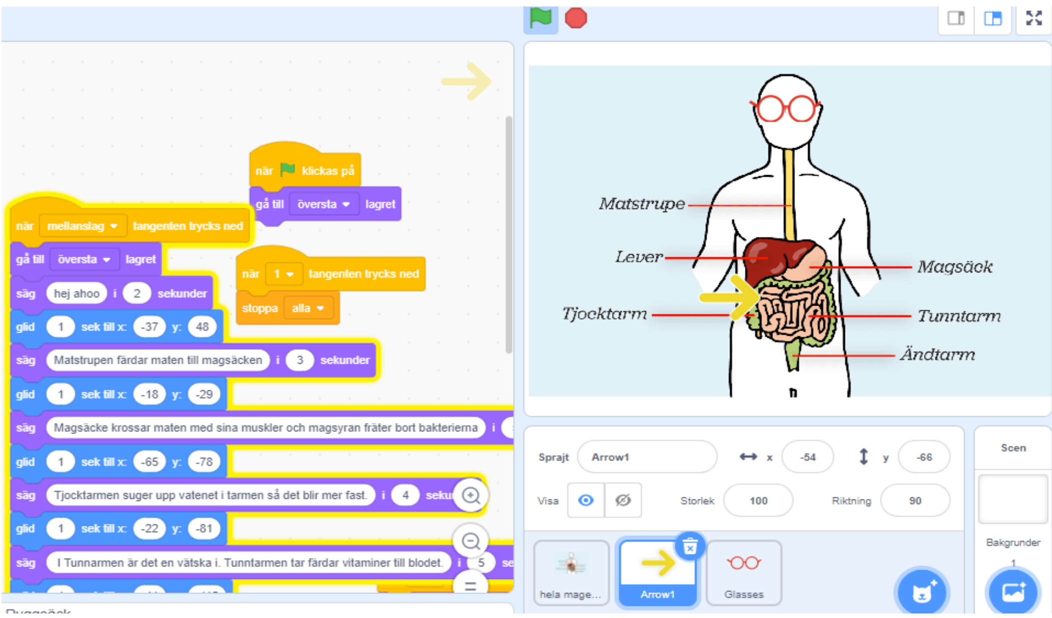
DEPARTMENT OF
APPLIED IT

UNIVERSITY OF GOTHENBURG

THE USE OF PROGRAMMING AS A TOOL FOR DESIGN-BASED LEARNING IN BIOLOGY

A classroom experiment in a 5th grade class



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Abstract

The purpose of education is to prepare students for the future. The goal of integrating STEM (Science, Technology, Engineering, and Mathematics) into education is to develop scientific and technological knowledge in students, to prepare them for an advanced technological and democratic society, and to broaden their perspective of how to use, create, and make decisions about technology, and not less important, to prepare them for their future jobs (Honey, Pearson, and Schweingruber, 2014; English and King, 2015; Holbrook, 2017; Lachapelle et al., 2018).

This study with class 5C began in the spring semester of 2021, in a school in Mölndal, during weeks 15-17 (april-may). Control and experimental groups were set up. Both groups used the same materials. In the control group, the common methods of teaching-learning were used, such as reading facts from books, watching films, answering questions based on the films and texts, writing texts, and conducting group discussions. The experiment group used the same material to reach the content, but they were supposed to use it as needed to create their own game with Scratch. Students utilized the material that they thought was relevant in the experiment group.

According to this study, a positive learning environment is created around designings games and students have expressed happiness and are more willing to collaborate with peers. The results gathered from pretest and posttest show that students who participated programming with Scratch showed significant knowledge development. Both students and the teacher mention that the time was very limited, and they wish to invest more time to complete their game and even to do more projects like this. The main issues that were considered as a hindrance have been competence, time, curriculum, and assessment.

Keywords

STEM education, Middle school, Block programming, Designed based learning, Inquiry-based learning,

Titel

SKAPA EGEN SPEL MED BLOCK PROGRAMMERING I SCRATCH FÖR ATT LÄRA MATSPJÄLKNINGSSYSTEMET

Ett klassrumexperiment i åk5

Studien är ett klassrumexperiment där eleverna använder block-programmering (Scratch) och skapar egna dataspel för att lära sig matspjälkningssystemet. Meningen är att integrera STEM och att genomföra en studentcentrerad aktivitet i form av designbaserad inlärning. Syftet med denna studie är att undersöka hur elevernas engagemang och kunskapsutveckling kan påverkas, men också undersöka svårigheter och hinder som kan påverka processen.

Resultaten visar ökning i elevernas engagemang, kunskapsutveckling. Några av svårigheterna som lärare och elever uppmarksammat är tidsbegränsningen, bedömningen, kopplingen till läroplan och tidsplan samt lärarens kompetens.

Keywords

STEM education, mellanstadiet, Block programmering, Designed based learning, Inquiry-based learning,

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1 Introduction

The technological society requires citizens to become aware of their technological acts, both as users and producers. In the technology era, there is a need for improved knowledge and awareness. Developing critical thinking is an important part of society's future as technology develops (Dakers J.R. 2018; Lachapelle, Cunningham, Davis, 2018; Moore, Glancy, Tank, Kersten, Smith and Stohlmann, 2014). The purpose of education is to prepare students for the future. The goal of integrating STEM (Science, Technology, Engineering, and Mathematics) into education is to develop scientific and technological knowledge in students, to prepare them for an advanced technological and democratic society, and to broaden their perspective of how to use, create, and make decisions about technology, and not less important, to prepare them for their future jobs (Honey, Pearson, and Schweingruber, 2014; English and King, 2015; Holbrook, 2017; Lachapelle et al., 2018).

The needs for STEM careers increase at a very high rate, while the number of those who choose technological paths as their future jobs does not grow at the same rate (Moore et al., 2014; Tran 2018; Keith 2018). Previous studies show that students' interests and confidence in STEM subjects and careers are mainly formed somewhere at the end of elementary schools and during middle schools (Daugherty and Carter, 2018). To keep motivation and interest in STEM, these subjects should be integrated into the curriculum at grade 4-5 (Kurz et al., 2015, Bonner & Dorneich, 2016). The interest and confidence in STEM subjects fades sharply after this period; still, the STEM projects are mainly implemented in late secondary school and high schools (Moore et al. 2014).

In a modern and technological society, full of distractions, education needs to motivate and engage students. Therefore, schools are responsible for teaching skills and for engaging, motivating, and preparing the citizens of the new world. For students to get engaged, they need to be the owner of their learning, and it is the teachers' challenge to provide such a task in an adopted environment. Integrating STEM in a student-centred learning environment can provide such a framework (Margot and Kettler, 2019). These projects can increase "*levels of curiosity,* *creativity, and innovation among participating students, but will also ensure that the next generation will have a markedly greater understanding of the core concepts of science, technology, engineering, and mathematics*" (Daugherty and Carter, 2018, p.167).

Research indicates that STEM projects should take place at an early age, but there are few schools that do so. Researchers suggest that to feel confident about introducing STEM in early childhood education, teachers need training and education (Sáez-López, González-Calero, & Cózar-Gutiérrez. 2020; Daugherty et al. 2018; Honey et al. 2014). While science and mathematics have been part of school curricula for many years, technology and engineering are relatively new and have recently been incorporated into education. Teachers avoid STEM integration primarily because of their lack of knowledge about its principles (Sentance & Csizmadia, 2017). Teachers in elementary schools tend to be experts in "education" as a whole rather than STEM disciplines (Daugherty and Carter, 2018). In a very concrete sense, this study illustrates how technology can be used and design can be practiced by students in the classroom. In my experience as a primary-school teacher, teachers' skills improve in tandem with students' skills in student-centered activities. When not afraid of challenges, educators can develop both leadership and content knowledge into the classroom when integrating problem-based learning – a student-centered method where students are allowed to take charge of their development through solving (often) real-world problems.

The project described in this thesis combines all STEM subjects: designing one's own product (engineering), learning about human digestion (science), and using block-based programming (technology). Students in fifth grade at a school in Mölndal have been given the opportunity to create a game in Scratch, an online visual programming. The study involves seven students whose parents approved their participation in the research. As a researcher, I observed them, while their science development and design processes were evaluated by the teacher. An interview with the teacher is then conducted at the end of the project. The study aims to answer the following research questions:

1. How is students' engagement affected in the studied subject when implementing programming as a design-tool according to observations?

2. How is students' knowledge and skill development affected in the studied subject when implementing programming as a design-tool in comparison with the control group?

3. What are the difficulties and obstacles that may occur?

2 Theoretical Framework

This section sets out the theoretical concepts that have been chosen from the literature - in coherence with the research questions - as the basis for developing and carrying out this study. I visualise the proposed framework in figure 1. The STEM project planned to enroll the basics of inquiry-based learning by giving students the opportunity to learn through problem-based learning and design-based learning. According to the definitions of engagement in the scholarly literature (see section 2.2), this approach will hopefully fulfill the prerequisites of increasing engagement and/or reengaging students.

