & Mandl, 2005). As for role distributing, it is an essential element and its absence might affect the quality of the outcome. However, it is tailored depending on the type of the script; sometimes the designer distributes the roles among the students based on a prior plan (micro script) and another time, the designer gives the freedom for the students to choose their roles by themselves (macro script). Finally, comes the representation; where the students need to present their result or product after progressing throughout the activities until they achieve the intended goal. After presenting scripts, collaboration scripts and its elements,

it is time to introduce collaborative interaction, to know what it is and how scripting can affect it.

2.2.5 What is Collaborative Interaction?

Jung, Choi, Lim, and Leem, (2002) studied the impact of different types of interactions on learning achievement, satisfaction, participation and attitude towards online learning in a Web-Based instruction environment. They introduced three types of interaction in learning; academic, collaborative and social and defined them as the following:

Academic interaction stands for the interaction between learners and online resources as well as task-oriented interaction between learners and instructor. Collaborative interaction among learners becomes possible when a group of learners work collaboratively on a specific topic or share ideas and materials to solve a given problem. Social interaction between learners and instructors occurs when instructors adopt strategies to promote interpersonal encouragement or social integration. p.153

They highlighted the importance of interaction in learning experiences as among the most essential factors in both in ordinary education and distance education (Vygotsky, 1987; Holmberg, 1983; Moore, 1993). In their study, they have compared the three types of interaction by dividing 124 undergraduate students among three different university courses in Korea, each with an interaction assigned to it. The outcomes of this study showed that in terms of learning achievement, the social interaction group outperformed the others. As for the level of satisfaction, the collaborative group was the most satisfied. However, the academic interaction group was the least active in terms of participation. In addition, regardless of the group, the positive attitude changed with respect to the use of Web in learning. They completed by stating that for improving learning and getting active participation in online discussions even for adult learners; social interaction with the instructors and collaborative interactions with the peers are essential.

In the current study, the researcher is interested in the collaborative interaction, so she wants to discover it. Productive collaborative interactions with shared knowledge construction are two vital elements for successful collaboration (Järvelä and Hadwin, 2013). While the group members are interacting with each other, this interaction enhances their cognitive processes and socio-cognitive processes. Since they are continuously assimilating other's ideas, reasoning, explanations and adapting them and they are collectively constructing knowledge and

negotiating meaning with each other. Consequently, complex cognitive processes such as analytical thinking, interpretation and assimilation of ideas are the outcomes of effective learning interactions (King, 2007).

There are three main conditions to identify that an interaction is collaborative or not. First, the situation needs to be *interactive*, however, the strength of interactivity is determined by the degree of impact of these interactions on group mates' cognitive processes and not by the recurrences of interaction. Second criterion would be '*doing something together*' which shows that the group members are working synchronously. As for the third criterion '*negotiable*' so not any member is imposing his idea or opinion on the others but there is a sense of mutuality among them, where everyone is presenting his idea or solution and trying to reach a common idea that all members agree on (Dillenbourg, 1999).

In her study, Barron (2003) examined comprehensively how collaborative interactions influenced problem-solving outcomes. She analyzed the conversation of twelve triads in sixth grade. Where, she was trying to figure out how and why the outcomes of the collaborative works differ, even if the knowledge produced by the group members does not differ between groups. Then, she presented three generalizations; first, attainment of joint attention would lead to problem-solving and learning. Second, a variety of attention regulating strategies can impact positively on how speakers and listeners are engaged in a dynamic, interdependent process. Third, collaboration involves dual-problem space that the group members need to follow and promote at the same time; these are content space and relational space. She concluded that "the quality of interaction had implications for learning" p.307.

After representing the theoretical framework, now it is time to represent the methodology of the study, its aim and research questions, the context and participants, how it was implemented, data collection and the analysis procedures.

3 Methodology

This research is following the interpretive paradigm; “this paradigm examines how people engage in the processes of constructing and reconstructing meanings through daily interactions.” (Leavy, 2017, p. 129). As for the research methodology, it is qualitative. Such methodology investigates the quality of relationships and situations and its aim is to achieve depth rather than breadth, through a detailed description of what happened in a specific situation (Basit, 2010). It is generally characterized by exploratory approaches for building knowledge intended to create meaning (Leavy, 2014). The research design of this study is a case study, which introduces detailed information about individuals or cases, and it presents the impact of different phenomena on those individuals in the social world and how they perceived it (Basit, 2010). This definition is compatible with the aim of this study in examining the collaboration script in a real context, students’ perception towards it and investigating the collaborative interaction. As for the analysis method it is qualitative content analysis because it has four distinctive features helpful in proceeding in the analysis of this study properly. The first feature is that it is an unobtrusive technique, second, it can handle unstructured matters as data. Third, it is context sensitive and therefore allows the researcher to process data texts that are significant, meaningful, informative, and even representational to others. And finally, it can cope with large volumes of data (Krippendorff, 2004).

I will use interchangeably teacher and researcher, students’ and participants. By mentioning the term “questionnaires”, the researcher means pre and post-questionnaires unless she specified it is the pre or the post-questionnaires.

3.1 Aim

The aim of this study to investigate how a specific collaborative script in maker culture affect students’ level of cognitive learning gain and their perception towards it. In addition, it investigates the impact of this specific design structure on students’ collaboration in terms of participation and collaborative interaction. The research questions are the following:

- 1) What is the students’ learning gain after the collaborative sessions?
- 2) How was the students’ collaboration: a) in terms of participation? b) in terms of collaborative interaction?

3) what is the students' perception of this collaborative script?

3.2 Participants and Research Context

The researcher implemented this case study as a classroom lesson in Learning Environments and Technology course at the University of Oulu. This course introduces basic concepts and ideas of how to use technology for problem-solving, reflection, sharing and collaboration. It also introduces basic concepts and ideas of using technological tools and environments for technology-enhanced learning, such as a) Learning Management Systems, cloud computing, and social media b) production and distribution of digital media, and c) classroom infrastructure and wireless Internet devices. As for the learning outcome, the students will apply theoretical ideas of learning sciences to the context of emerging technologies. They will use emerging technologies as teaching and learning tools, work in technology-rich teaching and learning environments as administrator, teacher or student. Hence it was a perfect environment for experimenting the researcher's design structure related to the maker culture. Although this course would last for a semester, the researcher conducted this classroom lesson in two sessions on 31st of October 2018. The first session was from 8:15 am to 12:00 am in a regular classroom. While the second session was from 13:00 till 15:00 in a different classroom, from 15:05 am till 15:45 pm in FabLab.

This course is obligatory in the curriculum of International Master Programme Learning, Education and Technology (LET) for 1st year students yet exchange students from different countries and students from other fields can join it as an optional course. The number of students took part in the first session was 19 students, 15 students belong to LET programme and 4 students are from different majors. As for the second session, 20 students took part, with an additional student from different major. In the first session, there were 7 males and 12 females, while in the second session they became 13 females. The class was rich with over fifteen nationalities from four of the continents, Africa, Asia, Europe and America.

As for those who conducted the sessions, they were two students from second year of LET studies, one of them is the writer of this thesis and the second one is a male student who was also using these sessions to conduct his own research in his area of interest and it was coherent with this case study and didn't contradict or hamper this study. The two researchers designed the lesson and the main teacher of this course was present most of the time during the sessions to make sure that everything was progressing and that we have no obstacles during our sessions.

The researchers divided the students into five groups; four groups with four students and one group with 3 students in the first session. One additional student joined this group in the second session; hence they became five groups with 4 students. The students were grouped randomly by the second researcher who didn't have much knowledge about the students, the writer of this thesis knew most of the students well, so she excluded herself from the grouping process to avoid any bias.

3.3 Pedagogical Design of the lesson

Educators took advantage of the use of Making in education to enhance the interest in STEM (Science, Technology, Engineering and Mathematics) themes (Chu et al.,2015). Luckily, one theme of Learning environments and technologies course was STEAM (Art is added to the previously mentioned majors) and Coding, so the researcher decided that it is the most compatible theme to the maker culture she is investigating in. Also, with such a long time from 8:15 till 14:45, the researcher decided that it is more convenient and applicable to introduce two different topics within this theme. These two topics were 3D designing and printing in the first session and coding in the second session.

In this study, the researcher's interest was about collaboration script in maker culture, hence, she was circumspect to ensure that the main five elements of collaboration script that Kollar, Fischer and Hesse (2006) stated exist in it (elaborated in section 3.3.2). In addition, among the different scripts existed in the literature, the researchers chose macro-script, because it is compatible and effective for the aim and goals of the study and she thought that micro-script might affect the degree of freedom the students have in maker context. How this was applied in the lesson design is elaborated further later (see section 4.2.2). The following table (see table 1) represents the summary of the pedagogical design of the first session in the following table

Table 1 Summary of the activities of the first session

	Date/Venue	No.	Activity	Duration	Type of task
		1	Introduction to learning objectives, schedule of the day	15 min	

Session 1 3D designing and Printing	31.10.2018		and general instructions		
		2.	Signing up the consent form online then filling the pre-test questionnaire on paper	10 min	Individual
		3.	Topic introduction	10 min	
		4.	Group division	5 min	
		5.	Introducing the activity and samples of 3D printed artefacts	5 min	
		6.	First phase of the activity “choosing the design”	25 min	Individual + Group
	KTK 122 8:15- 11:00		Break	10 min	
		7.	Second phase “Exploring Tinkercad”	25 min	Individual
		8.	Third phase “Designing the selected artefact”	50 min	Group
		9.	Filling post-questionnaire	10 min	Individual

The summary of the pedagogical design of the second session is represented in the following table 2

Table 2 Summary of the activities of the second session

	Date / Avenue	No.	Activity	Duration	Type of task
Session 2 MicroBit Coding	31.10.2018 HU 301 12:00-14:00	1.	Filling pre-questionnaires	10 min	Individual
		2.	Introduction about coding	10 min	
		2.	Introducing MicroBit	10 min	
		3.	Exploring MicroBit	15 min	Individual
		4.	Task 1: Rolling names	15 min	Individual + Group
			Break	10 min	
		5.	Task 2: Magic button	15 min	Group
		6.	Task 3: Rock- Paper- Scissors	25 min	Group
		7.	Or Task 4: MicroBit Compass	25 min	Group
			Filling post-questionnaires	10 min	Individual
Printing	FabLab 14:05-14:45	8.	Introducing 3D printers and how to print	40 min	Group

3.3.1 Classroom Topic and Equipment

As mentioned earlier, 3D printing and coding were the two topics chosen for this study. For 3D printing, they implemented it in the first session where the teachers used Google slides to show the lesson that included objectives, information about 3D printing and different software, guidelines, 3D artifacts pictures and instructions for each task. For the presentation purpose, the teachers used a computer, a projector, presentation software which was Google Slides and white screen. As for the students, they used their own laptops or Google Chromebook provided

by the teachers for exploring and designing the 3D artefacts with specific software named “TINKERCAD”.

Then in Fablab, a researcher specialized in FabLab environment presented different 3D printers and displayed how to use the software of the printer to transform your designed artefacts into a real 3D object.

While in the coding session, the teachers used also Google slides to represent their lesson including information about coding, different computational platforms, introduction to BBC MicroBit and the instructions for each task. The teachers also used 13 to 15 BBC MicroBit, with two batteries and a connecting wire for each MicroBit.

3.3.2 How the lesson proceeded

As mentioned earlier, asserted that every collaboration script comprises at least five central conceptual components, a) learning objectives, b) type of learning activities, c) sequencing of activities, d) role distribution mechanism (implicit or explicit), and e) type of representation that might be textual, oral or graphical (Kollar et al., 2006). If the researchers want their lesson to be collaborative, they need to ensure that it follows these elements in their lesson plan. In the following paragraphs, the process of lesson implementation in the class is described. However, the impact of the design choices on the students is expected to vary, since learners differ from each other (Dennen & Hoadley, 2013).

As previously mentioned, the teachers prepared their lesson on Google Slides. Google slides are easy to use, need no installation and you can reach from any place using any gadget not only your personal one. All the students taking part in this case study are students from the University of Oulu, hence they all have Gmail because it is one of the communication environments between the university and the students.

In the first session, the researchers gave the link for the consent form. The title of the first session was “3D printing”, the teachers introduced themselves and presented the schedule for the day on the slides. Later, they distributed the pre-questionnaires to the students to answer individually and then collected them. Then, they represented the objectives of the lesson; there were two objectives, one for each session. The first aim is the students become familiar with designing and fabricating simple 3D designs and the second one is that they will know how to use Micro:bit to make simple programming and coding.

After presenting the objectives, one teacher gave the general instructions, a) choose a group name, b) divide roles e.g. leader, secretary, etc. for each task (3D and Coding), c) for each task, plan how your group will progress with the tasks.

In both sessions, the researchers applied macro-scripting that “provide a sequence of rather general phases to be followed in a complex learning setting” (Fischer, Kollar, Stegmann, Wecker, & Zottmann, 2013, p. 526). They didn’t assign specific roles to each student. Also, they divided the students at this stage too.

After explaining and discussing what is 3D printing and designing, the teachers presented five pictures of 3D artefacts where the students need to choose from, so they can design a similar one. Preparing those designs in advance was on purpose for two reasons, first, the teachers make sure that the students could design them (based on their level). Second, to make sure not to choose a design that might take too much time designing or printing or choosing a design that is easy and won’t be applicable by a group of students. The time was essential since it was limited. Finally, to give the students the opportunity to choose from multiple designs and not to limit them in one or two designs. The designs were earbud holder (see fig 2), key chain (see fig 2), pages holder (see fig 3), wall outlet shelf (see fig 4) and USB holder (see fig 4) and are represented in the following figures respectively.



