Development of a tangible medium to foster STEAM education using storytelling and electronics

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Master's dissertation submitted in order to obtain the academic degree of Master of Science in de industriële wetenschappen: industrieel ontwerpen

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Faculty of Engineering and Architecture
Academic year 2015-2016
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20 August 2016
ACKNOWLEDGEMENTS

First and foremost, I offer my greatest gratitude to Maria-Cristina Ciocci. Her undying support and encouragement throughout this process, made me continuously improve my work. I would also like to thank my supervisors, Jelle Saldien and Xi Li for their comments and insights in the development of this Master’s thesis. Special appreciation to Benny Malengier and Thomas Van Riel for using their great programming skills to help me. I could have never done what they did for me. I also gratefully acknowledge the support of Microduino in providing me electronic modules to organise user tests. A special thanks for the enthusiasm and honest feedback of all children that took part in the development of this project. I hope they will never lose their wonderful imagination and creativity. My deepest thanks go to my best friend Pieter, who has been there for me during my entire engineering education. I’m grateful for his incredible ability to cheer me up every time I thought I was not going to make it. Finally, genuine thanks to my parents, who unconditionally support me in everything I do.

As a little girl I thought I would become an illustrator, graphic designer or architect, until my mom suggested me to study an engineering degree. Even though I was wearing pastel skirts and flower dresses, she always believed I had the power to accomplish anything my male classmates could do as well. I’m still grateful for her open-mindedness.
ABSTRACT (EN)

Children of the 21st century grow up in a world full of information and technology. These recent developments will have a great impact on their way of living, working and communicating in the future. Education should equip them with useful skills and competencies, allowing them to actively and effectively take part in a globalised society. Policymakers and educators are challenged to change a curriculum that remained the same for decennia, to the needs of the 21st century. Primary school teachers feel the need for educational tools that support innovative teaching.

The Diorama Project is a series of transdisciplinary workshops that combine familiar subjects, like language and art, with new topics such as programming and electronics, to foster valuable skills and knowledge in a more fun and tangible way. In the project, pupils team up to write, record and tinker a story. Programmable electronics let their theatre plays come alive. The project is supported by a kit that allows pupils to build a mini-theatre, and child-friendly electronic modules that can provide the theatre of movement, light and sound. An open source platform offers all the information for teachers to organise the workshops by themselves. They can use it to share their experience and knowledge with colleagues worldwide.

This thesis describes the design process of The Diorama Project. First, the current situation was examined, using literature research. Then, the concept of the mini-theatre was devised and tested. The project and its mini-theatre kit went through several user tests in which many children tested multiple projects plans and prototypes. The resulting project is explained in the final chapter.
ABSTRACT (NL)

Kinderen van de 21e eeuw groeien op in een wereld vol informatie en technologie. Deze recente ontwikkelingen zullen een grote invloed hebben op hun manier van wonen, werken en communiceren in de toekomst. Onderwijs moet hen voorzien van nuttige vaardigheden en competenties, zodat ze actief en effectief kunnen deelnemen aan de geglobaliseerde samenleving. Beleidmakers en onderwijzers staan voor de uitdaging om een curriculum dat al decennialang hetzelfde is, aan te passen aan de noden van de 21st eeuw. Leerkrachten voelen de behoefte aan didactische middelen die innovatieve onderwijsmethoden ondersteunen.

Het Diorama Project is een reeks transdisciplinaire workshops die vertrouwde schoolvakken, zoals taal en kunst, met nieuwe onderwerpen, zoals programmeren en elektronica, combineert om kinderen waardevolle vaardigheden en kennis bij te brengen op een leuke en tastbare manier. In het project werken leerlingen samen om een verhaal te schrijven, het op te nemen en te knutselen. Programmeerbare elektronica brengt hun theaterstukken tot leven. Het project wordt ondersteund door een bouwpakket waarmee leerlingen een minitheater kunnen bouwen en kindvriendelijke elektronica modules die het theater van beweging, licht en geluid kunnen voorzien. Een open source platform bevat alle informatie voor leerkrachten om de workshops zelf te organiseren. Ze kunnen het ook gebruiken om hun ervaringen en kennis te delen met collega's van over de hele wereld.