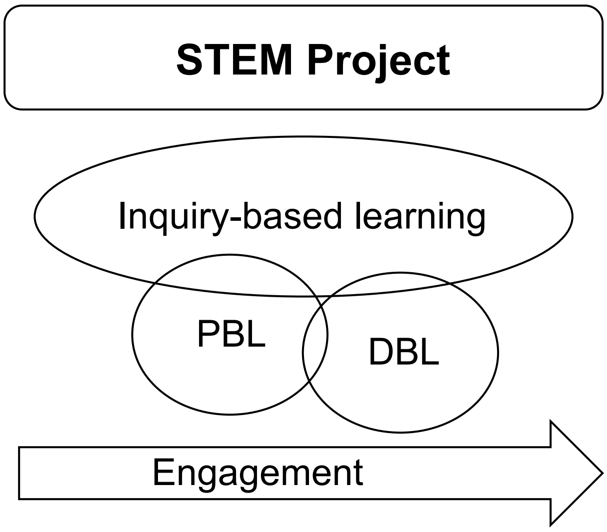

Figure1. Theoretical framework

2.1 Inquiry-based learning

Oxford, a dictionary of education, (2015), explains inquiry-based learning as:

"an approach to learning which encourages the student or pupil to engage actively and analytically with an investigation or inquiry... It is learner-centred in the sense that the student or pupil has the freedom to make decisions about the direction their inquiry will take, and to draw on their own existing knowledge or skills in order to extend them." (Wallace, 2015)

In general, inquiry-based learning is an activity, based on a problem that is supposed to be solved by students, through discussing, generating and testing solutions. Inquiry activities led by teachers have shown a positive effect on students' engagement, and have improved their capability of problem solving through better understanding of the relationships between different concepts, testing and refining ideas, and discussing solutions (Furtak, Seidel, Iverson, & Briggs, 2012). Providing well-designed problems that are challenging but solvable, as well as relevant and realistic, using technology, presents the opportunity to define relevant material that engages students and trains autonomous learners (Linn, Mcelhaney, Gerard, Matuk, 2018; Hmelo-Silver, Kapur, Hamstra, 2018)

A meta-analysis of 76 empirical studies in clinical and classroom experiments (McElhaney, Chang, Chiu, & Linn, 2014) concludes that inquiry-based learning provides students with the ability to predict, explain and reflect, and can even contribute to long-term memorizing in science subjects (McElhaney et al., 2014). According to Linn et al. (2018), this meta-analysis indicates that "inquiry-based scaffolds found to be most successful include interactive modeling features and prompts for promoting sense-making, self-monitoring, and reflection" (Linn et al., 2018, p.230). Inquiry learning activities have the potential to optimize science learning capacity through involving students the process of finding solutions systematically and logically, and to increase memorizing the knowledge that they have implemented (Margunayasa, Dantes, Marhaeni, & Suastra, 2019).

Problem-based learning/ Design based learning

Problem-based learning (PBL) - and similar methods such as project-based learning and design-based learning - have their roots in inquiry-based learning. They are learner-centered methods that allow students to take control over their learning process and make them responsible for their own development. (Sáez-López, Román-González, Vázquez-Cano, 2016; Savery, 2006). Sáez-López et. al. (2016) describes PBL as a dynamic experience that is based on student-centered designs and enables integrating collaborative educational technologies into the classroom (Sáez-López et al. 2016). Savery (2006) describes PBL as a framework in which students are provided with an "ill-structured" problem, which gives them the opportunity to freely define and analyze the problem and offer solutions. According to Savey (2006), collaborative learning, integrating different subjects and self-directed learning are essentials in PBL (Savey, 2006).

Design-based learning (DBL) follows the same principles as PBL. According to Doppelt (2009), the design process in general is much similar to the process of problem solving. While PBL is a more general method, DBL focuses on some special stages of the problem-solving process, such as planning, generating ideas, and reflecting (both self and peer reflection) on the solution (Doppelt, 2009). DBL is often aimed to integrate science and mathematics with engineering models, offering solutions to problems (Dym, Agogino, Eris, Frey & Leifer 2005). DBL process is similar to engineering design process and includes defining the problem, collecting facts/developing knowledge, generating ideas, discussing ideas, designing/constructing, evaluation/reflection (Dym et al. 2005; Doppelt, 2009; Mentzer 2011; Moore et al. 2014; English & King 2015). DBL is suggested as one of the opportunities to plan and progress STEM in education (Daugherty and Carter, 2018).

2.2 Engagement

Engagement is defined in different ways when it comes to education. One common concept is called "school-engagement" and is divided into different levels and dimensions. At this point, it is important to distinguish between school-engagement and academic achievement, even though the first might highly affect the latter. (Wang & degol, 2014). Fredricks, Bluemenfeld and Paris (2004) summarize the three dimensions of engagement as: "behavioral engagement encompasses doing the work and following the rules; emotional engagement includes interest, values, and emotions; and cognitive engagement incorporates motivation, effort, and strategy use." (Fredricks, Bluemenfeld, Paris, 2004, p.65). Happiness, sadness and interests are examples of emotional engagement, while following the rules, doing the activities and attending the classes are signs for behavioural engagement. Fredricks et al. (2004) further question the overlap between these categories, which make it complicated to distinguish these three types of engagement with clear criterias (Fredricks et al. 2014). The connection between these three dimensions is also defined differently. For example, some argue that emotional engagement is a precondition for other kinds, others argue that each type of engagement remains independent, and others describe the three dimensions as being interconnected in a circular form (Wang & Degol, 2014).

Willms (2003) in a result report from PISA2000 defines engagement criterias as "school and class attendance, being prepared for class, completing homework, attending lessons, and being involved in extracurricular sports or hobby clubs" (Willms, 2003, p.8). The engagement in his rapport is assessed by two main factors: "attitudes towards schooling and participation in school activities" (Willms, 2003, p.8). The first factor can be related to emotional engagement and the second is connected to behavioural engagement. Again, it is difficult to divide these two dimensions according to the existing definitions.

Although there are many different definitions of engagement, and different levels and dimensions to assess school-engagement, it is very important for a researcher to be clear with the factors that are to be studied (Wang & Dogel, 2014). This study will focus on behavioural engagement. Behavioural engagement is the outermost layer of engagement and maybe easiest to measure by observing students' attendance to the classes and doing their tasks. The emotional engagement might come to consideration by observing the factors such as increasing interests and enjoying the lessons and tasks.

3 Literature review

3.1 Searching strategy

Keywords in the main search for the relevant articles were:

- Block based programming
- 1st-6th grade
- STEM in education
- Simulation/coding/engineering
- Design-based learning

To obtain more articles containing these keywords, I searched in two different university libraries (University of Gothenburg och Linköping University). Google scholar was used to access some of the handbooks, reports, and some articles.

The articles selected for the review were mainly experiments/case studies published between 2010 and 2020. The focus of these articles (research questions) was evaluating and analysing different aspects of implementing STEM projects in elementary schools. Studies with participants older than 6th grade (middle school) and younger than 1st grade (pre-schools) were excluded. The selected articles were peer-reviewed scientific articles.

3.2 STEM in Education

Honey et al.'s (2014) provides a basic definition of STEM integration in education as: "working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines" (p.52). STEM in education is an approach to connect the disciplines of its four components by introducing and structuring real-world problems to the classroom. STEM integration offers connecting STEM subjects, often by utilizing the basics of inquiry learning and engineering design. This integration, especially when working on real-world problems, makes these subjects more relevant to young learners and contributes to an innovative environment in the classroom (Daugherty and Carter 2018). However, it is complicated and challenging for teachers to integrate all four aspects of one project. While science and mathematics have been taught in school for a long time, technology in education has a shorter history, and engineering is still mostly missing for the most part (de Vries, 2018).

3.3 Integrating STEM in education

Over the last few decades, teachers have combined science and technology and math, but adding engineering to STEM subjects takes a new approach, more work, and preparing teachers for the challenges (Swinson, Aaron, Jeremy, and Sutton, 2016; Mangiante and Moore, 2019). A focus on quality characterizes technology. Modeling and simulation are not measured and calculated in the way they should be in engineering design. Engineering has a quantitative characteristic and is more product-development focused (de Vries, 2018). By incorporating engineering into STEM lessons, students should be taught to design, model, analyze, evaluate, improve, and redesign (English, 2018; English et al., 2015; Swinson et al., 2016). It is also important that young students practice to apply their scientific and matemtic knowledge into their design (English, 2019).

The importance of STEM integration in schools has been internationally affirmed in the last decade (Daugherty et al., 2018; Wu-Rorrer, 2017; Moore, Glancy, Tank, Kersten, Smith, & Stohlmann, 2014; Honey et al. 2014; English and King, 2015). The aim of integrating STEM in education is to develop scientific-technological knowledge, prepare youth for an advanced technological society, and widen the perspective of society members to become smart technology users, whether they work within technology or not (Lachapelle et al., 2018; Honey et al., 2014; English and King, 2015). Research in the last decade indicates that in our complex technological world, integrating STEM in education is essential to make STEM subjects more related in students' perspectives and increase motivation and creativity (Daugherty et al. 2018). Many schools offer different kinds of STEM-based activities such as coding, programming, modeling, designing, and building constructions. The research shows that some of the important engineering aspects, such as the ability to design and redesign, annotating, reconstructing and implementing improvements are dependent strongly on concept knowledge and the ability to apply the knowledge (English et. al., 2017; Bowen, Deluca, and Franzen, 2016). Bowen et al. (2016) studied the relationship between students' knowledge and their performance in STEM-based activities. They concluded that "*students with a greater content knowledge initially have significantly better performance outcomes. However, if given enough opportunities to engage in the simulation activity, students with less content knowledge perform equally well*" (Bowen et al. 2016, p. 117).

STEM integration in elementary and early middle school and the role of teachers

Design and engineering are not easy subjects for young students to work on, but recent research agrees that even young students have the capability to find areas for improvement in the design stage, the construction stage, and the redesign stage (English, King and Smeed, 2017; English 2018; Swinson et al., 2016). Swinson et. al (2016) describes engineering practices this way: “it seems that there is always something that can be improved upon or redesigned in a new way that allows it to last longer or perform better” (Swinson et al., 2016, p. 8). Tran (2018) suggests that students at early ages should be trained to perceive the connection between different subjects in STEM learning (Tran, 2018, p. 292). Research also indicates that younger children have the potential to proceed with PBL activities and STEM education (English and King, 2015). English et al. (2017) come to the conclusion that skills such as system thinking, problem solving, visualising, reflecting, and improving, are the key to success with STEM projects and these should be trained in elementary and middle schools (English et al., 2017). STEM learning at early ages leads to better connection with STEM principles and higher chance to succeed in STEM fields in both education and future careers (Master, Cheryan, Meltzoff, 2017; Wu-Rorrer, 2017).