Figure 2. Earbud Holder (left) and Key Chain (right)

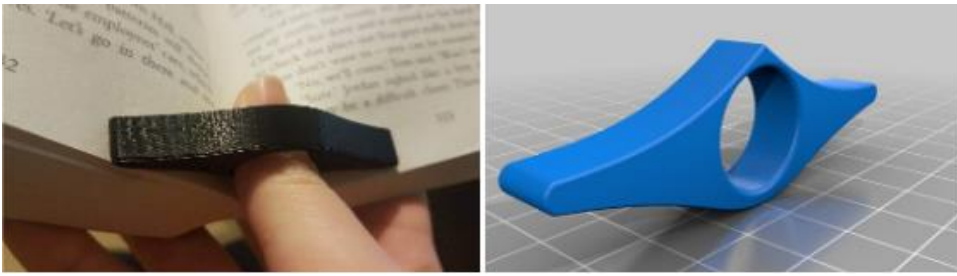


Figure 3. Pages Holder



Figure 4. Wall Outlet Shelf (left) and USB Holder (right)

The teachers assigned the students to their groups, and they had to choose a name for their group. The names of the groups were Fast but Not Furious, Pumpkins, White Midnight, Newborn Printers and Toilet Trollz. Later, the teachers introduced collaborative activity related to 3D printing. This activity had three phases where the students moved from one phase to the next. Those phases are a) choosing the design, b) exploring Tinkercad and c) designing the chosen artefact. Within each phase, there was a specific sequence of tasks that the students followed. Such sequencing aims at helping the students to interact better with each other on the collaborative task (Weinberger, Ertl, Fischer, & Mandl,

Epistemic and social scripts in computer-supported collaborative learning, 2005). Those tasks are represented in the following picture (see Figure 5)

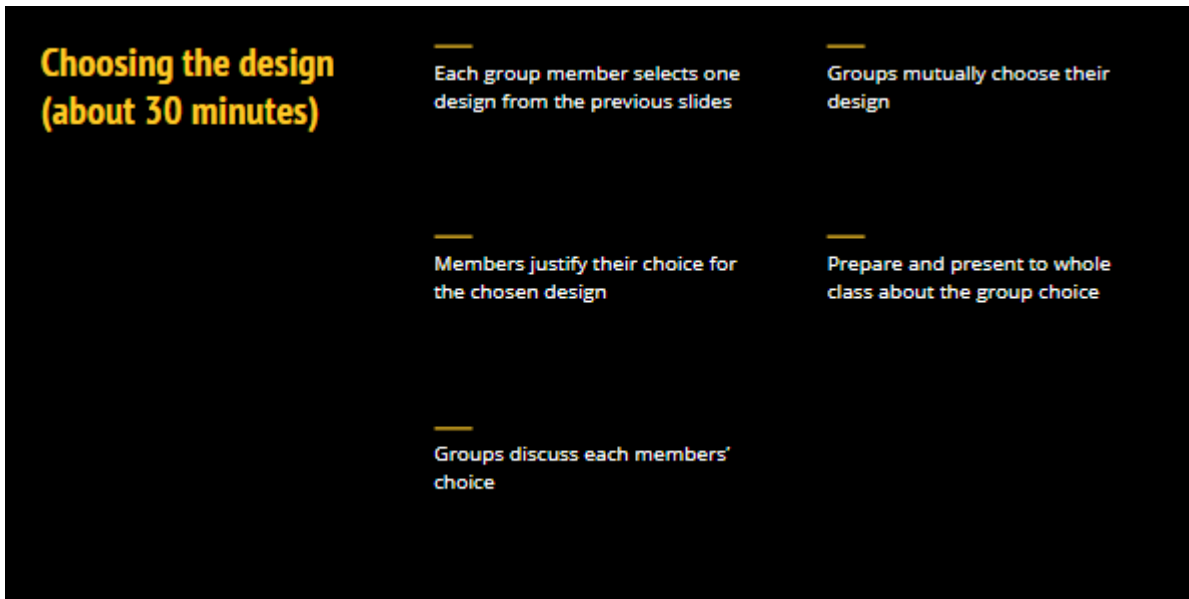


Figure 5. tasks for students to follow in the first phase

The students involved excitedly in these tasks and there were no disagreements between them about the design. They could reach a common design they all wanted to do. After finishing these tasks, the students had a 10 min break, some of them left the class and others stayed then everyone returned to the class when it was time. The second phase has started where the teachers asked the students to explore TINKERCAD individually through an introductory video for beginners in 3D printing, “All about 3D Printing All3DP” channel has published it on YouTube on July 7th, 2017.

After watching the video, the teachers asked them to perform 3 to 4 small tasks. Tasks like using basic shapes, texts, numbers, connectors and characters in TINKERCAD, also using the ruler to measure, grouping, ungrouping and aligning shapes and exporting TINKERCAD files. The researchers implement these tasks to refine what they have watched and to make sure they got the basics of this software.

Finally, the students reached the designing phase. The teachers presented the slide that has the steps that the students need to follow. In this phase, the students needed to work together again. The teachers gave the students the freedom of how to plan their design or dividing the roles between them, they only prompted them to do that. They only asked for distributing the tasks and that each student need to take part in the designing. After designing, they needed to discuss

among them how their design was as required. Then after this discussion, they presented the design to the whole class and gave reasons why they think their design fits the original 3D design.

It is good to mention that one group found the desired design readymade online, and they presented it to the teachers as if it was their work. But after a while, they told the teachers they found it. So, the teachers asked them to make another design for Tori Poliisi statue. But then the students decided to do their first design but with their own effort, not the readymade one. Two groups had finished their designing early, and they designed the Tori Poliisi design as an additional task; those groups were “Toilet Trolls” and “Newborn Printers”

After the five groups’ presentations, the teachers concluded the lesson and then distributed the post-questionnaires to the students to answer individually again and collected them after a while. Later, the class was dismissed for lunch, where they agreed to meet after an hour for the second session. The researcher present samples of the students’ design in the following figures (Figure 6, 7, 8, 9).

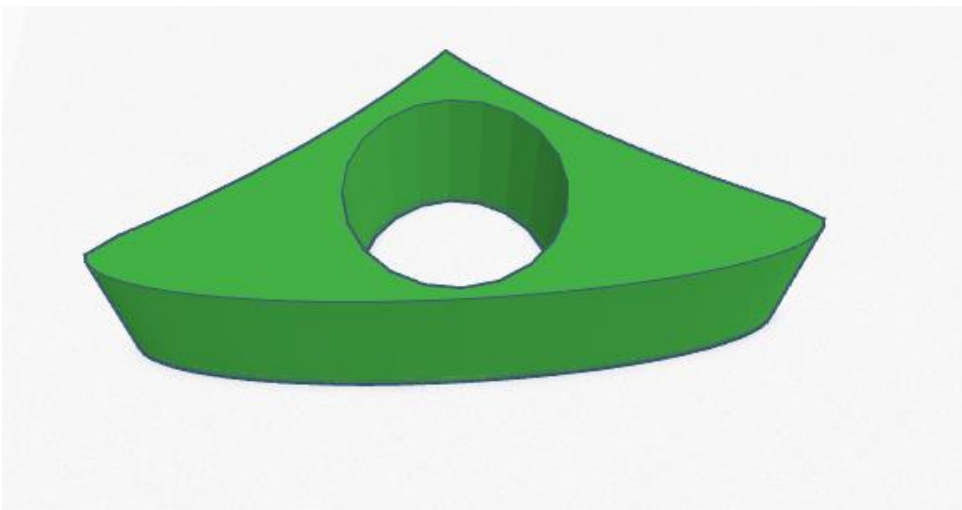


Figure 6. 3D design for group “Toilet Trolls”



Figure 7. 3D design for the additional task for group "Toilet Trollz"

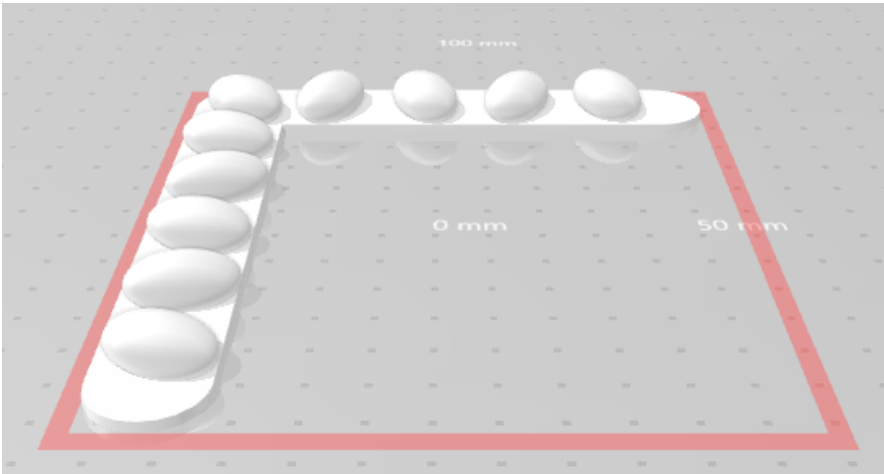


Figure 8. 3D design for group "Fast but Not Furious"

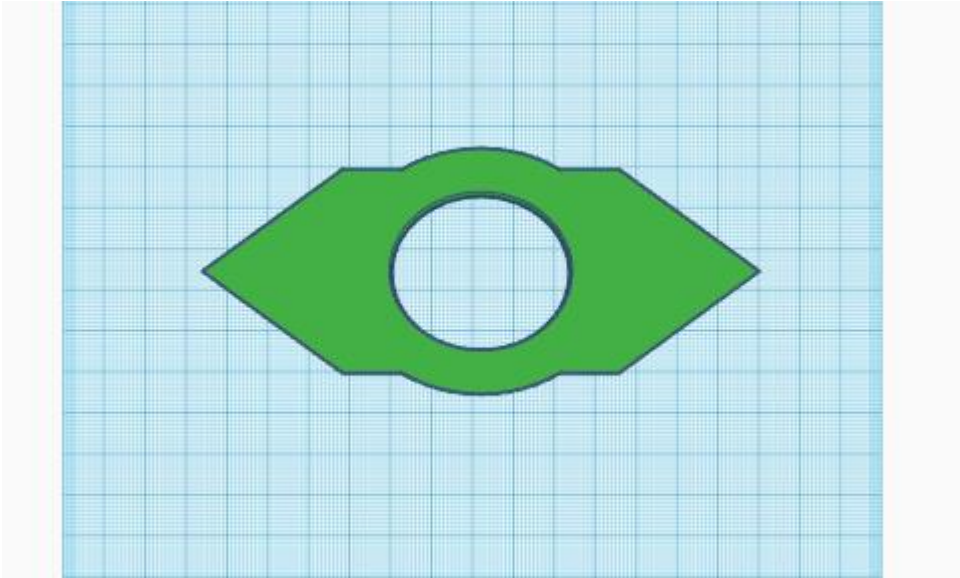


Figure 9. 3D design for group “Toilet Trollz”

After one hour the students and teachers were ready in another new class that was meant for the second session. The title of this session was Micro:bit coding. The students sat with their group mates from the first session. Then the teacher gave them the pre-questionnaires related to this session to answer and later collected them. Next, the teachers introduced what is meant by coding and the computing platforms used in education. Later, they introduced micro:bit and its definition. Then they presented a slide that has the tasks, for students to follow it.

The students did the exploration part collaboratively. Where each group had two micro:bits, and they were four. The teachers planned that the tasks are in different levels of difficulty; they started easy and got more difficult with each task they did. After the exploration together, the teachers asked them to do the first task which was the easiest. The teachers told to roll names in the micro:bit, they decided the order of rolling their names and the name of the group. After finishing the task, each group had represented his work to the others. Later they had a break for 10 minutes then the session started again.

The students started their second task where they had to make a magic trick with the micro:bit. The task was more difficult since it involved magnets; the student had to measure the magnetic force of the magnet then code the micro:bit that if it senses the magnet, it would swap the button. It took more time from them to do it and then each group presented it to the class.

Finally, the last task, there were two options; rock paper scissors and the compass. Rock paper scissors game is well known, and they use hands to play it but here they used the Micro:bit instead of hands to present specific signs and shaking the micro:bit. While the Micro:bit

compass, they had to code the built-in compass to show where the micro:bit is facing. Some group coded the micro:bit for rock paper scissors game and played with each other. While others chose the compass and coded their micro:bit for it. There was a group that finished the first optional task first and then did the second optional task too.

After the presentations of the students, the teachers concluded the lesson and gave them the post-questionnaire where they filled it and returned it to the teacher.

Then, all the students and teachers went to FabLab to continue their 3D printing session. A FabLab expert was waiting for them, she showed how to export TINKERCAD files to the 3D printing software and how to set up the printer and then give the order to print the design. The students printed their design later.

A sample of a printed design is presented in the following figure (see Figure 10).

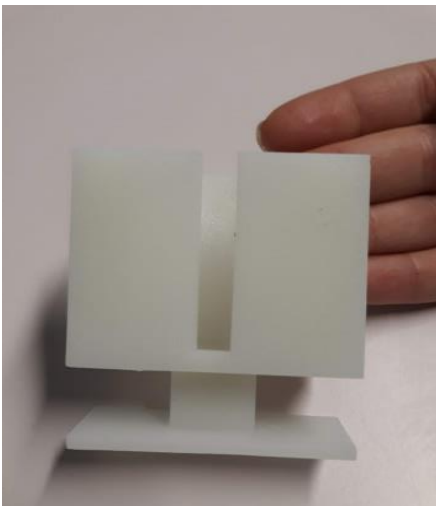


Figure 10. 3D Printed design for “Pumpkins” group

It is clear that the five elements of (Kollar, Fischer, & Hesse, Collaboration scripts—a conceptual analysis. , 2006) are implemented in this design. Where the objectives were stated, there were different activities with a specific sequence, role distribution among the members even if it was not explicitly defined and finally the presentation of the results. They added that in each collaborative learning, one can detect two levels of scaffolds: a) scaffolds that afford help on the conceptual level and b) scaffolds that afford help related to interactive actions among the collaborators. Again, this design had represented such support on both levels.

3.4 Data Collection

In order to capture the depth of the students' learning, their perception and their collaboration, different data collection methods were used. As for the first question about how deep they have learned, and the third research question related to their perception of the lesson design, the researcher used pre- and post-questionnaires. Furthermore, the second research question that investigated the students' collaboration in terms of participation and collaborative interaction, video data was collected from different cameras implemented with the groups. Each of the data collection methods is going to be discussed further in the following paragraphs.

3.4.1 Pre and Post-questionnaires

In total there are 78 questionnaires; 38 questionnaires in the 3D printing session and 40 questionnaires in the Micro:bit session since an additional student joined this one. In the 3D printing session, two students could not continue the session or came at the end of it so they didn't fill in the post-questionnaire. Hence, four questionnaires were eliminated from the analysis and that means in 3D printing session there were 34 questionnaires left for the analysis.

Pre-questionnaires

They consisted of six questions (See appendix 1 & 3), that were written by the researcher as she wanted to measure how much the level of cognitive competencies of the students would vary before and after the lesson. However, in the analysis part, the researcher found that the first three questions are enough to answer her first research question questionnaire. They were two open-ended questions and one closed question. The open-ended questions allow the participants to express with their own words, their explanations and responses without limitations from pre-set categories of responses (Basit, 2010).

Post-questionnaires

The researcher distributed the post-questionnaires at the end of each session (see appendix 2 &4). The difference between pre and post questionnaires is that the post-questionnaire has two additional sections other than the one in the pre-questionnaire. So, the first section in both has the same six questions but in pre, they are asking about the prior knowledge and in the post; they are asking about the knowledge gained after the sessions. The second section is related to planning, and it has five questions. As for the third section, it is related to the learning experience and lesson structure, and it has nine questions; four open-ended questions and five closed questions.