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Abstract Children of the 21st century grow up in a world full of information and technology. Education should equip them with useful skills and competencies, allowing them to actively and effectively take part in a globalised society. Teachers feel the need for educational tools that support innovative teaching. This paper describes the research and user tests conducted during the development of The Diorama Project. This series of trans-disciplinary workshops combines familiar subjects, like language and art, with new topics such as programming and electronics, to foster valuable skills and knowledge in a more fun and tangible way. Pupils team up to write, record and tinker a story. Programmable electronics let their theatre plays come alive. An open source platform provides all the information for teachers to organise the workshops by themselves. They can use it to share their experience and knowledge with colleagues worldwide.

Keywords STEAM Education, 21st Century Skills, educational tool, DIY electronics, storytelling

I. INTRODUCTION

As a result of the rapid development of information and communication technologies (ICT), our society undergoes major economic and social changes that have an enormous impact on the way people work, live and learn. Media are omnipresent and people make constantly use of it [1], [2].

Since our workspace and lifestyle have changed drastically, education systems should have been revised as well. However, the World Economic Forum (WEF) published a study [3] of nearly hundred countries revealing that all too often pupils are not attaining the essential skills they need to prosper in this century. Providing teachers with ready-to-use educational tools, is necessary to tackle this problem [2], [4].

II. RESEARCH

A. 21st Century Skills

While the industrial society of the last century aimed at mass consumption focusing on motorization [5], the modern society is by many seen as a ‘knowledge society’ [6]–[8] which refers to economic systems where ideas or knowledge function as commodities, according to Anderson [6]. Beside dynamic changes in the types of jobs demanded by the knowledge society [9], our society also experiences the challenges to educate young people for jobs that don’t exist yet [1], [7]. These new jobs have similar key tasks that require a different set of skills and competencies, often referred to as 21st century skills.

Many studies have been done to define what we should consider to be the ‘21st century skills’ [1], [6], [7]. In 2015, the WEF undertook a detailed analysis of research literature to define what they consider to be valuable competencies for this century. Although 21st century skills are categorized and grouped in numerous ways and various terminologies are used, they found in line with the conclusions from previous studies the sixteen most critical 21st-century skills as shown in Figure 1 [3].

B. 21st Century Education

21st century skills can be added as new subjects or new content within traditional subjects. However, most of them are not directly linked to a specific field but relevant across many fields. [11]. Integrating them as cross-curricular competences in projects and creative activities is a better approach.

1) Project-based learning

Project-based learning, is an educational approach where learning is organized around projects. It promotes links among subjects and is built around transversal themes, adaptable to different types of learners, learning situations and contemporary societal issues. In this way, pupils are encouraged to learn actively. Since creating, doing and learning are inextricably related, giving pupils the freedom to generate artefacts is a critical component of project-based learning. Their knowledge is generated through the process of constructing things [10].

Challenging problems require not only design, problem-solving and decision making, but also active engagement over a long period of time. There are several factors affecting whether or not pupils enthusiastically take part in a project. Besides being challenged, young people are more motivated when projects have value to them. Varied tasks and novel elements, as well as freedom in working method, encourage them to participate actively. They also particularly enjoy
working in teams [11]. Communicating, discussing ideas and working towards a common goal is crucial during projects.

2) **Playful and creative learning**

Another way to engage pupils, especially children, is the inclusion of play in the learning process. By combining what children learn and what they do for fun, exciting learning experiences can occur [12]. They develop creative thinking techniques that are important to many fields, but particularly useful for learning science and engineering [13]. Ferrari, Cachia and Puni [14] have identified that creativity and innovation have strong links with knowledge and learning. Creativity is seen as an essential skill that leads to knowledge creation and the construction of personal meaning

Tangible mediums as learning tools also benefit the learning process. Resnick’s [15] research group found that especially familiar objects used in unfamiliar ways can spark children’s interest in learning new subject matter. They let children use food as musical instruments, for example, to explore the resistance of different substances. Children were more comfortable experimenting and exploring while playing with familiar materials. At the same time, they were more triggered when unexpected things happened with these objects.

3) **The role of technology**

Most 21st century competencies can either be supported or enhanced by information and communications technologies (ICT) [16]. The use of technology can also expand children’s understanding of traditional school subjects, such as literacy, science and mathematics. Besides enhancing learning experiences, technologies can foster innovative teaching [17]. It gives teachers the opportunity to reconsider how courses and learning activities are organized [10], [18]. Multimedia, such as video and animation can be used during class to explain complicated concepts.

However, technology in the classroom isn’t always as effective as we may think. The purpose of technology is to facilitate learning, but ICT and other technological mediums can only be relevant when they are used as learning tools, and not just for the sake of using technology. Further, technology will only enhance the learning experience when it suits the age and the proficiency level of the pupils.