Regarding the role of teachers, Furtak et al. (2012) stress that teacher-led activities show a significantly better result in inquiry-based activities in science subjects, compared with the same activity led by learners. It is of course not an easy task for a teacher to design a problem that is just challenging enough to engage students at different levels, and create an environment in which students can share, discuss and evaluate different ideas. The role of the teacher in a PBL activity is to facilitate learning and scaffold a structure that enhances self-directed and autonomous learning (Linn et al., 2018; Daugherty and Carter, 2018). A STEM teacher needs to be confident to fully take advantage of teaching strategies and actively collaborate with learning groups in the classroom to stimulate and facilitate learning (Honey et al., 2014). The ability of teachers to understand STEM norms and principles and to integrate these norms into their teaching contributes to fostering a collaborative climate in the classroom, facilitates group discussions, and promotes idea generation (Mangiante and Moore, 2019). Previous research has proven that teacher quided inquiry-learning is an appropriate model for learning science in a student-centered atmosphere (Margunayasa et al., 2019).

3.4 Block-programming

Programming as a tool for design-based learning. Programming can be utilized as a tool that enables design and modeling and makes students the designer of their own learning. The process of designing and modeling with programming requires computational science and mathematics, i.e., being able to understand and implement flowcharts, algorithms, variables, and debugging, and the ability of understanding, generalising, experimenting the given problem (Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013). This process can be applied to different school subjects and can offer learners the opportunity to learn mathematics and programming concepts in a fun and motivating environment where students can lead their own learning process (Sáez-López et al., 2016).

Being a creator instead of a consumer of technology and learning computational thinking in early childhood, has recently gained the attention of researchers (Sáez-López et al. 2016). Sáez-López et al. (2016) indicates that students have a positive attitude and are highly motivated when they use blocked-programming to create, design, and learn other subjects and therefore "...there may be a great advantage in integrating these practices into pedagogical activities to enhance logic, math, Project Based Learning, problem solving, and critical thinking skills" (Sáez-López et al. 2016. s.131). Programming has officially been a part of the Swedish curriculum since 2017. In a later revision of curriculum (2019), it is defined clearly that programming should be used as one of the digital tools to define problems, suggest solutions, calculate, and present data (lgr 11, 2019, s. 54). Sáez-López et al. (2016) explains that programming as a digital tool in different subjects can integrate different skills such as logic and critical thinking, mathematics, and problem solving. He further suggests that programming should be used as the main tool in project-based learning in different school subjects, such as language, art, natural science, and social science (p. 130).

Programming as a base for project-based learning has the advantage of being adaptable to students at different levels of content knowledge, and of fulfilling the criteria for special adjustments when needed. King (2015) implemented programming as a project-based learning tool in a primary class, and he described how "students enjoyed being able to create fun Apps and games quickly, regardless of their skill level" (King, 2015, p.27). She described the positive environment, the joy that students felt while working on this project, how they enjoyed creating their own game at their individual pace, while they actively collaborated and helped each other to find solutions (King, 2015, p. 27).

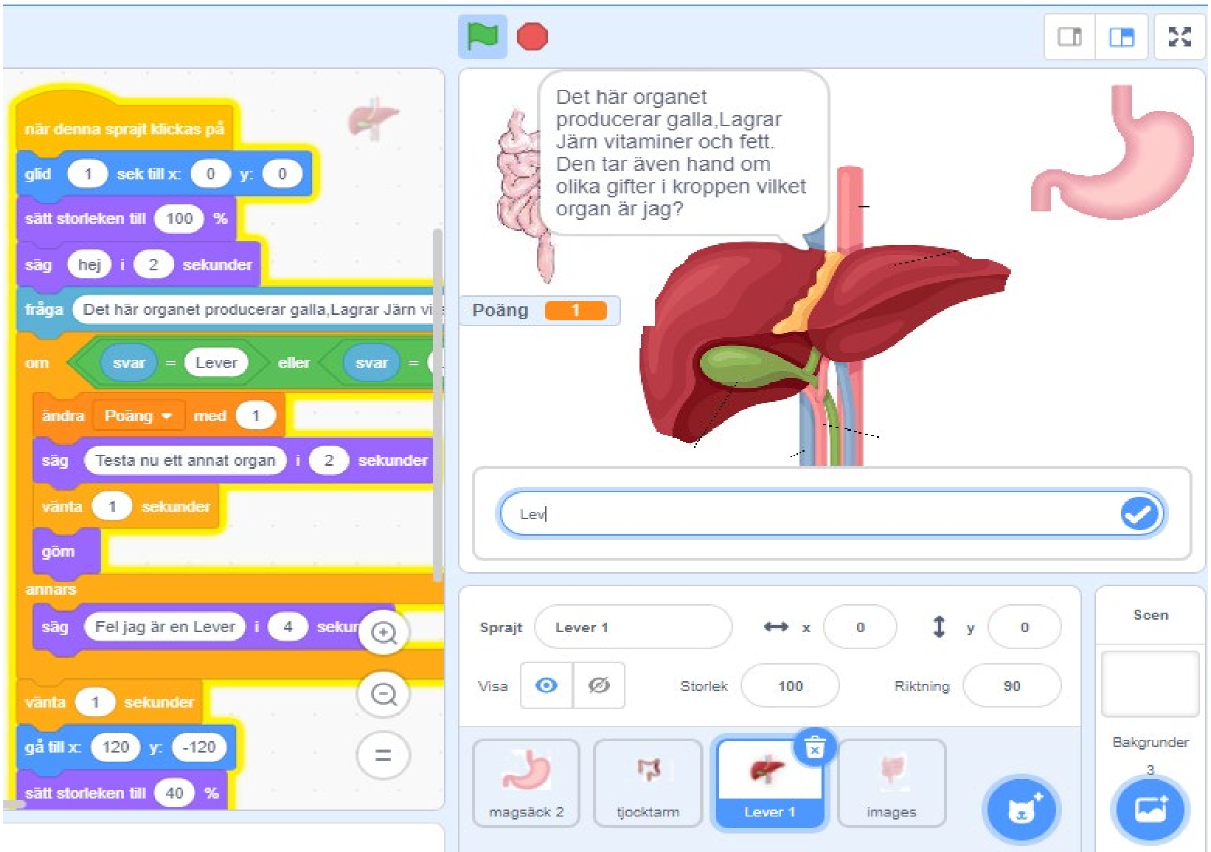

Figure 2. An example of a 5th grade student using programming to learn biology

Beside all the advantages, there are challenges in using programming as a digital tool to learn other subjects. The main challenge is that it is often very time consuming. Some other challenges that teachers have faced and reported are the teachers' lack of subject knowledge and programming knowledge, lack of training, and lack of sufficient support for teachers (Sentance, S. & Csizmadia, A. 2017. s.477).

3.5 Research gaps

Integrating STEM in education has gained more attention in the last decade but studying STEM education in younger grades has been very limited. According to previous research, studying methods and factors for implementing STEM in elementary schools needs more investigation (English and King, 2015; Tran, 2018). Recent research indicate that more studies is required on young learners learning the STEM basis, and how they learn during the iteration cycle of design, development and redesign. (English et al. 2017)

English et al (2017) suggest that future research needs to investigate on learning engineering process, and the development of system thinking in engineering-based problems for young learners (English and King, 2015; English et al., 2017). Other research also indicate that more research should be conducted on hands-on classroom projects to provide a wider range of schools and participants to increase the reliability of the existing and future research (Ziaeefard et al., 2017; Bonner & Dorneich, 2016). Since the area is rather new, it is also important to study the long-term influence of such projects in students' future behaviour and achievements (Nemiro, Larriva, Jawaharlal, 2017). How younger students develop their system thinking during implementing and developing different STEM disciplines need to be studied (English et al. 2017). There is also little research about how students' content knowledge and design knowledge can be applied and how much the learning process is influenced by these factors (Bowen et al. 2015). STEM in school curricula and how the curriculum development should be influenced by this integration is another aspect that remains ambiguous (English and King, 2015).

According to the literature review in this thesis, the future research in this area can be divided into three categories:

- Methods for effective integrating of STEM in younger ages
- Effects of STEM integration in younger ages
- Curriculum developments according to STEM principles

The goal of this study is to implement a design-based project in a classroom in middle school and observe and analyse how the students' learning process is influenced, i.e., short-term effects of STEM projects on middle-school students. The focus is on students' engagement and knowledge development during designing their own study, in a project that (with some limits) covers the STEM aspects. This study will be one of the very studies that attempts to complete the puzzle of STEM integration in middle school ages. The long-term effects and curriculum development is missing in this project due to time and resource limitations.

4 Methods and Implementation

4.1 Setting up an Experiment and Control group

This study with class 5C began in the spring semester of 2021, in the Fässberg middle-school in Mölndal, during weeks 15-17 (april-may). The school has three parallel classes in 5th grade. One class was chosen as an experiment group (5C), and one class was chosen as a control group (5A). The process of involving the students in “designing one's own game to learn the human digestive system” was part of the curriculum and was implemented in their biology class. For this reason, the whole class participated in the project. However, only the seven students whose parents gave consent for their participation participated in this study. Students and their parents in the class received a mail with information about the experiment and asked permission for individual observations. Seven parents responsed positive and gave the permission for observation. The students in the class were all informed about the study.

Control and experimental groups were set up. Both groups used the same materials. In the control group, the common methods of teaching-learning were used, such as reading facts from books, watching films, answering questions based on the films and texts, writing texts, and conducting group discussions. A teacher told me that they use the same methods in different subjects, and that the purpose is to engage as many students as possible. The experiment group used the same content material, but they were supposed to use it as needed to create their own game with Scratch. Students utilized the material that they thought was relevant in the experiment group. Both groups had three science lessons a week. There were 10 lessons in total (including the tests) for each class.