Worth to note that the planning section was omitted from the analysis in this study because it was related to a preliminary research question that was not tackled later in this study. Hence, the first section answered the first research question and the third section answered the third research question which is related to how the students perceived the structure of this designed lesson.

3.4.2 Videos

The reason for the researcher to choose video data is that it presents rich information about what happened during collaboration. Barron, Pea and Engel (2013) asserted that “Video allows researchers to replay the recording of collaborative interaction in order to gradually enrich their perceptions and understanding of its moment-by-moment processes reflected through intonation, facial expressions, and body language in addition to conversation” p. 204-205.

The two sessions (2 hours 45 minutes each) were video recorded. For the recording, the researchers brought 6 GoPro cameras and 1 Canon camera with their accessories such as stands, extra batteries and their chargers. There were five groups in each session, with one camera for each group hence 5 cameras were used and the other two were backup cameras. They fixed the camera to catch the four participants of the group the whole time.

Later, all the videos were uploaded from the laptop to the university google drive. Jari Laru opened a team drive for this purpose, hence there were 3 people that had access to this folder.

Before coding, the researcher needed to check the quality of the videos and see which she can use and which she can't. Table 3 presents the detailed information about how many videos in both sessions were coded, their total time and to which groups they belong too.

Table 3 Details about the videos used in this study

Name	3D session videos	No. of videos	Total time of coding in minutes	Micro:bit session videos	No. of videos	Total time of coding in minutes
Pumpkins	Yes	15	145	No	X	X

Fast but not Furious	Yes	10	173.8	Yes	7	52.7
Toilet Trollz	Yes	10	163	No	X	X
White Midnight	Yes	10	135	Yes	2	16.44
Newborn Printers	No	X*	X	Yes	4	109.7

X* represents the videos that were not used due to technical difficulties

The total time of coded videos for both sessions together is 795.6 minutes which is equal to 13 hours and 26 minutes.

3.5 Analysis Procedures

In this section, the researcher discusses thoroughly the analysis of the data. The researcher chose the content analysis approach. It is “a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use” (Krippendorff, 2019, p. 24). He also added that it is “a scientific tool” (Krippendorff, 2004, p.18). This approach was also defined comprehensively in Basit (2010, p.194), where she stated that “content analysis involves examination of spoken or written communication”. She elaborated that it as a method for inspecting qualitative research where it documents textual data by investigating the frequencies of instances; it involves coding or classifying sentences, statements or phrases into categories and comparing and making connections between these categories.

The researcher followed the division of components of content analysis that Krippendorff (2019; 2004) has presented in his books; they are unitizing, sampling, recording/coding, reducing, abductively inferring contextual phenomena and narrating the answer to the research questions. First, she unitized the data she wanted to analyze. Then she drew her sampling plan she will follow in her analysis. Later, there was the coding, it is the essential link between data collection and their clarification of meaning (Charmaz, 1996). Coding is creating a specific set

of words with a specific meaning for further analysis. The researcher created different coding schemes based on a thematic distinction (Krippendorff, 2004). Different coding schemes were assigned for each question and for the videos too. The coding schemes are represented in the upcoming section (see section 3.5.1). After coding the questionnaires and the video data, the researcher moved to reduce the data for efficient representations. Then, she abductively infer her data, this step “bridges the gap between descriptive accounts of texts and what they mean, refer to, entail, provoke or cause.” (Krippendorff, 2004, p.85). Finally, narrating the answers of the research question, hence the results are understandable by others.

First, the analysis of the questionnaires is presented; it is divided into two sections, one related to the 3D printing session and the second related to the Micro:bit session. Later comes the analysis of the videos. The questionnaires were meant to answer the first and third research questions. Whereas, the videos answer the second research question

3.5.1 Questionnaires

To maintain anonymity, the researcher assigned the letter “a” and a number from 1 to 20 for each participant. Hence, the participants’ names become a1, a2, a3, a4, a5, a6, ..., a20. Later, she categorized the students into their assigned groups. For example, a1, a2, a3 are Newborn Printers, a4, a5, a6, and a7 are Toilet Trollz, a8, a9, a10, a11 are Pumpkins, a12, a13, a14, and a15 are White Midnight, a16, a17, a18, a19 are Not Fast but Furious and finally, a20 is the additional participant as mentioned earlier that joined Newborn Printers.

Later, the researcher transcribed the questions and answers of the questionnaires into three Excel sheets; one has the names of the students and their assigned symbols such as a1 and their division in the five groups, the second sheet is for the 3D printing session and it contains the questions and answers of the pre and post- questionnaires. As for the third sheet, it is for the pre and post-questionnaires in the Micro:bit session.

The researcher is using a Computer Assisted Qualitative Data Analysis Software (CAQDAS). In their qualitative or mixed research, CAQDAS enable researchers to store and organize all sorts of data such as text, audio, video, emails, images, hence enabling “human analytic reflection” but coding the data is still the researcher liability (Saldaña, 2016). Finally, the researcher can visualize and discover the connections among the data in an attempt of interpreting these results. In this study CAQDAS is named QSR NVivo 12; “among others,

NVivo saves researchers from ‘time consuming’ transcription and boost the accuracy and speed of the analysis process.” (Zamawe, 2015, p.15)

After transcribing the researcher uploaded the sheets to QSR NVivo 12 software package, then the researcher first started with the 3D printing session, where she coded the answers of the first three questions from pre and post- questionnaires. The reason of this action is that she found that only the first three questions are purely related to prior and later knowledge. Since the researcher is working on data-driven data, she applied subsumption strategy (Schreier, 2012) for coding the answers.

3D printing session

The researcher started with the first section in the questionnaires, that is related to the knowledge assessment; in order to answer the first research question. In the pre-questionnaire, Question 1 (Q 1) was meant to measure the prior knowledge of the student about 3D printing; she asked, “What do you know about 3D printing?”. As for the second question (Q 2) it asked about the 3D softwares. And in the third question (Q 3), the researcher asked, “how much is your knowledge in using 3D softwares?”

Worth to mention that in both pre and post-questionnaires, Q 1 and 2 are open-ended questions and Q 3 was Likert scale. The researcher coded the answers of the pre-questionnaire based on the coding scheme represented in table 4. As for the post-questionnaires, the coding scheme of Q1 and Q2 are demonstrated in table 5.

Table 4 coding scheme for question 1 and 2 in pre-questionnaires of 3D printing session.

Code	Definition	Example
No prior knowledge	It is the code for the answers that shows no knowledge at all about 3D or 3D software	“nothing”, “not at all”, “don't know”, “no idea”, “not really anything”, “not much”
Shallow level of knowledge	It is the code for the answers that shows a low level of knowledge or at least they have an idea about it whether	“haven't used it only saw the tools”, “I know it in theory but never used it”, “it can create

	somehow a clear idea or a vague one	what user imagine and design in a tool (computer)”
Deep level of knowledge	It is the code for the answers that shows a good level of knowledge about 3D printing and the participants gave a partial or complete definition	"creating 3d objects (generally out of plastic) from software", "I know that you can 3D print using the machine at the fab lab and you can use different software" "they used 3D blueprint, and some materials to build on objects"

Table 5 coding scheme for question 1 and 2 in post questionnaires of 3D printing session.

Code	Definition	Example
No knowledge acquired	It is the code for answers that shows no additional knowledge has been gained by the participants after the lesson	“same”
Shallow level of acquired knowledge	It is the code for the answers that shows that students have gained low level of knowledge, where the students talked about the software in general or their answer was related to their emotions and attitude more than the software	“I know how to use Tinkercad”, “as easy and self-intuitive as expected”, “it's useful and can be used in future”

Deep level of acquired knowledge	It is the code for the answers that shows that students have gained deep level of knowledge, where the students wrote more detailed sentences about the software or the skills they gained after the lesson	“I know how to make, edit, use shapes”, “I learned how to design a key chain on my own”, “using Tinkercad, the basic of actions to build the product”
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In this part, the analysis related to the third research question is discussed. To understand the students’ perception towards this design structure of the collaborative lesson, the researcher analyzed the third section. As previously mentioned, this section had nine questions and the researcher assigned the numbers from seven to fifteen consequently. Question 7, 8, 9, 11,12 are Likert scale and questions 10, 13, 14, 15 are open-ended questions. Hence the coding scheme of the later questions is represented in the following tables.

Q10 is “Why do you think the structure of this learning design supports your collaboration with your groupmates? (If the answer was positive in the previous question)”. The researcher divided the answers of the students into two main nodes “support collaboration” and “didn’t support collaboration”. Furthermore, if the answer was positive it will be classified under one of the represented nodes then under “support collaboration”. While for negative comments, they will be classified under one of the represented nodes then under “don’t support collaboration.

Table 6 Coding scheme of tenth question

Code	Definition	Example
Interaction	the student is talking about involvement in the lesson, how the structure allowed him to know his/her friends, or prompted discussion	“it brought active involvement of each member”, “because it helped me to know each other”, “because it provided opportunity for lots of discussion among group members”

Peer support	The student is talking about how the structure allowed his friends' support to him	"I was supported by group members to complete the task effectively and fast"
Topic	the student is talking about the topic of the lesson	"It is new to all of us and we are all learning"
Strategy	the student is talking about the strategy that the teacher followed in dividing the students, whether groups or individually.	"we were divided in groups so that helped"
Materials	the student is talking about the materials used during the lesson such as videos	"Instruction video was very easy to understand"
Clear instructions	the student is talking about the instructions of the teachers	"easy to follow steps and make work effective"
Tool	the student is talking about the tools used in class	"learning in group in computer is not great"
Teamwork	when student is talking about what happened between them	"everyone tried learning the software independently having some shared tasks within this phase would have enhanced collaboration"

Individual circumstances	when student is talking about leaving the class due to commitments	“As I didn't study for the whole session, I didn't experience the collaborative learning experience”
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Next, Q13 which is “Why do you think this lesson design support your learning? (If the answer was positive in the previous question”. The coding scheme for it is in the following. Table (see table 7)

Table 7 Coding scheme of the thirteenth question

Code	Definition	Example
Applicable skills	the student is talking about how he/she can use it in the future or when needed	“can use the knowledge for some other tasks in the future”
collaboration	the student is talking about collaboration	“included collaboration”
individuality	the student expresses that he/she can work on their own	“ability to explore on our own was helpful”
peer support	student is talking about how they got help from their peers	“I get help in time and solve the problem which make me more motivated to learn”
instructions	The student is talking about the steps in the lesson, clear guidelines or instructions	“process is really clear. I believe clear instructions and process, and clear end goal made it supportive”, “we got clear guidelines”

gamification	the student is talking about how fun the task was or interesting or playful	“because it let us play with the program before making for a specific task. That reduced stress by creating a playful environment”, “being able to experiment with tinkercad was an enjoyable + fun way to learn how to create a design”
Novelty	the student is talking about the new things/skills/tools they learned or seen or practiced	“because it's new”, “new tools, which I haven't used before, “
freedom	the student is talking about that there no ground work rules	“not clear work ground rules”

Worth to note, that only the node “freedom” is categorized by the researcher under negative responses as the others were all positive.

Later comes Q 14, which is “Did you experience anything that hinder your learning process? Please state what was it and how did affect you?”. The coding scheme for the answers is demonstrated in the following table (table 8)

Table 8 Coding scheme for the fourteenth question

Code	Definition	Example
leaving class	The student expressed that leaving his/her class or one of their group mates doing that hindered their learning	“my teammate had to leave for a while and I was alone to do the task”, “our group having to split up was bad for the collaboration part”

technical difficulties	Student is talking about technical issues they faced in the class like touch screen, didn't like the software	“it's not as easy to use the program with a touchscreen touch mouse, and sometimes the program lacks abilities we would have liked”
physical difficulties	Student is talking about his/her suffering from some type of illness	“just my migraine was disturbing me with a nasty headache”, “today my knees pain”
task novelty	student is expressing that the task was new to him/her hence a bit frustrating in the beginning	“maybe the fact that we never did a task like that before was a bit frustrating at first”
team work	student is talking about no clear teamwork process	“not clear team work process”
no learning	the student expressed that there was no learning process	“admitted I don't think there was much of a learning process”

In Micro:bit session

In this section, the analysis of questionnaires related to the Micro:bit session is displayed. For question 1 and 2 in the pre-questionnaires table 10 represents the coding scheme.

Table 9 Coding scheme of the first and second questions

Code	Definition	Example
No prior knowledge	the code for participants that showed no familiarity or knowledge about programming and coding	“I don't know anything”, “not really much”, “not much”
Shallow level of knowledge	the code is for the answers that shows a low level of knowledge or at least they have an idea about programming and coding whether somehow a clear idea or a vague one	"nothing specific, I understand their purpose", "I had articles used coding to analyze data"
Deep level of knowledge	the code for the participants that showed good familiarity about programming, for example their previous major was highly related to programming or defined it in detail	I've done the very basics boolean, variables", "my bachelor major was IT", "I previously learned coding in java”

Finally, the researcher moved to question 1 and 2 in the post -questionnaires and she elaborated about the coding scheme in table 11

Table 10 Coding scheme for question 1 and 2 in the post -questionnaires

Code	Definition	example
No knowledge acquired	The code for participants that didn't gain additional knowledge	"you can obviously do it in funnier ways", "that it can be

	after the lesson, or the students' answers were not defining anything,	interesting and fun, but it takes some time to use it"
Shallow level of acquired knowledge	the code for the answers that shows that students has gained low level of knowledge about programming and coding	"a little bit", "I learnt how to do coding and how to use this software", "gained the basic idea how coding with micro:bit works"
Deep level of acquired knowledge	the code for the answers that shows that students has gained deep level of knowledge, the students wrote more detailed sentences about the software or the skills they gained after the lesson	"coding is a step by step algorithmic way to proceed solving problem. Programming uses coding in a particular development environments", "knew that there is a visual and easy to use tool that helps kids or novices to learn the basic coding"

As for the second research question, the researcher elaborates the coding schemes of Q10, 13 and 14 respectively since they are the open-ended questions. First, the coding scheme categorization and elaboration for Q 10 “why do you think the structure of the learning design support your collaboration with you classmates?” is presented in the following table (table 12).

Table 11 Coding scheme for the tenth question

Code	Definition	Example
Interaction	The student is talking about how they were actively involved, discussing, having fun and working together	“participants were actively involved”, “we didn't know us good before. We had to work together because everybody knew a little about the topic”, “we got chances for discussion”

Instructions	The student is talking about the instructions	“instructions were well structured and easy to follow”
Materials	the student is talking about the materials used during the lesson such as videos	“the videos and material on the internet were useful”
Peer support	The student is talking about supporting each other	“I was able to show my classmates how to use program”, “advanced students helped those who have weak technological skills”
Topic	the student is talking about the topic of the lesson	“it helped us in learning different things”, “it's new”
Strategy	The student is talking about the strategy that teacher followed in their division	“as it was the first-time using coding device for us, we would prefer probably to explain it individually first”
Team work	Student is talking about what happened between them	“because we did not have role description and role assigned clearly”

It is worth noting that the “strategy” and “team work” nodes were negative, hence the researcher categorized them under “didn’t support collaboration” as for the rest they were positive, so the researcher categorized them under supported collaboration.