4) **The role of teachers**

The implementation of new competencies and new education strategies, but also the use of technology in the classroom, are major challenges for teachers. To engage in this educational change, teachers need to feel competent and value what they are teaching [10], [16]. They should spend sufficient time on supporting their pupils and are also expected to have mastered all the skills and knowledge themselves [19]. To bring these theories into practice, teachers should be supported with educational tools [2], [4].

Special attention should be paid to the traditional mindset of teachers. They are likely to put more emphasis on grades and right answers than understanding concepts and the learning process itself. The textbooks, tight schedule and whole-class activities that teachers are used to stick to, discourage risk taking and intense engagement in doing projects [10]. The implementation of 21st century skills through project-based learning, creative learning and learning by doing strategies can only work when teachers are willing to rethink their beliefs about learning and teaching.

C. **STEAM Education**

An upcoming 21st century approach to learning is STEAM education. According to Georgette Yakman [20], STEAM stands for “Science and Technology interpreted through Engineering & the Arts, all understood with elements of Mathematics”. Even though opponents think the Arts are misplaced in this acronym, many educators believe they are crucial to support STEM skills [21]. Arts, in all its form, broaden pupil’s horizon, stimulates them to imagine the impossible and follow their intuition. Albert Einstein, for instance, stated that he worked intuitively before he expressed himself logically, having music as his guide to new and creative solutions [22].

Primary school is a good starting point to introduce STEAM education. Tytler [23] analysed multiply studies showing that most children decide whether to choose a STEM related career before the age of 14, based on early experiences. However, despite its importance, engineering as a field of study is often forgotten by teachers. Yet, it entails hands-on work, something children enjoy most in their education. Functional and educational toolsets developed for pupils and teachers, can be of great support for educators. A child’s learning process especially benefits from interaction with tangible objects. Lego Education WeDo 2.0 [24] and littleBits [25] are two popular education tools to bring STEAM subjects – especially electronics and coding – in primary schools.

III. **MINI-THEATRE CONCEPT**

To introduced children (age 9-12) to electronics and programming, a revolving, table top theatre was developed during this Master’s thesis. It is the heart of a long-term project in which pupils go through several STEAM-oriented activities in a fun and tangible way. The mini-theatre comes as a construction kit with four empty stages. Three to five pupils team up to create a mini-theatre play by building the mini-theatre (engineering), writing a script, recording it (spoken word, ICT) and tinkering the stages, props and characters (visual art, engineering). Finally, with Microduino mCookie’s programmable modules [26] they can let their theatre plays come alive (technology, math).

The project also integrates many of the 21st century skills described by WEF in Figure 1. Critical thinking, creativity, communication and collaboration are strongly encouraged. Besides, a long-term project also requires pupils to show persistence, leadership and take initiative to reach their goal.

Literacy is another major component of the project. By inventing a story for their mini-theatre, children enrich their vocabulary, improve writing and communication skills and stimulate their imagination. It encourages pupils to collaborate and share ideas, concepts and experiences. Also, research has shown that girls show more interest in learning computer programming when it is used for the purpose of storytelling [27].

Currently, a gender difference is often noticed in STEM disciplines. Boys are more familiar with construction toys (like LEGO), cars, robots and science topics [28]. LEGO is
commonly used in engineering classes and many educational tools for programming are robots. As a result, boys feel more confident and courageous when taking part in STEM activities. The mini-theatre concept has another approach; both boys and girls have written and listened to stories before. They also have taken part in tinkering and crafting activities since kindergarten. Hence, this project strives to be gender equal and stimulate both boys and girls to take part actively during the whole process of making.

Finally, a STEAM project should be fun. The mini-theatre fosters imagination and creativity of children. By storyboarding, sound recording, tinkering and programming, every group will finish with a unique product that reflects their personality and abilities. After all, learning valuable skills and competencies, is the project’s goal, but showing a magnificent theatre play is the ultimate goal of children.

IV. PRODUCT & PROJECT DEVELOPMENT

A. Methodology

The experience of children with the product took a central place in its development. This design approach is called user-centered design (UCD). It describes a design methodology in which end-users, in this case children of age 9-12, influence how the design takes shape. The product can only become functional and satisfying when users are involved throughout the whole process of designing. Therefore, usability tests were organized frequently during the entire design of the tangible medium and the content development of the project.

B. Design process

In total, four iterative user tests were conducted during the design process. Various project plans and prototypes were tested. The goal of each user test was to identify usability problems, collect qualitative data and determine the participant’s satisfaction with making the mini-theatre.