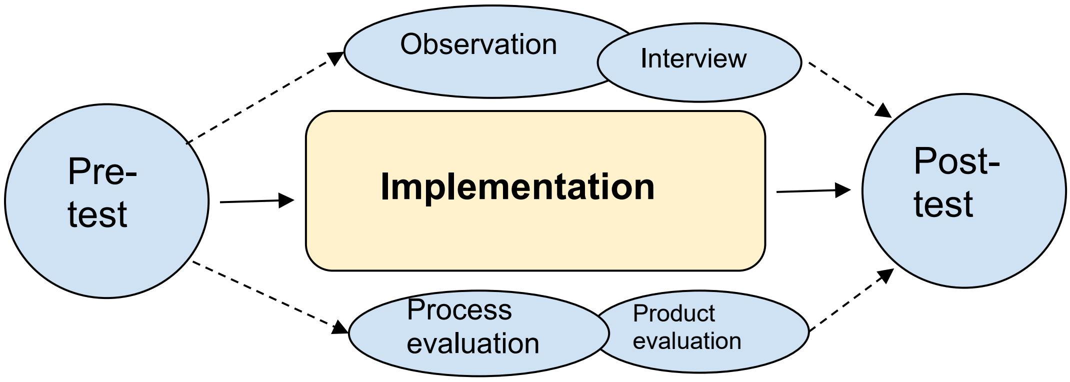

Figure 3: Methodology

Seven participants were observed, while only three of those were the focus of the observation. The class teacher was interviewed, the teacher sometimes addressed the whole class, or class climate. The teacher had taught the same class in both biology and programming, which means that she was aware of the backgrounds, difficulties and challenges that might occur. With school principals' permission, the (anonymous) result of the pretest/posttest from the whole class was analysed to evaluate the subject-knowledge development for the whole class.

4.2 Data collection

To choose the proper method for this study, an analysis of previous research methods is done. Previous empirical research on STEM integration has used methods including observations, interviews, pretest and post tests, science assessment tests, and surveys (Table B). For this study I chose a mixed-method approach, including interviews with the class teacher, pre-test post-test, and class observations.

Student Observation

Observation is a method for collecting data in a more natural way, as Silverman (2013) explains: "...naturally occurring data can serve as a wonderful basis for theorizing about things we could never imagine" (Silverman, p.52). The advantage of observation is that it might extend the limits that otherwise could affect the data gathered with a more structured form of data collection (like questionnaire and surveys). But observations have some limitations as well. In my work, I am going to observe students as participants. The class where I set up the experiment group is in the same school where I work. This was positive for me because during Corona-time and all the consequent limitations, I could still be in the classroom. However, since

I work at the same school and I taught the same class earlier, I might be emotionally involved in the students' progress and behavior. I can become a non-natural observer as a result. Furthermore, because I am a programming teacher, I tend to answer students' questions, or help them with some issues. To maintain a level of "objective" observation, I limited my observation to three lessons, during which I focused on three of the participants. The observational data come from these three lessons. During group work, I listened, observed, and took notes. I also created a simple observation grid (Table A). The observation includes not only direct comments, but also indirect expressions, participants' conversations, as well as their comments on their own and other products(games), their behaviour, and even parents' comments. I will now describe each of the three students in turn:

- **Student 1**: I will call him Johan. He is a student with a strong knowledge background. According to the teacher, he thinks that lessons are boring, and he never learns anything new. He wishes that he could in some lessons receive the degree of challenge that he deserves. According to the teacher, he does not like to work alone, and it is difficult for him to work on individual tasks at his level. He has a very high grade in natural science subjects. He has average knowledge of programming.
- **Student 2**: I will call her Aida. She is an average student in natural science. She does what she has to, but she is not especially interested in natural sciences. She has a medium grade in natural sciences. She has almost no knowledge of programming.
- **Student 3**: I will call her Nellie. She thinks that natural science is difficult and boring. She is not interested in programming and believes that it is too difficult to learn. Neither does she like maths. According to the teacher, she tries to do some of the tasks but often not well enough to pass.

For the observation, I did not record video/audio, and I took notes instead. As a primary teacher, I have learnt that young children are sensitive when it comes to recording, and it might affect their behavior and performance.

Interview with the teacher

A semi-structured interview was conducted with a class teacher at the end of the implementation process. The purpose of the interview was to get a teacher's perspective on students' engagement and knowledge and skill development, but also to have an understanding of what the teacher finds difficult or challenging and what are the hindrances. The teacher has been teaching the same class for the past two years. She knows her students' knowledge, skills, and engagement level. She has the same class in mathematics, techniques and natural science. She taught two intensive programming modules in the same class a few weeks before the experiment. While she has experience with programming and biology, she has no experience integrating these two subjects. The teacher has previously used inquiry-based learning and believes it is an appropriate method for this project.

Pre-test post-test

The pretest was conducted during the first lesson in both the control (5A) and the experiment group (5C). The post-test was run in both groups at the end of week three. With the permission of the school principal, considering confidentiality, the results of the pretest and posttest in both groups were used to evaluate the students' knowledge development in the biological concept.

Initially, when I had the idea that students could design their own game and learn human digestive systems, it was very doubtful if there would be any knowledge development in the desired area, or it would only gain students' interest and maybe improve computational/programming skills.

Students took two tests, one at the beginning of the period, and one at the end of the three weeks in which they worked on their Scratch projects. The test was implemented in both the experiment and the control group. The setup of a control group and the pre-test/post-test aimed to make sure that the students in the experiment group learned the biological concept and they did not miss the core concept knowledge that they were supposed to learn during those weeks. The test that used in this study, is the same examination that the teacher uses for assessing students’ knowledge in the area. According to the teacher, the test questions are mainly based on an examination from a teacher-guide book in biology and is the same time that teacher would have used as biology-test at the end of the session. In this manner, tha only chage was that we used the test two times, one in the beginning and one in the end of the process. The meaning of doing the tests in this study is not to assess students score according to any national or international scores, but to assess students’ knowledge development with the same methods that they would have done outside the experiment, and to compare their knowledge development with the controlgroup.

4.3 Ethical considerations

The Swedish Research Council's guidelines were applied in this study. Since the qualitative method here is based on observation (and individual interview), it is the researcher's responsibility to "prevent any damage, and for ensuring the identities of those observed will not be revealed" (Swedish Research Council, 2017 p. 27). It is important to consider dignity and privacy for those being researched, whether they are children or adults (Swedish Research Council, 2017).

This study was mainly based on observations and product evaluation. The study was part of schoolwork and therefore the school principal was informed. Parents and students were also informed about the study. They also were informed that the students' comments, presentations, and results were going to be used anonymously in this thesis. Out of a total of 22 students in the experimental group, 7 parents have approved that their children could take part in this study.

4.4 Limitations

Both the experimental group and the control group are very small. In the experiment group there are only 7 participants, and only 3 of them were closely observed due to time constraints. Researcher and observer are the same person who also works at the school where the study took place. The same teacher taught programming in her class. Relationships between the researcher and the participants might affect the implementation and observation of the study and raise questions about the validity of the results. For this reason, the researcher worked hard to get the support of other teachers involved in this class while analyzing the data gathered from observation

Involving a classroom experiment, this study is designed according to the class's background and opportunities. When implemented in other classes in other schools, it may need to be adjusted.

5 Data analysis

5.1 Qualitative data

Thematic analysis was implemented for both analysing the interview and the observational data. The qualitative data was analyzed using a manual iterative approach open-coding including primary-cycle coding and secondary-cycle coding (Tracy, 2013). In the first step I read and re-read the data. I started to recognize some concepts that were repeated more often. At the end of this stage, I used colors to mention different concepts and then cut them and categorized them. This process was done repeatedly in an iterative process and the data were assessed many times. A teacher in the classroom who was familiar with students helped with coding the data. The version that could best address the research question was chosen as the final version.

Table 1 shows some samples of codes, categories and themes from the thematic analysis implemented on the data:

5.2 Quantitative data

The quantitative data is the result of the pre-test post-test, in experiment and control group. The test is an assessment test which evaluates the concept-knowledge development in biology with questions about the human digestive system. The test was designed by the class teacher and was based on a standard test brought from a teacher-guide biology-book, containing questions about different organs, functions, nutritions, etc., including different types of questions such as multiple choices, short- and long-answers, The test was carried out as planned, one at the beginning of the session and one at the end. The result was then imported to the SPSS file for further analysis.

Theme	**Category**	**Code**	**Example from the data**
Manners	Behaviour	Focused Motivated Collaborative	“Students were so focused…” “I know how it works, I can help you…” “I worked on this the whole weekend”
	Attitude	Collaboration Making decision Fun Happy	“I like it that I can choose what I want to do…” “It is so fun, watch my game…” “It is ok, she can help me…” “Students were mostly happy during these lessons”
	Increase of inter-ests in the content	Fun Creative Choose Engagement	“I don’t like biology, but this is a fun way to learn” “I like it because I can decide how I want to do it”
Content knowledge	Skill and content knowledge development	Biology content knowledge	“I learned biology from my own game” “It is easier to remember the facts” “I am not sure how much focus was actually on the biology subject”
		Programming skill	“I can use if-sats here...”
Difficulties	For students	Support	“If the teacher is not here, the substituter can not help us”
	For teacher	Timing, planning, assessing	“It was unclear how to assess their product” “Difficult to find sufficient time for such projects”

Table 1: Sample of data analysis

6 Results

The first part of the result refers to the questions regarding engagement and indicates factors such as behaviour, interest, attitude, etc. The second part points out knowledge-development according to participants (both students and teachers). The result of the pretest and posttest in content-knowledge development in the field of human-digestive systems is also presented as quantitative evidence for knowledge development. Finally, some difficulties brought up by students and teachers are listed.