Subsequently, this table (see table 12) introduces the coding scheme for Q 13 "why do you think this lesson design support your learning? (if the answer was positive in the previous question)".

Table 12 Coding scheme for the thirteenth question

Code	Definition	Example
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Instructions	Positive	The sentences that talked about positive things related to instructions	“because we took small steps”
	Negative	The sentences talked about negative things related to instructions	“there were only instructions not feedback at all”
Freedom		when the students talked about his freedom in exploring	“lots of freedom to explore”
Novelty		the student is talking about the new things or skills they learned in the session	“I explored completely new things, so it definitely supported my learning”, “new skill”
Peer support		the student is talking about how their peer supported them or how helpful it was	“use each other's understanding was helpful in achieving our goals”
Practical		the student is talking about how they had the chance to experiment the program or had a practical experience	“I had practical experience with coding”

Finally, Q14 “Did you experience anything that hindered your learning process?”, in Micro:bit session the nodes differed a bit from those in 3D session, and they are presented in the following table 13.

Table 13 Coding scheme of the fourteenth question

Codes	Definition	Example
Task	The student is talking about the task, whether it is level, pace, duration or relevance to him/her	“the pace was too fast for me”, “Had trouble motivating myself as I couldn't clearly see the relevance of coding to my work”
Team members	The student is talking about a	“one of my group mates was harsh, rude, bossy and

	negative attitude of team members affected their peers	impatient”, “negative pessimistic attitude from group members limited control over screens/program”
Physical difficulties	The student is talking about some illness or tiredness	“migraine headache was quite a deteriorating factor for my productivity”
Technical difficulties	The student is talking about technical problems	“we faced a difficulty to work program properly”

As for question 15 “Any additional comments you want to add?”, most of them didn’t write anything, or some said thank you. However, some answers are tackled in discussion section (see 5.3).

3.5.2 Video Data

After uploading to the google drive and when the researcher started coding her data, she downloaded the videos again into her laptop to be imported to NVivo so she can code the videos there.

The coding procedure was done in three stages. First, the videos were coded “on-task” or “off-task”, to flesh out the general occurrences where the students were working on what the teacher has given them and when they are not. After this stage, the second stage started. Where the researcher has coded in the “on-task” node into four sub-nodes “4”, “3+1”, “2+2”, “1+3”. Then the final stage comes where the first three sub-nodes that was mentioned earlier were coded for the third time into “CL” which stands for collaborative and it showed the moments were the students actively engaged in the collaborative task together. The following table 8 presents the coding scheme for the three stages.

Table 14 coding scheme for the first stage in video coding

Name of node	What it resembles	Examples

On-task	The students are working on the given task (regardless the number of the students working on the task)	Students are watching a related video, coding on the laptop or discussing between each other the given task
Off-task	None of the students is working on different task	All the students are talking about different topic than the task, or doing something unrelated to the task, checking other groups and working on their phones in other things

Then the coding scheme for the second stage of coding the videos is displayed in table 16.

Table 15 coding scheme for the second stage of video coding

Name of sub-nodes	What it resembles	Examples
4	All team members are working on the task (regardless doing it together or individually)	<ol style="list-style-type: none"> 1) one student on laptop and others discussing the task or telling him/her what to do. 2) one student was on laptop another one was using the phone for task-related purposes and the rest are looking at the laptop. 3) A student on the laptop coding other one telling him what the code and the rest are listening or nodding their head or agreeing in or contributing in one way or another.
3+1	3 students are working on the task (regardless doing it together or individually) and one participant	<ol style="list-style-type: none"> 1) 3 students are working on the task whether together or individually and one student is working on his phone with something personal

	is doing something irrelevant to the task	2) 3 students are working on the task and one student is talking to a friend about something different than the task
2+2	2 students are working on the task (regardless doing it together or individually) and 2 students are not	1) 1 student is explaining something in the task to another student and two students are not listening and working on the phone 2) 2 students are working on the task but individually and another two are doing something else like talking to a friend
1+3	1 student is working on the task and the rest are not	1) One student is working on the task and the other three left the table 2) One student is working on the task and the other three are talking to each other about different issue

It is worthy to note that some students had to leave in the middle of the first session because they had an important meeting, or they had another class clashing with this class. The researcher coded them as off-task.

Finally, the third stage of coding. Fischer, et al. (2013) construed scripting as “specific instances of collaboration related scaffolds that provide interaction-related support rather than content-related support, which makes them a special scaffold for collaborative learning” p. 403. They further elaborated that there are two types of scaffolds occurs during collaborative activity; a scaffold that gives help on the conceptual level and a scaffold that grant support for interactive practices between collaborators. This aspect is what the researcher is interested in, hence she searched for the collaborative interactions (Dillenbourg, 1999), when the students were “on task” and in “4”, “3+1” and “2+2” sub-nodes. She adopted Dillenbourg (1999) definition in terms of collaborative interactions, where he stated that there are three criteria that can determine an interaction as collaborative, where the discussion between the students is interactive, they are doing something together and they are negotiating. The researcher coded the moments when the students are engaged and working together on the task. The researcher represents three different instances, from the videos resembling three different situations, are in the following paragraphs: The first involved collaborative interaction between four students,

then the second resembles collaborative interaction between three students and finally collaborative interaction between two students.

The following is a transcription of a sample that resembles an example of interactive collaboration in “4” node from 3D printing session. The group was Pumpkins, it is taken from video no.2, when they were deciding which design they would choose and why.

00:06:55-00:08:40

a8: which one do you think? I’m thinking of the page holder, it is smaller so might be the best

a9: I don’t think that the size is really matter

a8: ya that’s true, I agree. The shelf charger (explaining with her hands about the object she is referring to)

a9: (pointing at the picture on the board) this is useful

a8: ya, earphones are everywhere

a9: yes

a8 asking a10: which one do you like?

a10: I like the earbud holder, because I have always like that (hold her tangled earphones in her hand)

a11: we need to decide

a10: ya, I guess we have to decide

a11: both of them are equal

a10: like everything sounds super cool

a8: ya, I’m fine with earbud holder

a11: (gives sign of agreeing)

a10: but depends on you

a8: ya, the majority

a10: because I was thinking about the wall output shelf, is it going to fit like every (looking at the wall) charger? is it one form?

A11: I think it is base

a9: let us ask to show how it is again

a8: (raising her hands for the teachers)

a10: I would like earbuds

a8: but this is may be useful

a10: so, let us just choose the earbud holder

Next is a sample of the interactive collaboration in “3+1” node from 3D printing session. It is from fast but not Furious group, video no. 4. The three students are sitting together and designing their artefact

00:03:40-00:04:40

a17: I have one question

a18: is looking at a17

a16: ya

a17: Is it really useful? Because if we use one hand then your one hand can become easily tired, because you use two hands to hold is easier.

a16: I think we can try it and we can see

a17: but we don't have the product, how do we try?

a16: well, we're gonna print it

a17: print it out? Where are we gonna print it?

a16: in fablab

a16: oh ya

a18: (after listening to the whole discussion and he was nodding his head) that's a good question though, like what are the other objects that you guys want to print?

Finally, a sample from the interactive collaboration in "2+2" nodes in 3D session. the students here started designing the artefact. It is group White Midnight, video no.8.

00:03:40-00:05:00

a14: there would be a couple of iPads to go about that

a12: (looking at her a14's iPad)

a14: One way to go about that would be to do a reductive thing first, put a circle in here (pointing to the screen) and make it a hole

a12: aaaahhhhh

a14: right and then put another circle in that hole, that's a solid and then we have a rounded edge.

a12: aaaaaaah, I see (nodding her head) ok

a14: then we could add circles to the ends here (pointing at the screen) to the same end to get that curve as well

a12: aaaaaah, I see

a14: then just group the objects afterwards, that's ya actually that's ok

a12: ooooh

a12: or we can cut, like make a hole (explaining with her hands) cut the corner, would it be possible

a14: mmmmmmm, I was thinking about that, (looking at the screen) I think, this is what this would be like, so.

Finally, the researcher analyzed and discussed individually only the groups that have over two hours of videos since this amount of time is close to the full duration of the session which is 2 hours and 45 minutes. Thus, the data extracted from them might be meaningful more than the

others. The chosen groups were all related to the 3D session only. But when discussing the overall percentage of participation and collaborative interaction, all the videos were included.

4 Results

4.1 What is the students' learning gain after the collaborative sessions?

This question is answered by comparing the results of the pre and post-questionnaires of the first three questions in both sessions. 3D printing session is represented first then the Micro:bit session.

4.1.1 3D printing session

In the first question (see Figure 11) the results show that there is a good development in the students' learning gain. Where the students' percentage has decreased from 33% to only 6% in the no learning zone, that means only one student felt he/she added nothing to his/her prior knowledge. While in the shallow level and deep level of learning, their percentages have escalated but not with the same ratio.

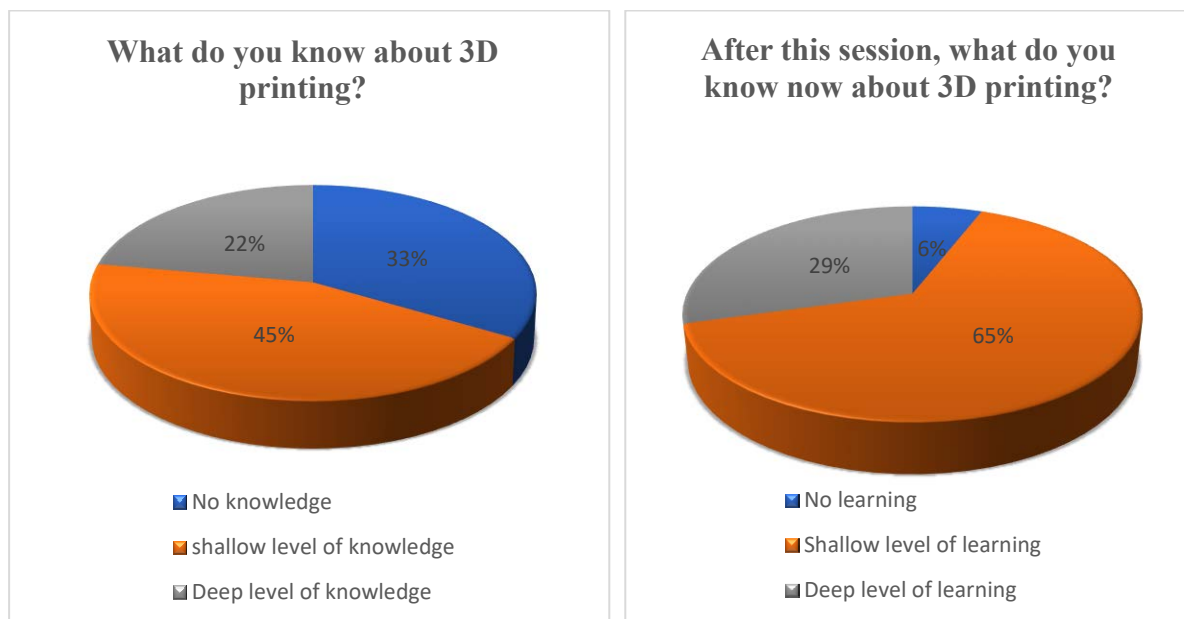


Figure 11. Results of Q 1 in pre and post-questionnaires

Next are the answers of the second question are presented in the following charts (see Figure 12). By looking at the graphs, it is evident that there is a significant increase in the level of learning among the students, where the majority had no knowledge at all about the topic then after the session all of them indicated that they learnt something. It is noted that the number of

students that ended with deep level of knowledge is significant and almost equal to the number of students in the shallow level of learning.

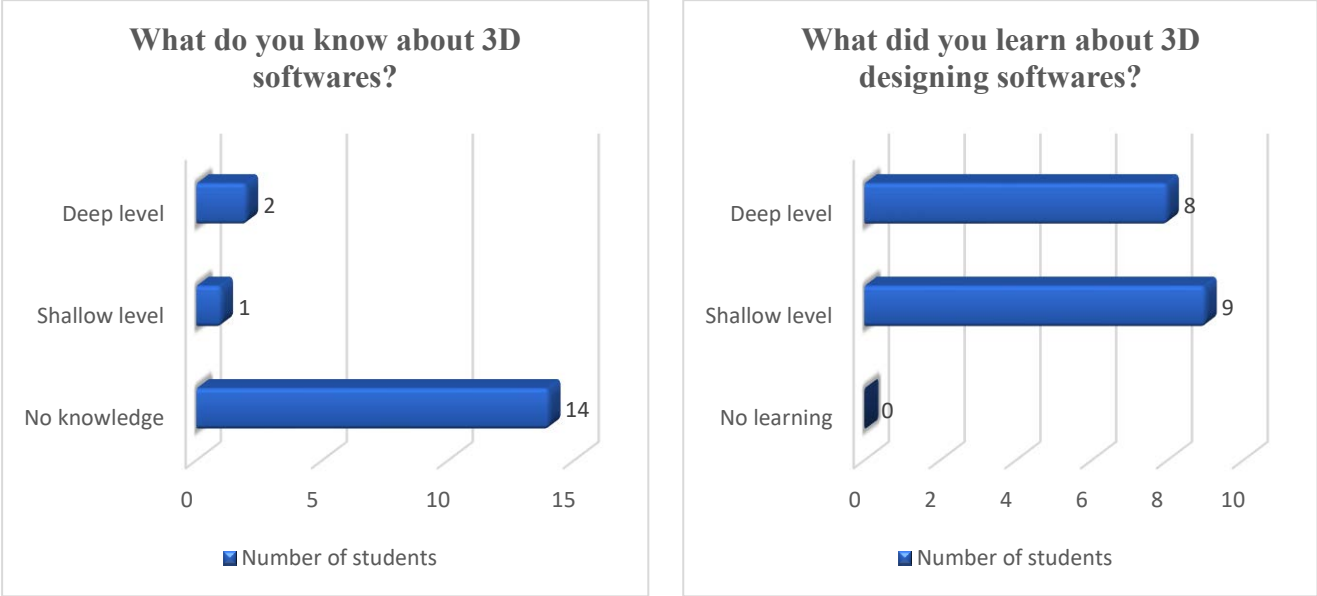


Figure 12. Results of Q2 in pre and post-questionnaires

Finally, in Q 3 the students had to choose from five options, starting from “very weak” indicator and gradually moving to “very good” indicator to show how much knowledge they have in using 3D printing, then how much it developed after the session. The results are represented in the following charts (see figure 13) and it shows that there is a notable improvement in the students’ learning gain with the majority reported it as moderate.