1) User test 1

A series of weekly workshops was organised to study the potential of the mini-theatre for show and tell presentations. The project consisted of four afterschool workshops, which lasted two hours each. Two projects started in the same week at different locations. Based on the observations during the workshops on Wednesday, updates were immediately implemented in the workshops on Saturday. Ten children from 10 to 12 years old participated in the test.

In teams of 3 to 4 member, the children gathered information about their topic (Figure 2), tinkered the stages of the mini-theatre and recorded the text. They were introduced to the Arduino IDE. Finally, they gave a presentation with their mini-theatre for their parents and siblings.

2) User test 2

A mini-theatre project was organised with the 5th grade (age 10-11) of a local primary school. Ten girls and eleven boys took part in a user test of three hours. They made teams of four to five members.

The teacher asked each group to think of a fictive story for their mini-theatre. She led the story writing activity. Next, the children did sound recording and tinkering under the supervision of the designer. Programming would be done in a later workshop.

Figure 2 Participants gather information

Figure 3 Tinkering activity

3) User test 3

A small class of 6th graders (age 11-13) was invited for a mini-theatre workshop at the local library. The workshop covered an entire school day (5 hours). Four girls and three boys took part in the test. The children were asked to base their story on a book that they could choose from the library. Since the time was limited, they were suggested to choose a picture book. They went through all activities of the project, including programming with a new visual programming platform.

1) User test 4

A final workshop was organised with the same group of children that took part in user test 2. The main focus of this workshop was programming with the new visual programming platform (Figure 4). Each group could use one laptop.

Figure 4 Participants during the programming workshop

The workshop lasted for three hours again. The teams also continued tinkering their mini-theatres in this workshop. The project ended with a final presentation of all mini-theatres.
C. Findings

During its development, the mini-theatre project was tested by nearly 40 children. In 5 project they made 10 different mini-theatres. After user test 2 and 4, the participants were asked to fill in a questionnaire. For each question five emoticons were listed, from very happy to very sad. The participants could mark them to indicate their feelings about an activity. Every workshop was observed and analysed to make continuous improvements on the mini-theatre prototypes, programming platform, project plan and activities.

After every user test, changes were made to the design of the mini-theatre. In the first mini-theatre was simple cardboard construction in which the servo motor was placed under the stages. Later, two gears were added and different materials were used. Only some minor changes were made to the design of the cardboard stages. Children enjoyed that they could take the stages apart while tinkering.

The project has the most value when it is organised in multiple workshops over several weeks. In this case, children can reflect on their work during the process of making it. They can still make adjustments before the project is finished.

The mini-theatre project works best in a storytelling context. Children can invent their own story, tell a fairy tale, remake a book; the possibilities are endless. The questionnaire data shows that the mini-theatre can have a positive impact on children’s attitude towards languages and writing (Table 1). Informative topics, however, are less suitable for this project, unless they are addressed in a storytelling manner.

Table 1 Questionnaire data about language and story writing

| Do you like language and story writing? | 😊 | 😊😊 | 😊😊😊 |
| Did you enjoy writing a story for your mini-theatre? | 😊😊😊😊😊 | 😊😊😊😊😊 | 😊😊😊😊😊 |

Sound recording is a rather unusual activity for schools, but children think it is a great thing to do. While they are using the computer in a purposeful way, they practice speaking skills, empathise with their character and gain self-confidence.

Tinkering the stages of the mini-theatre is by far children’s favourite part of the project (Figure 5). It requires teamwork and stimulates spatial thinking, which are both important skills for working in technology and engineering contexts. Crafting supplies, like recycled materials and little household items of all shapes, can encourage creativity.

![Figure 5 Questionnaire results for favourite activity](image)

Observations showed that children struggled with the syntax of Arduino’s C-based programming language. To meet the needs of the mini-theatre project, new visual blocks were developed for the visual programming platform Blockly4Arduino [29]. Hence, the project stimulates logical thinking without the hassle of forgetting semicolons or brackets.

V. THE DIORAMA PROJECT

The final project proposed in this thesis is called The Diorama Project. It is a series of transdisciplinary workshops in which familiar subjects, like languages and art, are combined with new topics such as programming and electronics, to make a table top theatre (Figure 6). Children team up to write, record and tinker a story. Programmable electronics let their theatre play come alive. During the workshops, children develop valuable 21st century skills and knowledge in a more fun and tangible way.