6.1 Behaviour and engagement

Analyzing and coding documents reveals that participants appreciated the project and were highly engaged during the lessons. Participants express that they felt free to plan their learning according to their own needs and that learning a new subject in this way was real fun. Johan, who has a good content knowledge in natural science, thinks that it is "at least funnier than the boring biology book" (Johan, 11 years). He believes that he could skip the boring part of the lessons that he otherwise struggles with all the time. Nellie, who otherwise does not like the science lessons, also thinks it was more effective to learn the biology without needing to read and write all the time:

"I don't like science because it is so much reading and writing, I don't even understand the texts, and become tired after a few minutes and can't memorize anything. When I made my own game, I could remember all the details. Because it was me who created them, I also played my game and my friends' game a hundred times." (Nellie, 11 years)

Figure 5. A screenshot from a student animation about nutritions, programmed with Scratch

The observation as well as the teacher interview indicate that the students liked the project. It was reported that participants had more fun creating their own games, and that it made biology concepts more interesting. The participants also said they were happy most of the time and did not get bored. Students who were observed used the terms "freedom", "make a decision", and "free to choose" repeatedly. Also, they were happy with the help they received from each other, as well as their ability to help others. The students and the teacher both mentioned that they were more focused during the lesson. Teacher adds that students were more open to challenges and more willing to solve problems. Aida explains for example:

"I like it because it feels like it is my choice how I make my game, I can make it easy or very difficult. I learn many things either way, and I learn to program and make games, it is the funniest way to learn something new" (Aida, 11 years)

Observation and interview data indicated that students were highly engaged throughout the process. The following keywords are repeatedly mentioned in both interviews and observations: fun, interesting, creative, freedom. Some indication for engagement was students working together during the weekend, sharing knowledge, and helping each other to develop their games, and staying during the breaks to keep working on their games.

"I can work on this all evenings at home and all weekends, it is MY game, it should become a funny game, maybe I can sell it later." (Aida, 11 years)

6.2 Knowledge and skill development

Both teacher and students agreed that the project enhanced their programming skills. Teacher was pleased that there was a clear framework for the game design at the same time that it was quite open. According to the teacher, who has been teaching programming with Scratch before, it is a challenge to teach programming basics with Scratch. She explains that most students focus on figures, backgrounds, sounds and other details that do not develop computational thinking and programming skills. And some try to create a very challenging game and give up already in the first steps without progressing. The advantage of this project was that the framework for the design was very clear and limited to the human digestive system. While it gives some freedom for learning biology, it is very limited when it comes to designing and programming in Scratch. As the teacher described it "*the students had not many choices when it comes to the stomach or liver. In order to make it look interesting, they need to work mostly on programming skills. It was impressive to see how young students implement conditional blocks, if-else statements and loops. It really improved programming skills and computational thinking.*" (Class teacher, personal communication, March 19, 2021)

While students were quite positive about the skill development and the learning process, the teacher was unsure about the degree of knowledge development in biology concepts. Students stated that it was free and fun, at the same time that they learned more: *"we see what we need to learn all the time, we should test the program many times, and each time we repeat the concept we need to learn"*. (Nellie, 11 years)

There were a few instances when the teacher expressed uncertainty about the biology content and whether enough time had been allocated to improve student comprehension:

"*Sometimes it feels like the focus is on the game/Scratch, and I am not sure how much they have learned the biological concept and how deep they have studied the subject. The most questions are about how they make the program work and not about what the organ's function is*". (Class teacher, personal communication, March 19, 2021)

She adds that she can not assess their knowledge development by their game: *"I am interested in seeing the result of the posttest to assess their biological knowledge development. I am a bit* *worried that this knowledge was not prioritized during the project, but I am sure that they were more interested and more focused while working"* (Class teacher, personal communication, March 19, 2021).

Knowledge development according to test results

While the programming skills were evaluated during the design process and according to the final product (Scratch game), the content knowledge development in biology was evaluated mainly by pretest-posttest. The importance of these tests was enabling a summative assessment and evaluating if students had learned the main concepts in biology. The test included four different categories, including the organs' name, organs' function, nutrients and their function in the human body. The test is the same test that the class teacher would have used to assess knowledge development out of the framework of this project. The pretest was implemented in both the experiment group (n=16) and control group (n=17) and the total score was 26. The mean for pretest was 4.47 in the control group and 4.38 in the experiment group. Which shows that groups had the same knowledge level by start. The posttest shows the mean of 11.41 in the control group and 16.44 in the experiment group.

The participants' results are shown in table 4.

Participants score development	Pretest	Posttest
Johan	9	25
Nellie	2	19
Aida	5	20

Table 2: The result of pretest and posttest from the three observed participants

Report

1: control 2:experiment		Pretest	Posttest
Control	Mean	4,47	11,41
	N	17	17
	Std. Deviation	3,105	5,409
	Minimum	1	1
	Maximum	11	20
Experiment	Mean	4,38	16,44
	N	16	16
	Std. Deviation	3,284	6,811
	Minimum	0	4
	Maximum	11	25
Total	Mean	4,42	13,85
	N	33	33
	Std. Deviation	3,143	6,548
	Minimum	0	1
	Maximum	11	25

Table 3: SPSS descriptive statistic report on pretest and posttest

6.3 Difficulties

The difficulties and limitations of the project came out mostly from the interview with the class teacher, but some were even mentioned in the students' comments. During the thematic analysis, I grouped difficulties into four categories: time, assessment, curriculum, and competences.

Competencies. Lack of teacher competence in programming with scratch was mainly named by students, as one participant mentioned "*Only our teacher (the class teacher) knows how it works, if she is not here, the substitute teacher cannot help us. She can not program and does not know how scratch works" (Aida).* Another participant expressed that "*only one teacher could the programming and we always had to wait until she is at place*" (Johan)

The teacher encountered difficulties in the field of leading a design-based learning. She was very unsure about the level of providing students with the right amount of information and instructions. *"It feels like I totally lose the control, and I don't know how much I should/could interrupt and glide in"* (Class teacher, personal communication, March 19, 2021). She found it very difficult to lead a student-centered classroom and find the balance between supporting, providing, and trusting. She was for example stressed that the experiment group who designed their game with Scratch, did not receive the same amount of information and facts, therefore there is a risk that they have missed some parts, and she has no tools to examine it.

Time. The teacher believed that time was not enough to finalize and follow the project. Both the teacher and the students wished to have more lessons to finalize their game. The students also wished to do similar projects in different subjects, but the teacher didn't see the possibility because of the time limitation.

"I could have thought of more such projects, but they take so long to plan, apply, and assess. I am afraid that we miss many other parts of the core content in the curriculum" (Class teacher, personal communication, March 19, 2021)

Curriculum. The teacher also found it difficult to spend as much time in different subjects: "*we have a curriculum to catch, and while these projects are not a part of curriculum, it will be difficult to implement many projects like this'* (teacher interview). She was impressed with the level of engagement and development but believed that it is difficult to fit such projects in the curriculum "if not teachers in other subjects collaborate and make it the part of the school schedule" (Class teacher, personal communication, March 19, 2021).

Assessment. The teacher found it difficult to assess students' content knowledge development when it comes to biology subjects: "*I see how much they have developed their programming skills, but it is difficult to assess their content knowledge in biology. I need more assessment tools rather than looking at their game design*" (Class teacher, personal communication, March 19, 2021teacher interview).

7 Discussion

The analysis of the result supports the idea that being the owner of one's own learning can improve skill development, knowledge development, and engagement. According to the result, not only students in the experimental group have been more engaged during the lessons, but also showed a higher result on the final test. The design and planning of the lessons was quite compatible with the definitions of inquiry-based learning, and students confirmed that they felt the freedom to make decisions and develop their knowledge and skills according to their needs and desire. Participants have mentioned a few times that the freedom they experienced in this module, made them feel happy and more willing to study and learn. The results confirm earlier studies' finding about how block programming and inquiry-based learning increase motivation and engagement, as well as developing content knowledge, computer skills and digital competences (Sáez-López, 2021). The main challenges that are reported are time, curriculum, and teacher competence for integrating STEM and assessing students' work.

7.1 Question 1: Students engagement

As mentioned earlier, it is not possible to strictly divide and underline one specific type of engagement without considering others. At the same time, it is difficult to measure emotional or cognitive engagement by using observations. Observations can trace students' behaviour and willingness to do the tasks which is the definition of behaviour engagement. The result of this study shows a high level of behavioural engagement in terms of involving and committing to the tasks, willingness to help peers, and expressing happiness and excitement.

Including and integrating subjects that are not otherwise officially included in students everyday practice increases engagement and excitement (Ziaeefard et al. 2017). To make science lessons more interesting and more relevant to the real world in the 21st century, we should be able to give the students the opportunity to choose and lead their learning process, i.e., we need to move from teacher-centered activities to student-centered activities (Holbrook, 2017). According to this study, there is a significant relationship between the students' freedom of choice and being at the center of the learning process, and their willingness to do the task, to learn and to develop. This supports earlier research which indicate that interactive lessons, relevance of material, and an appropriate challenge level are important factors for re-engagement of students

(Nicholson & Putwain, 2015). These re-engagement factors are covered in a design-based STEM project, in which students design their own game to learn the human body, and thus the engagement has highly increased. Students in previous studies have also expressed that being active during the lessons, working at their own pace, giving and receiving help from peers, using proper modern techniques, and in general a happy and free environment have contributed to their learning enthusiasm (Nicholson and Putwain, 2015; Schussler 2009). Changing in students' behaviors such as attending the lessons and doing the tasks can lead to more positive feedback which in its turn will increase the emotional engagement. Emotional engagement can help learners to be more confident and participate more actively in their learning process, which in its term contributes to cognitive engagement (Wang and Dogel, 2014). Still, and as mentioned before, this study has just monitored behavioural engagement.

The teacher in this study confirms that students were more engaged in the task than she expected. According to the teacher, engagement and happiness contributed to a very positive environment, which in its own turn, created more self-confidence and joy. Teacher confirms that students, despite the very clear framework for the task, felt freedom and believed that they could choose their way to learn. She agreed that such an open and positive environment required a high degree of openness and acceptance from her side. She also stresses that *"while they are progressing, I should learn to let them do it and agree to lose the control and leave the role of the traditional teacher behind"* (Class teacher, personal communication, March 19, 2021). Nemiro et al. (2017) recommends that teachers should create an unstructured open space that allows free movement and cooperation between students. Previous research also stressed that the process of planning, creating, evaluating and improving, and the ability to work at one's own rate in a collaborative environment, with a right level of scaffolding from the educator, increase the joy, happiness and energy level in the classroom. (King, A. 2015; Nemiro et al. 2017; Lesseig, Nelson, Slavit & Seidel, 2016)

7.2 Question 2: Knowledge and skill development

The test result in this study shows a statistically significant difference between the experience group who experienced DBL and the control group. The online test consists of 26 fact-based questions about the human digestive system, which covers two aspects in Swedish curriculum (Lgr 11, revision 2018*) when it comes to "body and health":

*Lgr11 revision 2018 is translated to english, this part is not changed in later versions (2019, 2021).