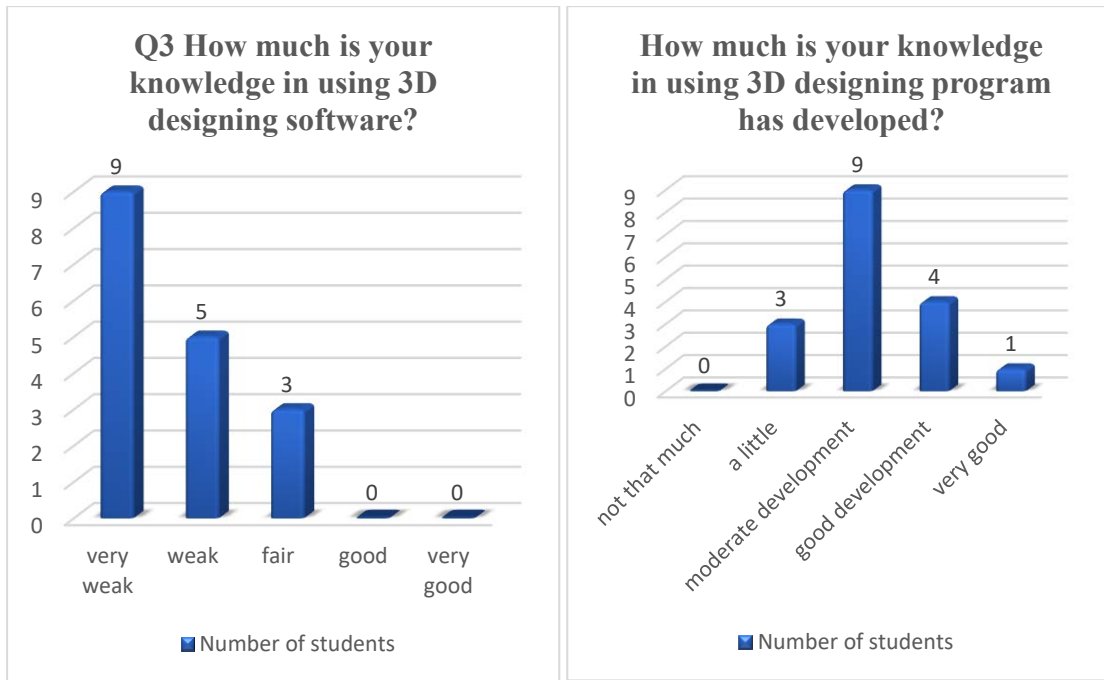


Figure 13. Results of Q3 in pre and post-questionnaires

4.1.2 Micro:bit session

Results of the first and second questions are represented in the following figures respectively (fig 14, 15). As for the results of the first question (see figure 14), there is an increase at least the double, in the shallow level of learning, with a decrease in both deep level of learning and no learning. Worth to highlight that the decrease in the number of the students that had deep level before the session and after it is because the questionnaires were measuring the level of knowledge they gained after the session, hence if they already had a deep level of knowledge in the topic, this means they didn't learn a lot after the session and this would lead to the results to be like that.

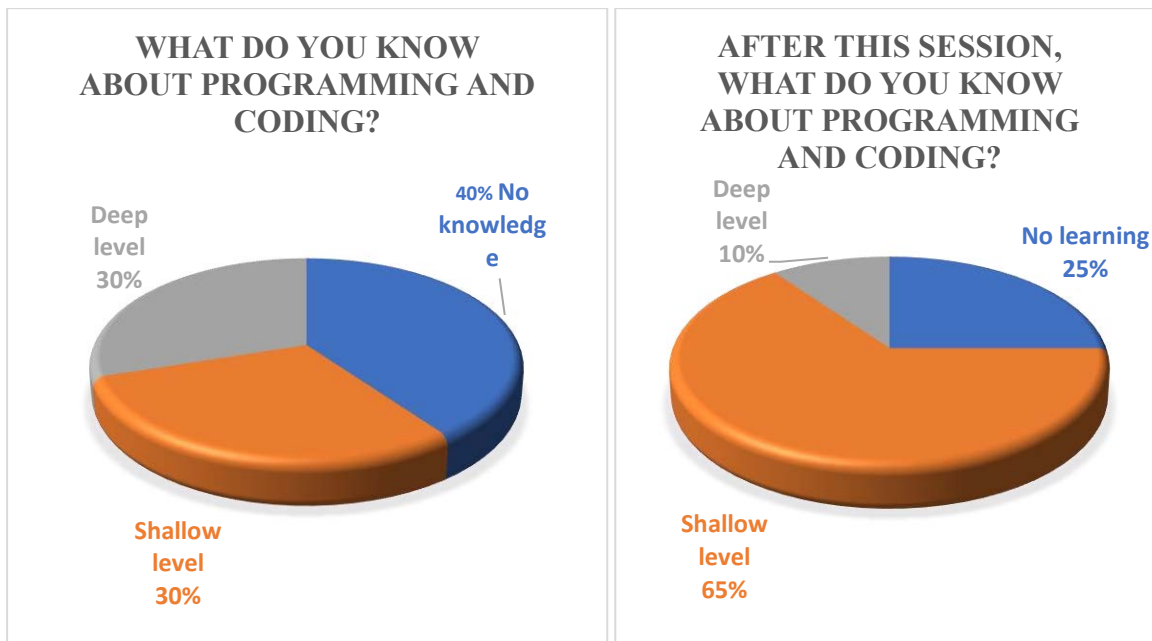


Figure 14. Results of Q1 in pre and post-questionnaires

Later comes the results of the second question, in these pie charts (see figure 15), it is noticeable that more than half of the students had no earlier knowledge about computing platforms, and this percentage decreased to the quarter after the session with an increase in the shallow level reached the double. As for the reason of having quarter of the students with no learning, it is the same as the aforementioned one in the previous question.

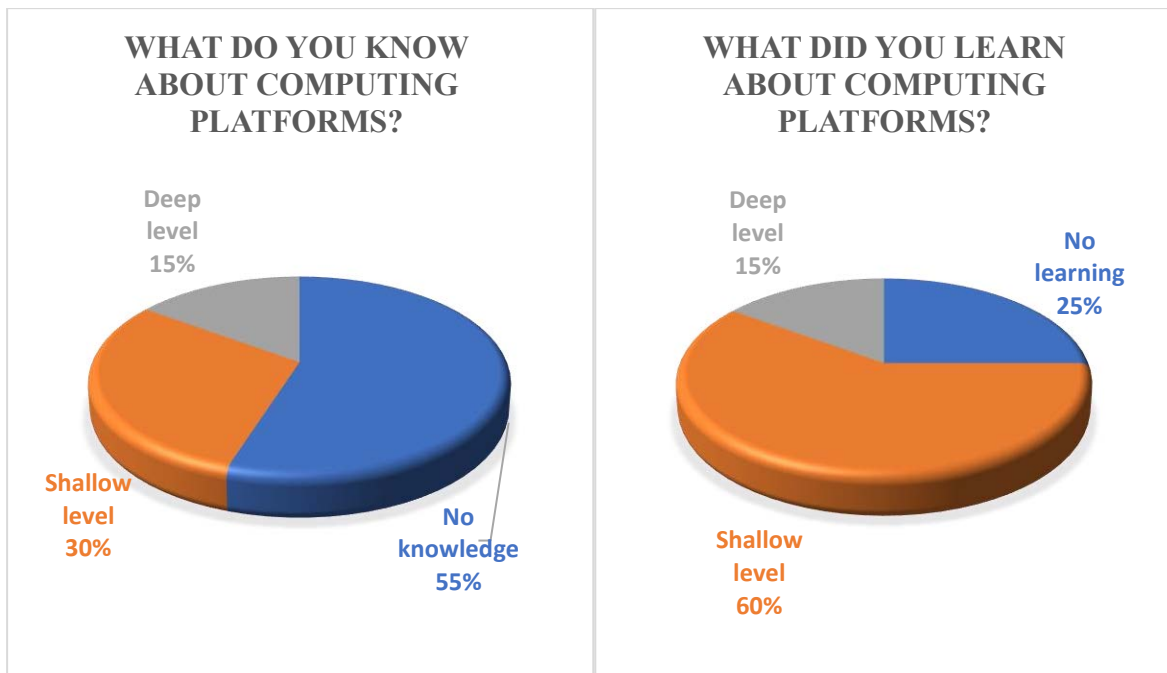


Figure 15. Results of Q2 in the pre and post-questionnaires

As for Q3, the students answered for the question “how much is your knowledge in using computing platforms?”, the following bar charts (see figure 16) are representing the results. Those graphs show that again the level of advancement of the learning gain is significant, especially at the “good level of development” indicator where it increased from 1 to 7 students. While the “fair” indicator increased 2 students and “a little” stayed the same

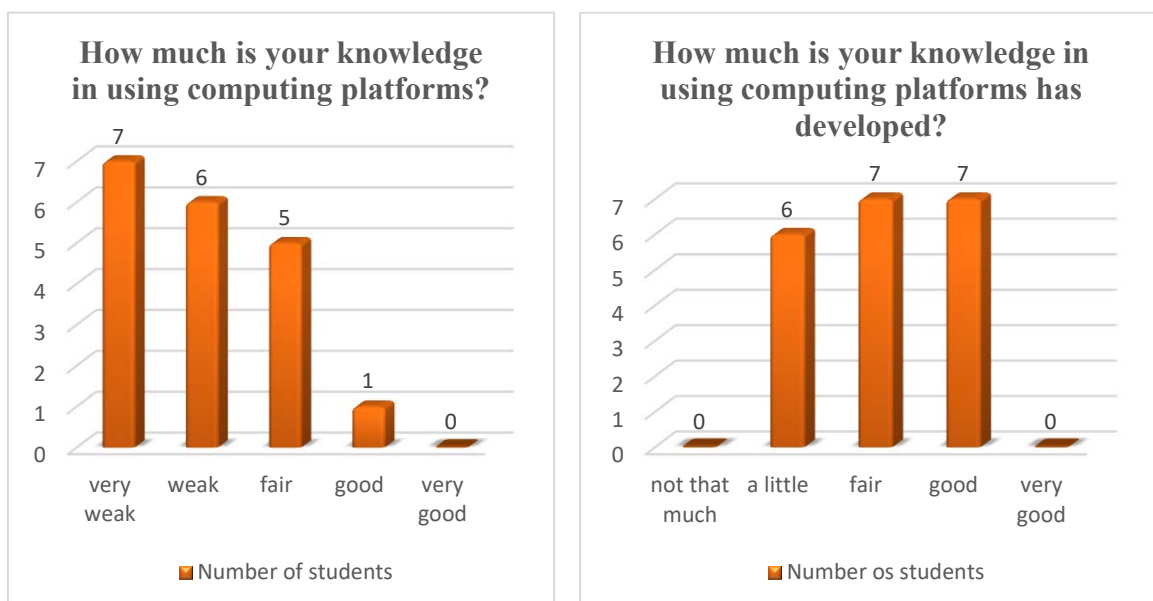


Figure 16. Answers of Q3 in the pre and post- questionnaire

4.2 How was the students' collaboration? a) in terms of participation? b) in terms of collaborative interaction?

The results of the coding of the videos of each group are represented with graphs. Those show the percentage of coverage of each node in the videos related to the specific group in either the 3D printing session or the Micro:bit session. In addition, there is a graph that represents the total percentage coverage for the nodes in all the videos together.

4.2.1 3D printing session

The following bar graphs (see figure 17, 18, 19, 20, 21) show the different percentage of coverage for different nodes. As explained in the coding scheme earlier (see table 15, 16), “on-task” node shows when the students were working on the task, “collaborative interaction (CI)” node resembles the moments where the students are interacting and negotiating together. The node “4” means that four students were working on the task regardless if they were together or individually, while “3+1” node means three students were working on the task and one is not. As for the “2+2” node, it presents the equal division of the students working on the task and students are not working on the task, “1+3” node displays the moments that there was only one student working on the task and finally “off-task” that resembles the moments that all the students were not working on the task.

The following charts (see figure 17) shows that the percentage of “on-task” node is high in both Pumpkins and White Midnight groups. As for the participation, in Pumpkins it is clear that all the students were engaged together most of the time. But in the second group, the participation is distributed between different types of nodes, with two students working on the task has the highest percentage among them. As for the collaborative interaction, it is clear that Pumpkins group has a higher percentage than the second group.

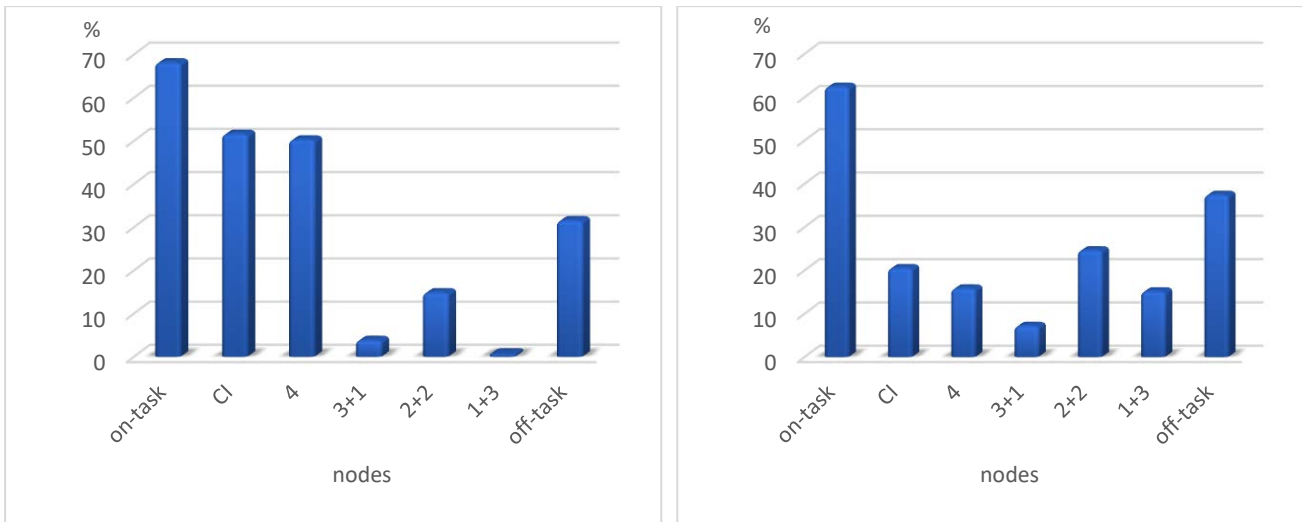


Figure 17. Pumpkins group (left) and White Midnight (right)

In the charts below (see figure 18) it is apparent that students in Toilet Trollz group were participating and working on the task more than Fast but Not Furious group since they have 79% on task while Fast but Not Furious has 49% . In both groups, the participation is distributed between all the nodes (4, 3+1, 2+2, 1+3). While looking at the CI nodes, one can notice that although Toilet Trollz has a higher percentage in participating, however, the difference in the CI node is not significant.