- “How mental and physical health are affected by sleep, diet, movement, social relationships and addictive substances. Some common diseases and how they can be prevented and treated” (Lgr 11, revision 2018, p.168)
- “Organ system of the human body. Names of organs, appearance, location, function and interaction.” (Lgr 11, revision 2018, p.169)

The control group received the same material to start with, but then chose their own way to process and deal with the facts. Students were supported by each other and received help from peers. The inquiry-based learning provides an environment for students to collaborate and process the learning according to their own desire and built on the knowledge they have at the level they find appropriate and adequate. Increased desire to learn can increase one's own content knowledge and even other skills, such as cooperation, problem solving, and generating ideas.

”inquiry-based materials can emphasize issues that students will find relevant at the individual, community, and/or global levels. Selecting relevant contexts can engage diverse students, and promote their agency and identities as inquiring citizens” (Linn et al. 2018)

There is also other research that means inquiry-based learning, in the form of design-based and problem-solving, provides a good basis for group work, and increases young learners’ confidence (English et al. 2017). The higher the confidence level, the more self-regulated the learning process becomes. This enhances learners' ability to build on their current knowledge according to their need. As we see in this study, Nellie, who otherwise is not interested in biology, shows a very good result in the post-test. She says that she can not explain how, but she could remember things, because she made them in her mind when she was designing her game. She also addresses a very friendly environment in which she doesn't feel like there is some competition, but contrariwise, “everybody helps everybody!”. She believes that less stress for being teased or laughed at, gave her the confidence to ask questions to her peers (Nellie’s comment when talking to the teacher). This is an example of how design-based learning can contribute to the whole class environment, and to the skill development.

There is a little research about how programming and robotic lessons can contribute to programming skill development and content knowledge development. This study is in the same line with earlier research and evidence that robotics, programming, and other proper techniques can enhance 21st century skills, and improve content knowledge in different areas (Lesseig et al., 2016; Wu-Rorrer, 2017; Nemiro et al., 2017; Sáez-López et al. 2020). The evaluation and study of the outcomes of inquiry-based learning and integration of STEM principles, the outcomes that go beyond simple content knowledge development is an important area of future research (Condiffe, Quint, Visher, Bangser, Drohojowska, and Nelson, 2017). There is also a need for frther research about how students apply their knowledge into their designs (English, 2019).

"When a project is student-driven, PBL has the potential to impact students' self-efficacy and for students to recognize their roles as active members, contributors to, and possible change agents in their community!" (Lesseig et al., 2016)

7.3 Question 3: Difficulties and hinderance

Observations, test results, and teacher comments all indicate a strong increase in student engagement and skill development, but the teacher mentioned some issues that she had to deal with. Teachers play a significant role in DBL and teacher-led inquiry-based activities have shown significantly better results (Furtak et al.,2012). This teacher is the one who has a comprehension of the inquiry-based learning principles and the knowledge and the confidence to utilize the tools and strategies which ease this leading (Honey et al. 2014; Mangiante and Moore, 2019). The teacher should feel comfortable with leaving the teacher-centered methods and be convinced about the effectiveness and advantages of a student-center designed-based problem-solving practice. Teachers should be able to plan, progress, and assess the work. Challenges that are brought up by the teacher in this study, can be used as a guideline for future STEM project planners and can suggest a trace for future research.

Competencies: The teacher in this study was uncertain about her role in a student-centered activity and how to balance guiding students, supporting them with facts, and letting them go on their own. Teachers' roles in DBL are more as a guidance who supports students with basic principles and leading them through their cycle of design, development, and redesign. An appropriate support can increase motivation and help students to apply the content knowledge into their designs, therefore there should be a balance between the information that students are provided with, and their freedom to choose their own way to learn and apply their knowledge (English and King, 2015). The interview with the teacher in this study demonstrates that finding this balance is a challenge. Teacher's role in guiding inquiry learning is also facilitating students conceptual and logical development, which makes the teaching a reall challenge (Margunayasa et al., 2019)

Students on the other side, mentioned that not all teachers were competent enough in programming with Scratch, and they did not always receive the support in the programming procedure that they were looking after. According to Sáez-López (2020) recent research evidence that applying Scratch into different subjects is very motivating for students and can develop competences such as digital skills, creativity, etx, but many teachers are yet not comfortable with using these opportunities in the classroom: "New approaches are needed to integrate technology into education and train digitally competent teachers" (Sáez-López, 2020, p.1).

Practicing such a framework in the long term, maybe already from elementary school and during the whole school years, can improve students and teachers' confidence, and can make students the leader and designer of their own development. Practicing STEM principles in early school ages increases the young students' interest in STEM (Daugherty and Carter, 2018). Future research should study how teachers' competens can influence the quality of inquiry-based learning and STEM integration into the classroom (Condiffe et al., 2017).

Time and curriculum: According to the teacher, despite all the advantages and benefits that she finds in applying STEM in her planning, she finds it time consuming and not always compatible with the current school curriculum. She acknowledges that integrating technology and new forms of learning are recommended in the curriculum, but still, it is very difficult to directly connect STEM projects to each individual subject. Other teachers in previous research have also mentioned that they are not able to fit the goals of the curriculum with STEM projects. They mean that even if STEM principles have their ground in curriculum, the level of the content knowledge that is assumed as sufficient in a STEM project does not always match the level of knowledge that the curriculum requires (Lesseig et al., 2016; Margot and Kettler, 2019).

Swedish curriculum (2018) recommends in different paragraphs that integrating technology, using modern and new learning methods, and developing computer and digital skills is a part of schools' task. Here are some examples from Lgr11, 2018:

"Pupils should be able to find their way around and act in a complex reality with a vast information flow, increased digitalisation and a rapid pace of change. It is therefore important to have the ability to study and methods to acquire and use new knowledge.” (Lgr11, revision 2018, p.7)

“The educational programme should thus provide pupils with conditions to develop digital competence and an attitude that promotes entrepreneurship” (Lgr11, revision 2018, p.8).

“Pupils should have the opportunity of experiencing knowledge in different ways… Creative ability is a part of what the pupils should acquire”(Lgr11, revision 2018, p.9).

However, it is still difficult to find an appropriate model to apply in STEM projects in an inquiry-based environment. Mentioning these aspects in the curriculum does not make it clear for teachers and students to identify and connect them into different subjects (Moore et al, 2014) and teachers find it difficult to shift from the existing curriculum to a STEM-curriculum (Margot and Kettler, 2019).

Studies on implementing all STEM approaches and connecting them into core content knowledge in the current curriculum is very limited (English, 2016; Gale, Alemdar, Lingle, & Newton, 2020). Most teachers who are interested in problem-based learning and STEM integration should find out and plan some projects on their own (Condiffe et al., 2017). Studying different tools and models, upgrading curricula according to STEM principles, and offering some research-based frameworks can facilitate implementing STEM in lower grades.

Assessment: This study shows that the teacher found it very difficult to assess students’ development according to the curriculum's core knowledge requirements. She used the final test to evaluate and grade students' knowledge development, but according to her it does not cover all aspects of the knowledge requirement according to curriculum. The knowledge requirement at the end of early middle school (grade 6) requires for example that:

“Pupils can search for information on the natural sciences and use different sources and apply well developed reasoning to the usefulness of the information and sources. Pupils can use the information in discussions and create texts and other communications with good adaptation to the context. “ (Lgr11, 2018, p.173)

Participants in this study have shown an incredible development in the first part, they have practiced searching for facts and apply them to their designs. But they have not used this knowledge to carry out discussions or create texts. Although the Swedish Curriculum does not mention that students need to make discussions and create texts in all areas, it remains ambiguous, it is up to each teacher to translate these requirements. Margot and Kettler (2019) stress that assessing students in STEM lessons has been one of the main teachers' concerns and recommend that further studies should be conducted on effective assessment strategies and tools for teachers (Margot and Kettler, 2019).

8 Conclusion

This empirical study has implemented programming with Scratch into a series of biology lessons in a 5th grade class in Sweden, Mölndal. Observation and test results show an increase in engagement and skill and content knowledge development in this group, but also brings up some issues to be considered. It is noted in both observations and the teacher interview that students' engagement and interests in the subject have increased. A positive learning environment is created around designings their games and students have expressed happiness and are more willing to collaborate with peers. The results gathered from pretest and posttest show that students who participated programming with Scratch showed significant knowledge development. Both students and the teacher mention that the time was very limited, and they wish to invest more time to complete their game and even to do more projects like this. The main issues that were considered as a hindrance have been competence, time, curriculum, and assessment.

STEM education offers the opportunity to introduce design-based problem-solving projects in the classroom. It includes different stages such as discussion, design, reflection, and redesign, these are some bases of the engineering process. During the whole process, students are given the opportunity to develop their knowledge by putting it out there, sharing with others and making new practices. STEM projects are supposed to create an environment for students to integrate the new knowledge with the existing ones and apply their knowledge to solve a real-life problem. This study evidenced the previous research on the positive effect of integrating block-programming into a STEM project, in a student-centered structure.

Future research needs to be conducted to connect STEM education into the current curricula and create a guideline for curricula developers. There is also a need for future studies on how to implement, scaffold, and assess a STEM project in early ages.

9 References

Bonner, D., & Dorneich, M. (2016). Developing Game-Based Learning Requirements to Increase Female Middle School Students Interest in Computer Science. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *60*(1), 380-384. https://doi-org.ezproxy.ub.gu.se/10.1177/1541931213601086

Bowen, B., Deluca, V., & Franzen, M. (2016). Measuring how the degree of content knowledge determines performance outcomes in an engineering design-based simulation environment for middle school students. *Computers and Education*, *92-93*, 117-124. https://doi.org/10.1016/j.compedu.2015.10.005

Condliffe, B., Quint, J., Visher, M.G., Bangser, M. R., Drohojowska, S. Saco, L., and Nelson, E. (2017). Project Based Learning: A Literature Review, 1-78. New York, NY: MDRC.

Dakers J.R. (2018) Philosophy of Technology and Engineering. In: de Vries M. (eds) *Handbook of Technology Education. Springer International Handbooks of Education.* Springer, Cham. https://doi-org.ezproxy.ub.gu.se/10.1007/978-3-319-44687-5_67

Daugherty M.K., Carter V. (2018) The Nature of Interdisciplinary STEM Education. In: de Vries M. (eds) *Handbook of Technology Education. Springer International Handbooks of Education*. Springer, Cham. https://doi-org.ezproxy.ub.gu.se/10.1007/978-3-319-44687-5_12

de Vries M.J. (2018) Technology Education: An International History. In: de Vries M. (eds) *Handbook of Technology Education. Springer International Handbooks of Education*. Springer, Cham. https://doi-org.ezproxy.ub.gu.se/10.1007/978-3-319-44687-5_8

Doppelt, Y. (2009). Assessing creative thinking in design-based learning. International *Journal of Technology and Design Education*, *19*(1), 55–65. https://doi-org.ezproxy.ub.gu.se/10.1007/s10798-006-9008-y

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103–120. https://doi-org.ezproxy.ub.gu.se/10.1002/j.2168-9830.2005.tb00832.x

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), 1-8. doi:http://dx.doi.org.ezproxy.ub.gu.se/10.1186/s40594-016-0036-1

English, L. (2019). Learning while designing in a fourth-grade integrated STEM problem. *International Journal of Technology and Design Education*, *29*(5), 1011-1032. https://doi-org.ezproxy.ub.gu.se/10.1007/s10798-018-9482-z

English, L., King, D., & Smeed, J. (2017). Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake resistant buildings. *The Journal of Educational Research (Washington, D.C.), 110(*3), 255-271. https://doi-org.ezproxy.ub.gu.se/10.1080/00220671.2016.1264053

English, L., & King, D. (2015). STEM learning through engineering design: Fourth-grade students' investigations in aerospace. *International Journal of STEM Education, 2*(1), 1-18. https://doi.org/10.1186/s40594-015-0027-7

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82(3), 300–329. doi:10.3102/0034654312457206*

Gale, J., Alemdar, M., Lingle, J., & Newton, S. (2020). Exploring critical components of an integrated STEM curriculum: An application of the innovation implementation framework. *International Journal of STEM Education, 7*(1), 1-17. https://doi.org/10.1186/s40594-020-0204-1

Hmelo-Silver, C., Kapur, M., Hamstra, M., (2018). Learning Through Problem Solving. in: Fischer, F., Goldman, S., & Reimann, P., International Handbook of the Learning Sciences (1st ed., pp. 210-220). Routledge. https://doi-org.ezproxy.ub.gu.se/10.4324/9781315617572

Holbrook, Jack. (n.d.), (2017) 21st Century Skills and Science Learning Environments. In *Science Education* (New Directions in Mathematics and Science Education, pp. 385-401). Rotterdam: Sense.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academy Press. https://doi.org/10.17226/18612

Keith, K. (2018). *Case study: Exploring the implementation of an integrated STEM curriculum program in elementary first grade classes* (Order No. 10933622). Available from ProQuest Dissertations & Theses Global. (2189878988).

Kurz, M., Yoder, S., & Zu, L. (2015). Effects of exposure on attitudes towards stem interests. *Education*, 136(2), 229-241.

Lachapelle C.P., Cunningham C.M., Davis M.E. (2018) Middle Childhood Education: Engineering Concepts, Practices, and Trajectories. In: de Vries M. (eds) *Handbook of Technology Education*. Springer International Handbooks of Education. Springer, Cham. https://doi-org.ezproxy.ub.gu.se/10.1007/978-3-319-44687-5_23

Lesseig, K., Nelson, T., Slavit, D., & Seidel, R. (2016). Supporting Middle School Teachers' Implementation of STEM Design Challenges. *School Science and Mathematics*, 116(4), 177-188. https://doi-org.ezproxy.ub.gu.se/10.1111/ssm.12172

Lgr 11 (2019). *Läroplan för grundskolan, förskoleklassen och fritidshemmet: reviderad 2019*. Stockholm:Skolverket.https://www.skolverket.se/publikationsserier/styrdokument/2019/laroplan-for-grundskolan-forskoleklassen-och-fritidshemmet-reviderad-2019

Lgr 11 (2018) Curriculum for the compulsory school, preschool class and school-age educare (revised 2018)Stockholm: Skolverket. https://www.skolverket.se/publikationer?id=3984

Linn, M., Mcelhaney, K., Gerard, L., Matuk, C., (2018). Inquiry Learning and Opportunities for Technology. In Fischer, F., Hmelo-Silver, Goldman S., Reimann, P. (2018) *International Handbook of the Learning Sciences* (1st ed., pp. 221-233). Routledge.

Mangiante, E., & Moore, A. (2019). Pre-Service Teachers' Perceptions of Norms of Interaction for Fourth-Grade Students' Engineering Design Problem-Solving. *Journal of Classroom Interaction*, 54(2), 57-73.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education, 6*(1), 1-16. doi:http://dx.doi.org.ezproxy.ub.gu.se/10.1186/s40594-018-0151-2

Margunayasa, I., Dantes, N., Marhaeni, A., & Suastra, I. (2019). The Effect of Guided Inquiry Learning and Cognitive Style on Science Learning Achievement. *International Journal of Instruction*, *12*(1), 737-750. https://doi.org/10.29333/iji.2019.12147a

Master, A., Cheryan, S., & Meltzoff, A. (2017). Social Group Membership Increases STEM Engagement Among Preschoolers. *Developmental Psychology*, 53(2), 201-209. http://dx.doi.org/10.1037/dev0000195.supp

Mcelhaney, K., Chang, H., Chiu, J., & Linn, M. (2015). Evidence for effective uses of dynamic visualisations in science curriculum materials. Studies in Science Education, 51(1), 49-85. https://doi-org.ezproxy.ub.gu.se/10.1080/03057267.2014.984506

Mentzer, N. (2011). High School Engineering and Technology Education Integration through Design Challenges. *Journal of STEM Teacher Education, 48*(2), 103-136. DOI: doi.org/10.30707/JSTE48.2Mentzer

Moore, Tamara, Aran Glancy, Kristina Tank, Jennifer Kersten, Karl Smith, and Micah Stohlmann. "A Framework for Quality K-12 Engineering Education: Research and Development." *Journal of Pre-College Engineering Education Research 4*.1 (2014): 1-13. Web. https://doi.org/10.7771/2157-9288.1069

Nemiro, J., Larriva, C., & Jawaharlal, M. (2017). Developing Creative Behavior in Elementary School Students with Robotics. *Journal of Creative Behavior, 51*(1), 70-90. https://doi-org.ezproxy.ub.gu.se/10.1002/jocb.87

Nicholson, Laura & Putwain, Dave. (2015). Facilitating re-engagement in learning: A disengaged student perspective. *The Psychology of Education Review. 39*. 37-41.

Sáez-López, José-Manuel, Marcos Román-González, and Esteban Vázquez-Cano. "Visual Programming Languages Integrated across the Curriculum in Elementary School: A Two Year Case Study Using "Scratch" in Five Schools." *Computers and Education* 97 (2016): 129-41. Web. https://doi.org/10.1016/j.compedu.2016.03.003

Sáez-López, González-Calero, & Cózar-Gutiérrez. (2020). Exploring the Effect of Training in Visual Block Programming for Preservice Teachers. *Multimodal Technologies and Interaction*, 4(3), 65. https://doi.org/10.3390/mti4030065

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning, 1*(1). https://doi.org/10.7771/1541-5015.1002

Sengupta, P., Kinnebrew, J., Basu, S., Biswas, S., & Clark, G. (2013). Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework. *Education and Information Technologies, 18*(2), 351-380. https://doi-org.ezproxy.ub.gu.se/10.1007/s10639-012-9240-x

Sentance, Sue, & Csizmadia, Andrew. (2017). Computing in the curriculum: Challenges and strategies from a teacher's perspective. *Education and Information Technologies, 22(2)*, 469-495. https://doi-org.ezproxy.ub.gu.se/10.1007/s10639-016-9482-0

Schussler, D. (2009). Beyond Content: How Teachers Manage Classrooms to Facilitate Intellectual Engagement for Disengaged Students. *Theory Into Practice, 48*(2), 114–121 https://doi-org.ezproxy.ub.gu.se/10.1080/00405840902776376

Silverman D. (2013). *A Very Short, Fairly Interesting and Reasonably Cheap Book about Qualitative Research.* 2nd edition. London: Sage.