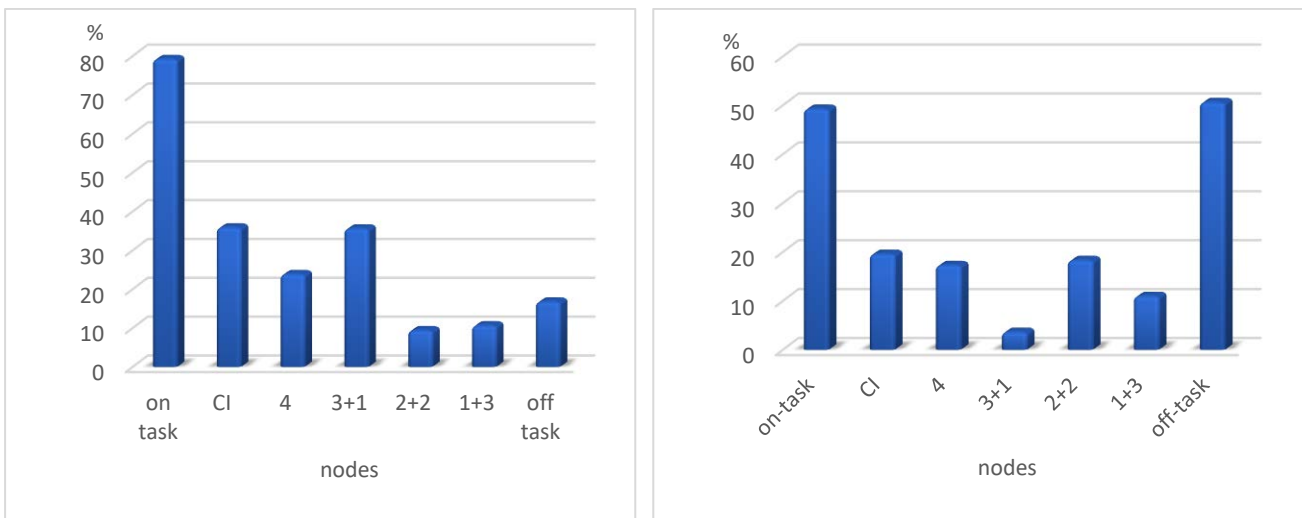


Figure 18. Toilet Trollz group (left) and Fast but Not Furious group (right)

Finally, the percentage of coverage of participation and collaborative interaction for all the videos of the seven groups is demonstrated in this graph (see figure 19). This graph shows that the students were working on the task for almost 60%. As for the percentage of CI for all the videos it is apparent that it is not equal to that of “on-task” node but it is slightly more than half.

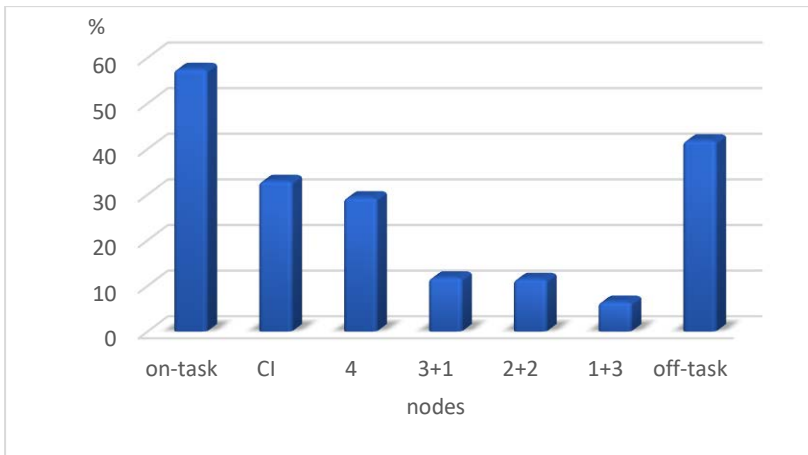


Figure 19. Coverage of all the videos together

4.3 What is the students' perception of this collaborative script?

The result is extracted from the answers of the students from questions 7 to question 14 in both sessions. As mentioned earlier, the researcher notices that the students' answers are almost the same and even the codes are common in both sessions, so she decides to display the results of both sessions simultaneously. However, she points out what is different between them too when needed. The following graphs (See figure 20, 21, 22) represents the results from Q7, Q8, Q9 respectively.

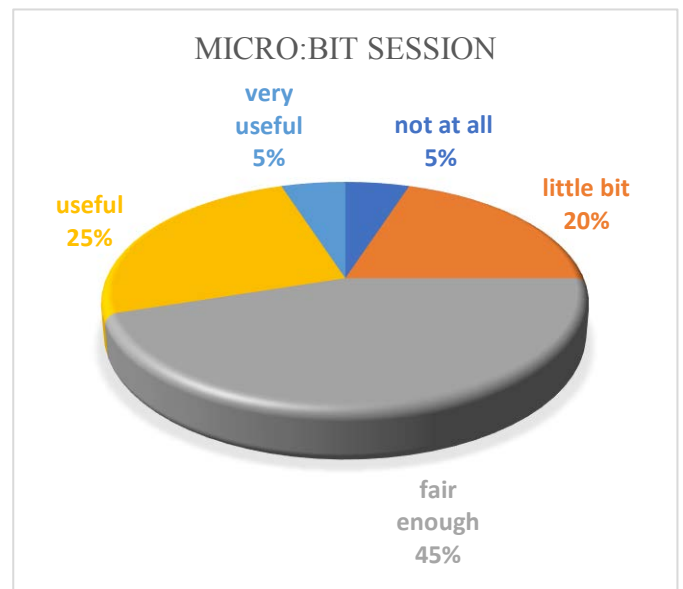
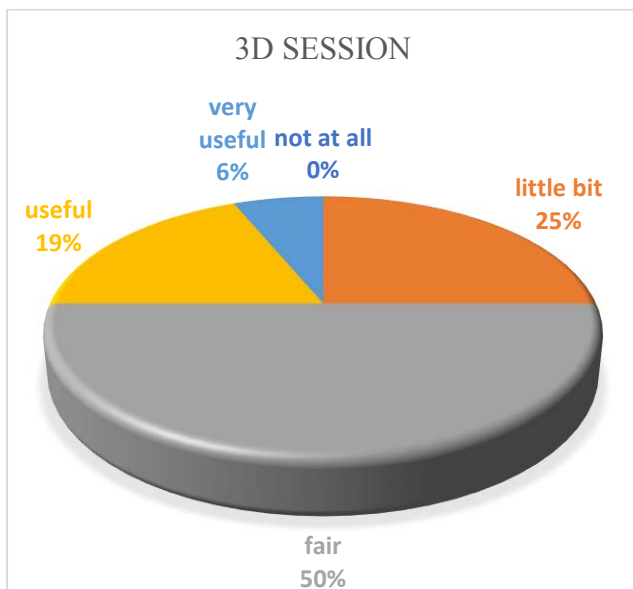


Figure 20. Results of Q 7 “How much did you find the teachers' instruction useful?”

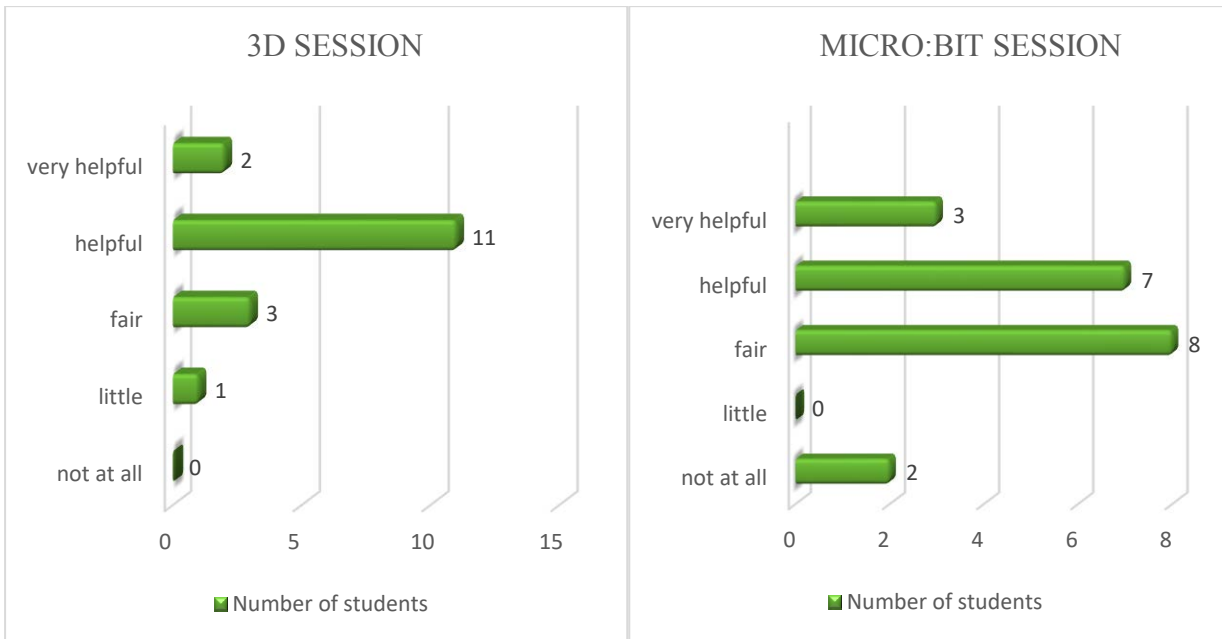


Figure 21. Results of Q 8 “How much did you find the sequence of activities helpful for your understanding of the task?”

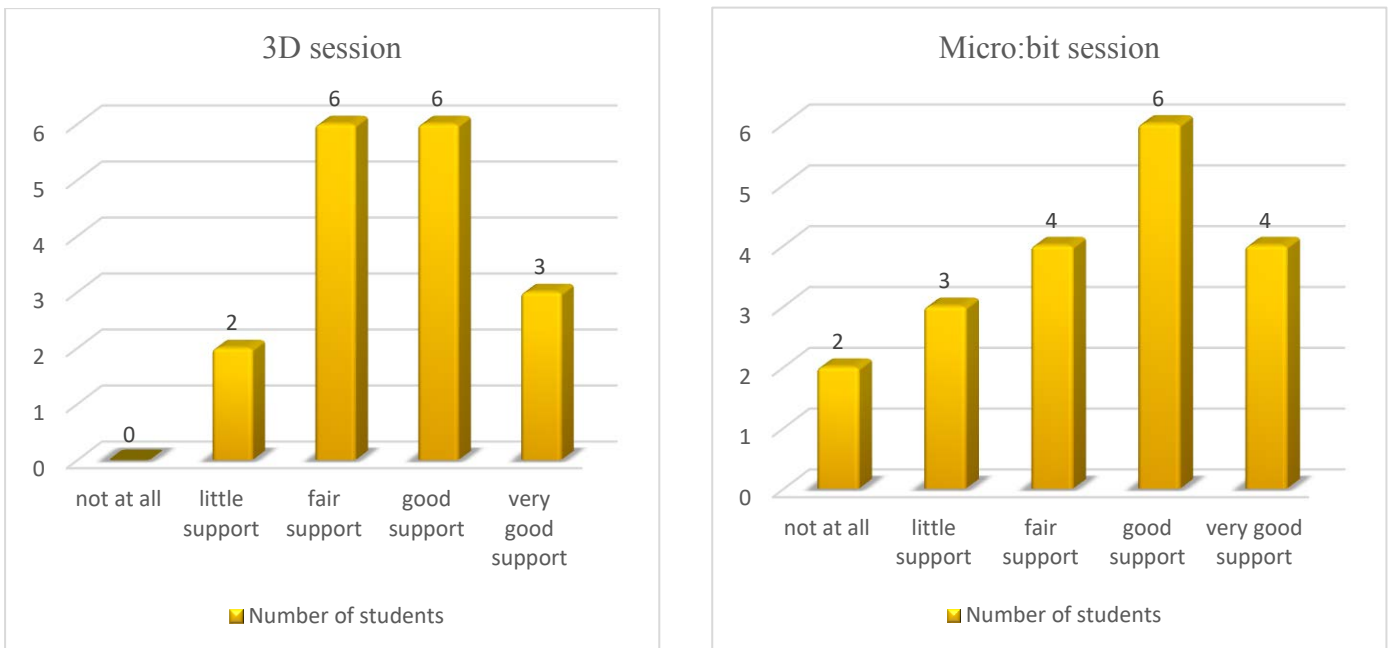


Figure 22. Results of Q 9 “How much do you think the structure of this learning design support your collaboration with your classmates?”

Later comes Q 10, “Why do you think the structure of this learning design support your collaboration with your groupmates? (If the answer was positive in the previous question)”. In this question, the students report that the aspects supported collaboration are more frequent than

those who didn't support collaboration. As for the most frequent aspect that supported collaboration in both sessions is "interaction", then "peer support" comes after it. Later comes the node "topic". While those who are considered as unsupportive for collaboration were scarcely mentioned and they are "tool", "missing tasks" and "individual circumstances" in 3D session and strategy and team work in Micro:bit session.