Tran, Y. (2018). Computer Programming Effects in Elementary: Perceptions and Career Aspirations in STEM. *Technology, Knowledge and Learning, 23*(2), 273-299. https://doi-org.ezproxy.ub.gu.se/10.1007/s10758-018-9358-z

Vetenskapsrådet [Swedish Research Council] (2017). Good research practice. Retrieved from https://www.vr.se/english/analysis/reports/our-reports/2017-08-31-good-research-practice.html

Susan Wallace. (2015). Enquiry-based learning. *A Dictionary of Education,* A Dictionary of Education, 2015-01-01. DOI:10.1093/acref/9780199679393.001.0001

Wang, Ming-Te, & Degol, Jessica. (2014). Staying Engaged: Knowledge and Research Needs in Student Engagement. *Child Development Perspectives, 8(3)*, 137-143. https://doi-org.ezproxy.ub.gu.se/10.1111/cdep.12073

Willms, J., & Organisation for Economic Co-operation Development. Programme for International Student Assessment. (2003). *Student engagement at school a sense of belonging and participation : Results from PISA 2000*. Paris: Organisation for Economic Co-operation and Development (OECD). https://www.oecd.org/education/school/programmeforinternationalstudentassessmentpisa/33689437.pdf

Wu-Rorrer, R. (2017). Filling the gap: Integrating STEM into career and technical education middle school programs. *Technology and Engineering Teacher,* 77(2), 8-15.
Ziaeefard, S., Page, B., Knop, L., Ribeiro, G., Miller, M., Rastgaar, M., & Mahmoudian, N. (2017). GUPPIE program - A hands-on STEM learning experience for middle school students. *2017 IEEE Frontiers in Education Conference* (FIE), 2017, 1-8. http://doi.org/10.1109/FIE.2017.8190546

10 Appendices

Appendix 1. Observation grid

Nr			
	Inquiry-based context	**Block-programming context**	**Biology context**
Conversations			
Comments			
Behaviour			
Parents comment			
Others			

Appendix 2. Interview protocol

Notes: the interview questions are inspired by previous studies where teachers were in focus. The questions are adapted for the current study.

Q1. What is your science/technology background? And when you graduated from university?

Q2. What is your background as a teacher? And what science units do you normally teach?

Q3. Did you have experiences in STEM education, block-programming, and student-centered activities before this project?

Q4. What was the students first reaction when they got the instruction?

Q5. How were students engaged during the lessons? Do you think that STEM education and design-based learning has sufficient supplements to engage students?

Q6. How did the students progress? Skill development, knowledge development, design, production, engagement?

Q7. What are the weaknesses of this project, or similar projects? What is missing?

Q8. How do you evaluate students' skill/knowledge development in the subject? What needs to be changed/improved?

Q9. How do you evaluate students' skill/knowledge development in the STEM disciplines. What needs to be changed/improved?

Q10. Additional comments?

Appendix 3. pre-test and post-test questions

The test that is taken at the beginning and the end of the project is an online test designed in google forms. The test is designed as below:

The names of different organs	4 points
The function of different organs in the human digestive system	8 points
The function of different nutritions in the human body	8 points
The nutrition of different foods	6 points

Appendix 4. Article review table

Table A: summary of articles in review: participants, field of subject, method

Author(s)	STEM project	Participants	Subjects/methods	Research method
English 2019	Shoe design	3rd-6th grade student	STEM, material properties, d sign, measurement DBL	Analysis of workbook and sketches (open coding) Analysis of film, iterative refinement cycles
English et ak 2017	Earthquake	6th grade students	Science, fysik, teknik, design Problem-based learning	Systematic practice of collecting data: Audio and video recording, Workbook analyse, students work and activity book Iterative refinement cycles Basic quantitative method: frequency distribution
English et al. 2015	Aerospace	4th grade students	Science, design, teknik, Engineering design-based lea ing	Video, audio, workbook, documenting discussions, Grounded theory approach Constant comparative strategies Analysis: Coding and recoding, Iterative refinement cycles
Tran 2018	Coding	Elementary schools students	Computational thinking Hands-on Online coding	Pre- and post-test Interviews Oservations

				Triangulation data analyse Cronbach's alpha (for surveys)
Mangiante et 2015	Lightning/ electricity	Elementary school Teachers	Fysik, Computer science, de- sign, teknik Engineering design based lea ing	Written responses Post-unit interviews Triangulate report
Keith 2018	Light and sound	1st grade students	Fysik, engineering, PLTW	Interviews, Surveys, Students science assessment
Kurz et.al.	---	Elementary school students	STEM interest	Survey
Sáez-López, al. 2020	Visual programming	Teachers	Teacher confidence and inter in teaching programming	Pre-test post-test
Margunayas 2019	Science	5th grade	Inquiry based learning STEM	Science learning achievement test Pre-test post-test
Nemiro et al 2017	Creative robotic	4th-6th grade	Problem-based learning Programming Open-ended task	Observation
Lesseig et al 2016	Crystal grow Lego robotic	Middle school studer & teachers	STEM design challenge Problem based learning	Observation Survey Interview

Nicholas- Figueroa et a 2017	Climate change	Middle school & hig school students	Biologi, lab/ society, Open discussions	Student assignment Pre-test post-test
Sullivan et a 2018	Programming	Early elementary students	STEM, robotics, programmi	Knowledge assessment, quantitative
Schmit et al. 2019	GoAnimate science a math	Elementary students 3rd grade	Collaborative inquiry learnin Achievement thinking Science and mathematic	Qualitative interviews Observation notes
Bonnoer et a 2016	Programming	Middle school studer	STEM Game-based learning	Pre-test post-test survey
Master et al. 2017	Pet-robot laboration	First grade students	Visual programming Prototyping	Immediate test after lab
Ziaeefard et 2017	Under-water robot GUPPIE	Middle school studer	problem-solving	Quantitative and qualitative surveys Interviews Observations
Kong et al. 2019	Visual programming	5th grade students	Programming concept Computational thinking	Pre-test post-test knowledge assessment
King 2015	Geometri	Middle school	Spatial reasoning (visualisin Graphing skills	Observation

Sáez-López et al. 2016	Visual programming	5th-6th grade students	Project-based learning Computational thinking	Design-based research Quazi experimental design Pre-test post-test Survey

English, L. (2019). Learning while designing in a fourth-grade integrated STEM problem. *International Journal of Technology and Design Education*, 29(5), 1011-1032.

English, L., King, D., & Smeed, J. (2017). Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake resistant buildings. *The Journal of Educational Research* (Washington, D.C.), 110(3), 255-271.

English, Lyn, and D. King. "STEM Learning through Engineering Design: Fourth-grade Students' Investigations in Aerospace." International *Journal of STEM Education* 2.1 (2015): 1-18. Web.

Tran, Y. (2018). Computer Programming Effects in Elementary: Perceptions and Career Aspirations in STEM. *Technology, Knowledge and Learning*, 23(2), 273-299.

Mangiante, E., & Moore, A. (2019). Pre-Service Teachers' Perceptions of Norms of Interaction for Fourth-Grade Students' Engineering Design Problem-Solving. *Journal of Classroom Interaction*, 54(2), 57-73.

Keith, K., Evans, Sally, Foster, Lisa, & Thomas-Dixon, LaToya. (2018). Case Study: Exploring the Implementation of an Integrated STEM Curriculum Program in Elementary First Grade Classes, *ProQuest Dissertations and Theses*.

Kurz, M., Yoder, S., & Zu, L. (2015). Effects of exposure on attitudes towards stem interests. *Education*, 136(2), 229-241.

Sáez-López, González-Calero, & Cózar-Gutiérrez. (2020). Exploring the Effect of Training in Visual Block Programming for Preservice Teachers. *Multimodal Technologies and Interaction*, 4(3), 65.

Margunayasa, I., Dantes, N., Marhaeni, A., & Suastra, I. (2019). The Effect of Guided Inquiry Learning and Cognitive Style on Science Learning Achievement. *International Journal of Instruction*, 12(1), 737-750.

Nemiro, J., Larriva, C., & Jawaharlal, M. (2017). Developing Creative Behavior in Elementary School Students with Robotics. *Journal of Creative Behavior, 51*(1), 70-90.

Lesseig, K., Nelson, T., Slavit, D., & Seidel, R. (2016). Supporting Middle School Teachers' Implementation of STEM Design Challenges. *School Science and Mathematics*, 116(4), 177-188.

Nicholas-Figueroa, L., Hare, R., Van Muelken, M., Duffy, L., & Middlecamp, C. (2017). Iḷisaġvik Tribal College's summer climate program: Teaching STEM concepts to North Slope Alaska high school and middle-school students. *Journal of Environmental Studies and Sciences*, 7(3), 425-434.

Sullivan A., Umashi Bers M., (2018). The Impact of Teacher Gender on Girls' Performance on Programming Tasks in Early Elementary School. (2018). *Journal of Information Technology Education: Innovations in Practice,* 17, 153-162.

Schmit, E., Smith, R., Ratanavivan, W., Ermis-Demirtas, H., Rosenbaum, L., Monteiro, M., & Dyurich, A. (2019). A STEM Achievement Motivation Program: Perspectives of Elementary School Students. Professional School Counseling, 23(1), 2156759X1989458.

Bonner, D., & Dorneich, M. (2016). Developing Game-Based Learning Requirements to Increase Female Middle School Students Interest in Computer Science. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 60(1), 380-384.

Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A. (2017). Programming experience promotes higher STEM motivation among first-grade girls. *Journal of Experimental Child Psychology*, 160, 92-106.

Ziaeefard, S., Page, B., Knop, L., Ribeiro, G., Miller, M., Rastgaar, M., & Mahmoudian, N. (2017). GUPPIE program - A hands-on STEM learning experience for middle school students. *2017 IEEE Frontiers in Education Conference* (FIE), 2017, 1-8.

Kong, S., & Wang, Y. (2019). Assessing Programming Concepts in the Visual Block-Based Programming Course for Primary School Students. European Conference on E-Learning, 2019, 294-XVIII.

King, A. (2015). Reflecting on Classroom Practice: Spatial Reasoning and Simple Coding. Australian Mathematics Teacher, 71(4), 21-27.

Sáez-López, José-Manuel, Marcos Román-González, and Esteban Vázquez-Cano. "Visual Programming Languages Integrated across the Curriculum in Elementary School: A Two Year Case Study Using “Scratch” in Five Schools." *Computers and Education* 97 (2016): 129-41. Web.

Ihrig, L., Lane, E., Mahatmya, D., Assouline, S., & Chamberlin, S. (2018). STEM Excellence and Leadership Program: Increasing the Level of STEM Challenge and Engagement for High-Achieving Students in Economically Disadvantaged Rural Communities. *Journal for the Education of the Gifted*, 41(1), 24-42.

https://education.stateuniversity.com/pages/1835/Classroom-Observation.html