Next are the results of the answers of Q 11 and Q 12, which is displayed in the following graphs (see figure 23 and 24 respectively)

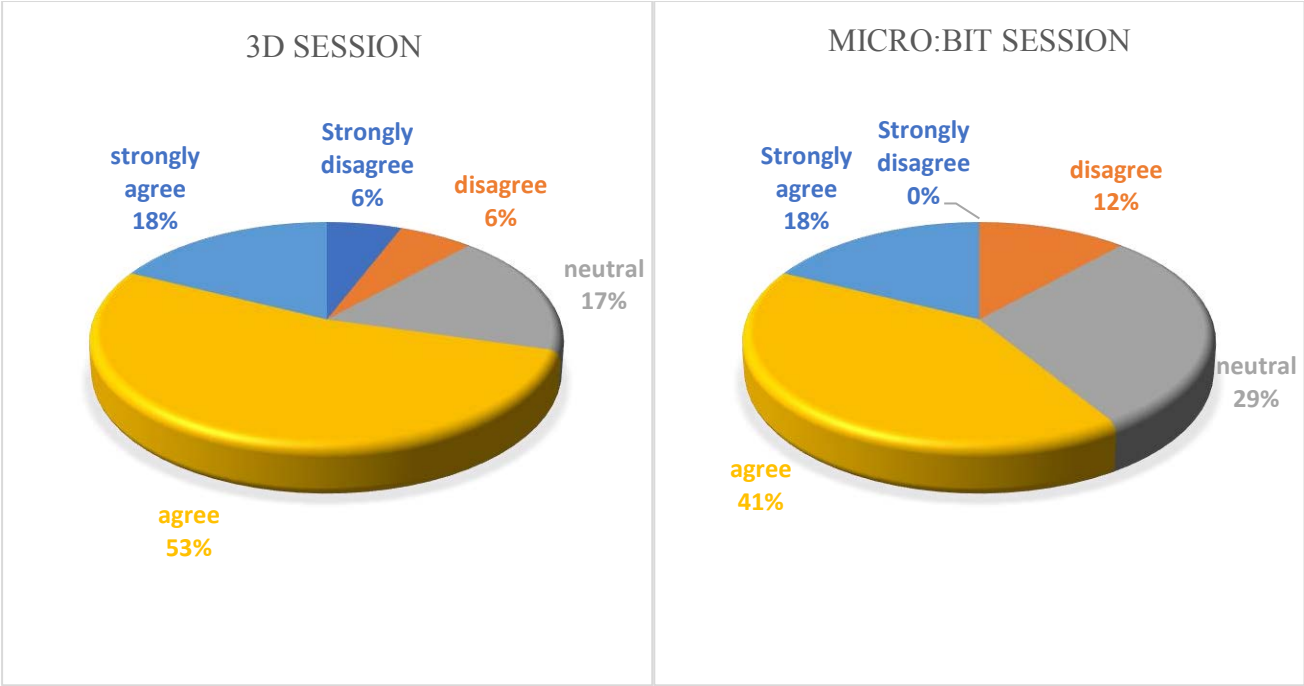


Figure 23. Results of Q 11 “After discussing the task with your groupmates, the task was clearer for you?”

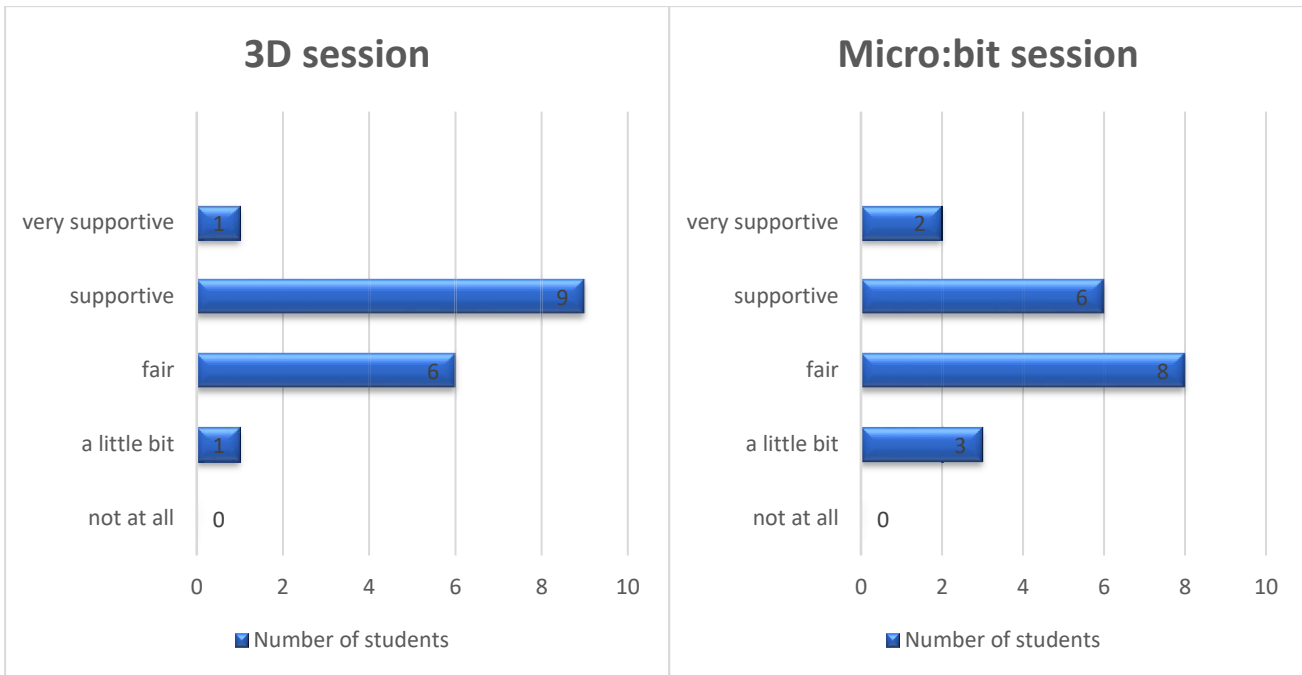


Figure 24. Results of Q 12 “How much do you think this lesson design support your learning?”

Next is Q 13, “Why do you think the lesson design support your learning? (If the answer was positive in the previous question). The node with the highest frequency in both sessions is “novelty”, after it directly is “gamification” node then “peer support” node. Worth to note that in 3D session there is no reported node as unsupportive for learning, while in Micro:bit session the “instructions” node is reported by some students as supportive and others as unsupportive but in both cases the frequency is insignificant.

The final question is Q 14, “Did you experience anything that hinders your learning processes? Please state what is it and how did it affect you?”. The most frequent node which resembles the most reported reason for debilitating collaboration in 3D printing session is “technical difficulties”, however, this same node is the least reported in Micro:bit session. Later comes the “team member” node so one of their group mates is the reason for hindering their learning. Also, the “task” node has an equal frequency as “team member”; where some students reported that the task is too long, too fast, too easy or irrelevant for their field. Last but not least, “leaving class” node is frequent in 3D session but not in Micro:bit session. Finally, “physical difficulties” node is the least frequent, but it is mentioned in both sessions.

5 Discussion

The aim of this study is to explore a macro collaborative script in maker culture from three aspects: the cognitive learning gain of the students after it, 2) the students' participation and collaborative interaction during the collaborative lesson, and 3) the students' perception for this design structure. In the following, the researcher discusses the main results under the light of previous studies and collaborative learning theory.

5.1 RQ1) What is the students' learning gain after the collaborative sessions?

By comparing the graphs that represent the level of knowledge of the student before having the collaborative session and after it, the cognitive learning gain of the students in both sessions has increased significantly. However, the level of significance of the learning varied between the 3D printing session and Micro:bit session. It fluctuated between deep level and shallow level with a tendency to the latter. This study results confirm the common understanding of collaboration and its positive impact on classroom results (Laal and Ghodsi, 2012) were most of the students have gained knowledge after collaborating with each other. This result coincides too with Terenzini (2001) study, where he compared between 480 engineering students in collaborative courses and in courses with traditional instructional methods. His study outcomes showed that those who were in the collaborative courses had greater learning gains than the ones in the traditional courses. However, the increase in deep level and the shallow level was almost equivalent, and that raised the researcher curiosity to find out the reason, so she looked at videos to see how the participation and collaborative interaction in each group was and if these might be connected with such result. She found a connection that is going to be highlighted in the discussion of the next research question.

However, it is worth to mention that due to the prior knowledge of some students with the topic of the session had led them not to develop more knowledge since it was an introductory session about 3D printing and programming. Hence, taking into consideration the different level of knowledge in students is needed for the next implementation. Prior knowledge is one of the individual learning variables that affect group work (Aalst, 2013). Concerning this issue, Kollar (2006) proposed that highly structured collaboration scripts would be best for the learners with low domain-specific knowledge while a minimally structured collaboration script might be better for those with high domain-specific knowledge.

5.2 RQ2 How was the students' collaboration? a) in terms of participation? b) in terms of collaborative interaction?

Although the researcher presented the percentage of coverage of different participation (4,3+1,2+2,1+3) and collaborative interaction in each group, she can't compare between all groups since they are not equivalent in the length of the videos because of the loss of some data that made some groups had a shorter duration of videos than others. However, the researcher could compare two pairs of groups in 3D session, since they had an almost equivalent duration of time with around 10 minutes as a difference between them. The groups are Pumpkins with White Midnight group and Toilet Trollz with Fast but Not Furious group.

Looking at Pumpkins and White Midnight students' participation and interaction, the two groups almost had the same percentages in terms of the "on-task" and "off-task" nodes, with a minor difference less than 10% for the latter group, so they can be considered as participating equivalently during the session. However, the two groups resemble contrasting examples of how collaboration might occur between group members. On one hand, White Midnight group participation was not stable on one type of participation such as four or three of them are working but it fluctuated between the different nodes with slight significance for "2+2" node. On the other hand, participation percentage was much higher in Pumpkins group, with "4" node having the greatest percentage; this resembles that all the students were working on the task. Remarkably, in Pumpkins group, collaborative interaction reaches 51% while in the second group it barely reached 20% although they had almost the same percentage of "on-task" node. This result might be because of negative group atmosphere or a type of disagreement between the students.

The video data related to micro:bit session for Pumpkins group was lost and only short videos were recovered for White Midnight group. Such loss debilitated further deeper analysis of what might affect the relationship between the students. By looking at the questionnaires; nothing was alarming in the 3D printing session, but in the micro:bit session, the researcher found that two members of White Midnight group reported that their relationship with their group mates as a problem that hindered their learning. One student stated, "one of my groupmates was harsh, rude, bossy and impatient" and the other one stated "negative pessimistic attitude from group members limited control over screens/program", the last quote additionally reveals that there was some type of suppressed participation which also inhibit successful collaborative learning (Webb, 2013). With such answers, it might be deduced that

there was some type of disagreement between the students and that affected their participation and interaction. This is in line with previous studies, which stated that negative socioemotional processes like rudeness, hostility and unresponsiveness might hinder students' participation in group work (Webb, 2013). Negative criticism such as rude comments on others' answers, would affect negatively the quality of the outcome of a group problem solving, hence limiting the opportunities of learning among group members (Chiu & Khoo, 2003). Furthermore, negative group interactions are crippling for group members because they obstruct communication among them, which is essential for planning and monitoring actions in group-level. In addition, they may discourage the participation of all group members causing significant off-task behavior, thus affecting the students' abilities to regulate their engagement when they are on-task (Rogat & Linnenbrink-Garcia, 2011), and this might be the answer for the low percentage of collaborative interaction in White Midnight group.

As for Toilet Trollz and Fast but Not Furious, there is also a difference in the collaborative interaction and participation. Albeit, Toilet Trollz group had a much higher percentage of "on-task" node than Fast but Not Furious group; with 80% for the first group and 49% for the latter. Hence, one can deduce that the students in the first group were participating and working on the task more than the students in the second group. Surprisingly, their percentage of collaborative interaction are both can be considered low. Which shows that even if the students were participating together in solving a task that does not mean they are having collaborative interaction (Dillenbourg, 2002; Cohen 1994, Järvenoja & Järvelä 2009; Volet et al., 2009, Burdett 2003). Although, it was apparent Toilet Trollz group was more active in participating than the other group which might lead to the assumption that they would have a much higher percentage of interactive collaboration than the other group. But after the analysis, it turned out the opposite, and that that they had low collaborative interaction.

As overall, the researcher can clearly see from figure 19, that the students' percentage of participation and being on-task was slightly higher than being off-task. In addition, their collaborative interaction resembles a good but not significant percentage. Which confirm what has been said earlier about grouping students together does not mean they will collaborate together nor learn effectively (Dillenbourg, 2002; Cohen 1994, Järvenoja & Järvelä 2009; Volet et al., 2009, Burdett 2003). These results might be the reason for the students to gain shallow level of knowledge rather than deep knowledge. Deep learning can be achieved by enhancing

the cognitive activity of individuals through productive collaborative interactions (Bereiter,2002). Hence, low percentage in the collaborative interactions within a group might lead to achieving a shallow level of knowledge.

When implementing a new design in class, the students' perception of it is crucial to know how successful it was from students' point of view, the lesson is for them and to benefit them. By looking at the students' perception the designer could notice the strong points to implement or weak points to avoid in future designing. With the nine questions in the questionnaires, the researcher could grasp a bigger picture of how the students saw the structure of the lesson from different aspects; teacher's instructions, the sequence of activities, interaction with group mates, reasons they find it supportive their collaboration with their group mates and their learning. The results provide the researcher with the answers needed for the third research question. The researcher discusses the results of the close-ended questions in both sessions together then she discusses the open-ended questions.

5.3 RQ3) what is the students' perception of this collaborative script?

As previously mentioned, the closed questions are Q 7, 8, 9, 11 and 12. In both sessions, most of the students found the design of the sessions as helpful for their collaboration with their group mates and supportive for their learning. However, the majority find the teacher's instruction as fair in the level of usefulness, while the rest found it useful or very useful. An exception of two students in micro:bit session that their answers were negative. That means the teacher might need a slight improvement in her instructions and the way she is delivering them. Since the students have perceived them positively, which show that such a design was successful in reaching its goal and aim, hence it can be replicated. Exceptionally, there was a minor disagreement only in the micro:bit session was two students' found that the lesson structure is not supportive nor helpful. That would raise the question of why they didn't find it supportive, and the answer for that lies in the open-ended questions that will be further elaborated in the next paragraph.

In the open-ended questions, the students had the freedom to answer the questions however they want. Although the two sessions were different in topic and tasks, the researcher could drive almost the same nodes from both, thus she discusses now both sessions together, with mentioning the most prominent nodes.

The first open-ended question in this section was Q10 that was asking for giving explanations if the student find the design structure enhanced their collaboration. The most frequent node was the interaction, where the students found that the lesson structure helped in introducing them to each other, encouraged their discussion, gave them a sense of involvement and they could support each other. Clear instructions and peer support was prominent too, where students described how knowledgeable students were helpful for those who are novice in these topics.

Next, is Q 13 where the students gave reasons for perceiving the lesson as supportive for their learning. The most frequent reason in both sessions were the novelty of the topic where students thought the topic of the lesson was a crucial factor in their learning. Later comes instructions and practicality of the lesson where the students had to experience by themselves the micro:bit and code it to produce actions, which was interesting for them. Furthermore, other students perceived the micro:bit lesson as a type of a gamified lesson that promoted their motivation. Peer support was highly noted by students in both sessions too. Collaboration was mentioned too but not as frequent as the others.

To sum up, the students have perceived the design structure positively and found it useful for their collaboration and learning. The most prominent aspects that were repeated by the students was not only interaction, but novelty too, later comes instructions and peer support. However, peer support was commonly mentioned in all the answers in both sessions, which shows that its impact on the students might be greater than the other aspects. For example, one student stated that “I could learn new things from other peers”. This is in line with Vygotskian zone of proximal development, where a student can’t achieve certain level igroup mate without the help of his more experienced groupmate (O’Donnelle & Hmelo-Silver, 2013). Peer support does not mean only a student helping another, but it also means that the students feel a sense of involvement together, a status of unity among them. Such status was apparent in the questionnaires. For example, a student wrote, “use each other’s understanding was helpful in achieving our goal”, which corresponds with what Johnson and Johnson (1990) have pointed out, in a learning situation, the goal achievements for students are interconnected, that means the students feel that there is a binding condition to achieve their goals and that is they need to achieve them simultaneously with their group mates.

As for the challenges they perceived as inhibiting for their learning, the students reported a couple of common challenges in the two sessions and some challenges are related to each session dependently. One of the common challenges was teamwork, and it was discussed earlier

in RQ2. In addition, technical and physical difficulties are also common in both sessions, that means that even if the environment was well prepared and the task was planned appropriately, sometimes there are things the researcher can't control, for example, the individual emotional or physical status of the student which might affect their attitude and efficiency during the session. For instance, one student answered Q15 and wrote "I do apologize for not contributing that much to the process, it was not a good day for me" and another one stated, "I'm sorry I was a bit grumpy". The researcher while watching the videos could see how these two were demotivated and how they were even affecting their group mates with their attitude. For example, in video 4 in FNF group, 00:04:30 – 00:04:36

A18: that's a good question though, like what are the other objects that you guys want to print?

A16: I do not want to print anything; I do not care about it.

Another student suffered from migraine and reported about it in the two sessions. However, the researcher did not go deeper into the analysis of motivation or socio-emotional aspects and how it affected collaboration since it was not her focus on this study. But maybe for future studies, this aspect can be investigated comprehensively from the same data.

Among the challenges that the students reported is that the topic is irrelevant to the student's field of work, which was reported also by Aalst (2013) as one of the influencing learning individual variables that affect group achievement. The duration of the task was problematic for some students too. Couple of them has reported that having such new information in two different topics is too much for one day. It would be better if the sessions were split in two days and even if the study was investigating collaboration within maker culture context was done on a longer duration, this would have given more precise and richer data and results. Berg (1993) had an intervention that lasted for 30 days. The intervention was scripted collaboration with individual learning in a traditional teacher-centred class and it improved the students' learning.

6 Conclusion

Collaborative learning in Maker Culture is new and important to research. It has its advantages and challenges as presented in this study. The researcher represents in this chapter the main findings, practical implications and further research.

6.1 Main findings

This case study reinforces the understanding of the importance and significance of collaborative learning on students' construction of knowledge (Damon & Phelps, 1989; Dillenbourg, 1999; Stahl et al., 2005; Dillenbourg & Jermann, 2007; Webb, 2013; Cornelius, Herrenkohl & Wolfstone-Hay, 2013; Rummel, Mullins, & Spada, 2012; Silvola, 2017) even if the context is new. Collaborative learning increase learning gain (Laal & Ghodsi 2012; Terenzini, 2001). It also showed that the topic of the lesson plays an important role in enhancing the interaction. It confirms that if the students are grouped together and discussing do not mean they are interacting effectively (Burdett 2003, Cohen 1994, Dillenbourg, 2002; Järvenoja & Järvelä 2009; Rau, Bowman & Moore, 2017; Volet et al., 2009). Finally, it showed that students had perceived this lesson in a positive way (Tsompanoudi, Satratzemi and Xinogalos, 2014, Laal and Ghodsi, 2012).

6.2 Practical Implications

As the results help in understanding how the nature of collaborative learning might differ based on the context and the topic. And based on what the researcher has experienced in this case study, she is presenting some suggestions that might enhance implementing collaborative learning in maker culture. In terms of the script, leaving the freedom for the students to divide the roles and tasks has affected negatively on this lesson progress. Where there were superior students that suppressed other students (Webb, 2013), didn't take their suggestions into consideration and followed their own opinion. Also, the fact that students work on one computer or several computers both affected the task. When it was one computer, the student didn't share it with his friends, hence they didn't have the chance to experience by themselves (although the script requested that all group mates need to do part of it, but gave them the freedom of choice of turns and task division). And when every student in the group had a computer to work on, this created a gap between the students and discouraged interaction

between them. Hence, having two computers maximum per one group (considering the number of group members is four or five) is a convenient number. In terms of instructions, the steps and tasks given by the teacher should be printed out on papers and distributed to each group so they can refer to it whenever it is needed. In terms of the materials used, the teacher should pay careful attention to the length of the videos used for elaboration or introducing a certain topic, it should not exceed 3-5 minutes per video. As a recommendation, the script needs to be adaptive, for example, to be narrowed down in some phases; such as in the planning phase when they are distributing the roles and dividing the tasks and to become loose as for the exploratory phase, were some students would prefer to explore by themselves and others prefer to be with their group mates. Another recommendation is related to implementing the lesson, the teacher needs to pay attention for the class size and how it is convenient for the number of the students involved in the session, especially it is a collaborative lesson. In this study, there were around twenty students, the first class was good for group work while the second class was too small, and it ended up crowded a bit. Such a situation might annoy for them and might affect their learning opportunity.

7 Evaluation

In any academic research, its data and results need to be evaluated appropriately for credibility, where “researcher needs to demonstrate the trustworthiness of their data by measuring their reliability” (Krippendorff, 2019, p.278). In addition, validity is also important, because the readers would acknowledge the research as correct because of its quality (Krippendorff, 2019). Hence, valid research means research with good quality. This section presents the ethical issues, validity, reliability and finally the limitations.

7.1 Ethical issues

The researcher was keen to follow the guidelines established by the Finnish National Board on Research Integrity (TENK) (2009). First, she respected the autonomy of the research subjects, where participation in this study was voluntary. Before the start of the sessions, both parties and the participants signed an online consent form. In addition, the participants had the right to withdraw and leave the class at any stage of the research, later the record was kept with the researchers. Second, the researcher avoided any mental, social or financial harm on the participants. Where they were treated with respect and equal treatment for all of them and the published results are far from being judgmental or giving any negative picture of the participants. Third, privacy and data protection were taken into serious consideration. All the information related to participants were handled with confidentiality from the moment the data was collected and uploaded to the university system was only the research members and their supervisor had the access to it, also during the analysis of the data where the names of the participants were replaced with a letter 'a' and a number and later in reporting the data.

7.2 Validity and Reliability

The data collection tool is considered valid if it proves that it measures what it was meant for (Krippendorff, 2019). The questionnaires were validated by presenting them to two experts in the field. They checked it and approved it. Expert evaluation can establish face validity or content validity (Gay, Mills, and Airasian, 2009). In addition, only one researcher was responsible for uploading the videos into the laptop and the other one was responsible for changing the memory cards and batteries too among different cameras, such strategy would

enhance the trustworthiness of collecting the data and avoiding any mistakes that would lead to inaccurate data collection.

As for the reliability of this study, it was ensured by measuring the percentage of agreement in coding between the researcher and another independent coder. This coder has coded 20% of the pre- and post-questionnaire data based on the coding scheme offered by the researcher. The percentage of agreement between the researcher and the coder is 95.5, which is considered as a significant percentage. Hence, the coding schemes of the pre- and post-questionnaires are reliable leading to a reliable analysis of the results.

7.3 Limitations

Like any academic research, there are some limitations to this research. First, the findings in this research cannot be generalized for two reasons, a) the sample size is too small (Yin, 2017), b) losing part of the data had affected the results. Such loss of data also happened previously with researchers in previous studies such as Rummel et al. (2012), where they were investigating the interaction of the students and the learning effects. They could come up with results related to the students' interaction, but their loss of data prevented them from finding a concrete answer related to learning effects. Researchers need to be adaptive and have the resilience to cope with what he/she has and try their best to come up with meaningful results that can add value to previous studies. Another limitation is timing, two sessions for implementing collaborative learning might not provide the beneficial deep results and effect if it is compared to a prolonged course with multiple sessions. Rummel et al. (2012) hypothesized that practising collaborative learning over a longer duration would enhance its benefits in learning situations and such enhancement can be advanced by supporting students with scripts. Such a hypothesis was supported by Westermann and Rummel (2012) study where they had a four weeks study. They have compared between collaborative learning condition and non-collaborative learning condition, with a significant difference for the first group, what was interesting is that the benefits in the collaborative condition were progressively developing till the end of the study.

7.4 Future Research

This study provided a view on collaborative learning in Maker culture and how a specific script had an impact on students' collaborative interaction. Yet more research needed in this area,

what is interesting the researcher and can be considered as a continuity to this study is how can the teachers script effective collaborative learning related to STEM topics in Maker culture, what do they need and what are the challenges they might face while implementing such lessons. Furthermore, a comparison between microscript and macrosript can be investigated to see how each of them impact the students' collaborative interactions. Or even how can a traditional lesson differ from a collaborative lesson in terms of learning outcomes in Maker culture. Finally, self-regulation, motivation and socially shared regulation aspects form a rich area in FabLab context, while the students are working collaboratively on a problem solving, or a specific task like fabricating an artefact.

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Appendix 1

Pre-questionnaire 1

Name:

Age:

Gender: Male Female

ICT Literacy: (1 novice – 5 Expert)

1 2 3 4 5

Questions related to prior knowledge

1. What do you know about 3D printing?

2. What do you know about 3D softwares?

3. How much is your knowledge in using 3D softwares?

(1 very weak – 2 weak – 3 fair – 4 good – 5 very good)

1 2 3 4 5

4. What kind of possibilities do you see in 3D printing in your career in the future?

5. What are your expectations for this task?

6. You are motivated to experience 3D printing

(1 strongly disagree – 2 disagree - 3 neutral – 4 agree – 5 strongly agree)

1 2 3 4 5

Appendix 2

Name:

Post-questionnaire 1

1. After this session, what did you know now about 3D printing?

2. What did you learn about 3D designing software?

3. How much is your knowledge in using 3D designing program has developed?

(1 not that much – 2 a little – 3 moderate development – 4 good development – 5 very good)

1 2 3 4 5

4. After this lesson, what kind of possibilities you see for 3D printing in your career in the future?

5. You have achieved your expectations for this task

(1 strongly disagree – 2 disagree – 3 neutral – 4 agree – 5 strongly agree)

1 2 3 4 5

6. After finishing this task, how much are you motivated to use 3D printing again?

(1 not at all – 2 little bit – 3 neutral – 4 motivated – 5 very motivated)

1 2 3 4 5

Questions related to planning:

1. Did you set goals with your groupmates?

Yes No

2. How was your setting for the goals within your team?
(1 very weak – 2 weak – 3 fair – 4 good – 5 very good)

1 2 3 4 5

3. How did you divide your time for executing your goals?

4. How did you plan for your design within your groupmates?

5. How did you organize your work to reach your goal?

Questions related to the learning experience

1. How much did you find the teacher's instructions useful in this session?
(1 not at all – 2 little bit – 3 fair enough – 4 useful – 5 very useful)

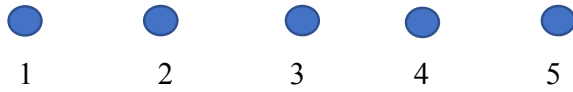
1 2 3 4 5

2. How much did you find the sequence of activities helpful for your understanding of the task?
(1 not at all – 2 little – 3 fair – 4 helpful – 5 very helpful)

1 2 3 4 5

3. How much do you think the structure of this learning design support your collaboration with your groupmates?

(1 not at all – 2 little support – 3 Fair support – 4 good support – 5 very good support)



4. **Why** do you think the structure of this learning design support your collaboration with your groupmates? (If the answer was positive in the previous question)

5. After discussing the task with your groupmates, the task for you was clearer

(1 strongly disagree – 2 disagree – 3 neutral – 4 agree – 5 strongly agree)



6. How much do you think this lesson design support your learning?

(1 not at all – 2 a little bit – 3 fair – 4 supportive – 5 very supportive)



7. **Why** do you think this lesson design support your learning? (If the answer was positive in the previous question)

8. Did you experience anything that hinder your learning process? Please state what was it and how did it affect you?

9. Any additional comments you want to add

Thank you very much, your participation is really appreciated

Appendix 3

Pre-questionnaire 2

Name:

Age:

Gender: Male Female

Computer Literacy: (1 novice – 5 Expert)

1 2 3 4 5

Questions related to prior Knowledge

1. What do you know about programming and coding?

2. What do you know about computing platforms?

3. How much is your knowledge in using computing platforms?

(1 very weak – 2 weak – 3 fair – 4 good – 5 very good)

1 2 3 4 5

4. What kind of possibilities do you see in using computing platforms in your career in the future?

5. What are your expectations for this task?

6. you are motivated to experience coding a computer platform

(1 strongly disagree – 2 disagree - 3 neutral – 4 agree – 5 strongly agree)

1 2 3 4 5

Appendix 4

Name:

Post-questionnaire 2

1. After this session, what did you know now about coding and programing?

2. What did you learn about computing platform?

3. How much is your knowledge in using a computing platform has developed?

(1 not that much – 2 a little – 3 moderate – 4 good – 5 very good)

1 2 3 4 5

4. After this lesson, what kind of possibilities you see for coding and the computing platform in your career in the future?

5. You have achieved your expectations for this task

(1 strongly disagree – 2 disagree – 3 neutral – 4 agree – 5 strongly agree)

1 2 3 4 5

6. After finishing this task, how much are you motivated to use the computing platform again?

(1 not at all – 2 little bit – 3 neutral – 4 motivated – 5 very motivated)

1 2 3 4 5

Questions related to planning:

1. Did you set goals with your groupmates?

Yes No

2. How was your setting for the goals within your team?
(1 very weak – 2 weak – 3 fair – 4 good – 5 very good)

1 2 3 4 5

3. How did you divide your time for executing your goals?

4. How did you plan for your design within your groupmates?

5. How did you organize your work to reach your goal?

Questions related to the learning experience

1. How much did you find the teacher's instructions useful in this session?
(1 not at all – 2 little bit – 3 fair enough – 4 useful – 5 very useful)

1 2 3 4 5

2. How much did you find the sequence of activities helpful for your understanding of the task?
(1 not at all – 2 little – 3 fair – 4 helpful – 5 very helpful)

1 2 3 4 5

3. How much do you think the structure of this learning design support your collaboration with your groupmates?

(1 not at all – 2 little support – 3 Fair support – 4 good support – 5 very good support)

1 2 3 4 5

4. **Why** do you think the structure of this learning design support your collaboration with your groupmates? (If the answer was positive in the previous question)

5. After discussing the task with your groupmates, the task for you was clearer

(1 strongly disagree – 2 disagree – 3 neutral – 4 agree – 5 strongly agree)

1 2 3 4 5

6. How much do you think this lesson design support your learning?

(1 not at all – 2 a little bit – 3 fair – 4 supportive – 5 very supportive)

1 2 3 4 5

7. **Why** do you think this lesson design support your learning? (If the answer was positive in the previous question)

8. Did you experience anything that hinder your learning process? Please state what was it and how did it affect you?

9. Any additional comments you want to add

Thank you very much