![Figure 6 The Diorama Project](image)

A. Project plan

The project consists of a series of activities that can be organised independently of one another. Teachers choose when their Diorama Project starts and ends, spreading it over an entire month or one week. An open source platform provides them all the information to organize the workshops by themselves, or they can ask help of people familiar with computer science and programming.

Although teachers are free to plan the workshops according to their own schedule, user tests have shown that it is recommendable to follow the order given below.

1) Story writing

Story writing starts with a brainstorm about all types of stories that children could tell. Which stories do they enjoy listening to? Have they ever seen a theatre play? Can famous stories be changed? Whatever they can imagine, they can write. Next, each team chooses one of story from the brainstorm for their mini-theatre. They learn about storyboarding and the basic elements of a story’s structure. Finally, they write the script of their story. The activity takes about 1,5 hours.

2) Tinkering

Before they start tinkering, every team takes a look at their script and storyboard again. Together, they make a plan, so everybody knows what each member is going to make. Ideally, this is done a few days before the tinkering activity, in case pupils want to bring extra crafting supplies for their mini-theatre. The teams can tinker for about two hours, but the stages shouldn’t be finished yet after this activity.
3) **Sound recording**
This workshop starts by listening to audio clips of theatre plays, animation films, stories and dialogues. Pupils hear that some character have different voices, temper and dialects. This is the art of spoken word and voice acting. It is important that children learn to empathise with their character and use intonation while speaking. After short practice, they can record their play with a voice recording application, like the Online Voice Recorder by 123apps (http://online-voice-recorder.com/). This activity should take no longer than 1.5 hours.

4) **Tinkering**
Since they have already written and recorded their stories, pupils have a better understanding of what they want to make. As they continue tinkering, they can implement new ideas, adjust and improve what they had made, and give feedback to their classmates. They should finish all stages at the end of this workshop (1.5 hours).

5) **Programming**
Everything is ready, now they only have to bring it alive with the electronic modules. First, the children follow the instructions to get familiar with the programming interface. By doing this, they will end up with a basic diorama that can rotate and play sound. Next, they can choose from a list of features to add light, more buttons or extra sounds. By following specific instructions, every group enhances their theatre play with unique features. This activity will take at least three hours, but depending on the interest of the pupils and the time the teacher can give, the workshop can be extended.

6) **Presentation**
Each team presents their play to their classmates and teacher. Classmates get the chance to provide useful feedback.

7) **Filming and video-editing**
After the presentations, this optional workshop can be added. The children can use a camera or phone to film their play. Next, they use a simple video editor, like Wondershare Filmora, to enrich their story with text, visual and sound effects, or adjust volume and brightness. Ultimately, the video is sent to the diorama platform and shared on the school website.

**B. Diorama Kit**
To organise the workshops a supporting kit was developed. Each team of three to five pupils uses one Diorama Kit, including:
- instruction booklets for every activity;
- a microphone for the sound recording activity;
- Microduino mCookie modules;
- all the building parts to assemble the mini-theatre.

The mini-theatre is a modular building kit giving children the freedom to build and rebuild many different constructions for their theatre. All parts of the kit are 3D printed with PLA or laser cut of 3mm PMMA sheets. Since many materials, such as plywood, MDF and cardboard, are available in 3 mm, pupils and teachers can create extra parts by themselves to enhance their mini-theatres.

The kit is designed in such a way that the four stages can also be replaced by either two or three stages. The stages are not included in the diorama kit. Children can cut them out of cardboard sheets by themselves. Hence, teachers can reuse the diorama kits as many times as they want.

Furthermore, all the production files are open source. Schools, workshop organisers and makers worldwide can use a laser cutter or other production techniques - even a cutter knife and some patience will work - to make the mini-theatre by themselves. They can easily make adjustments or use other electronic modules as well.

**C. Visual programming platform**
For this project Microduino mCookie smart modules are used to control the mini-theatre. Children can program these modules with Blockly4Arduino (Figure 7). This is a web-based, visual programming application for Arduino developed by Ingegno. The visual interface is colourful, easy to use and accessible for children of all programming levels.

![Figure 7 Blockly4Arduino](image)

**D. Online Teacher’s Guide**
A complete instruction guide will be available for teachers at github.com/thedioramoproject. Github seems to be the best platform to host The Diorama Project. It is a website allowing developers to collaborate on open source software projects. All files of the project are downloadable for free. Teachers can even collaborate by send suggestions or report mistakes in the project. On the wiki page, they can find all information about the project, as well as a list of education goals, assessment tools, links to example codes et cetera. Educators can organise all workshops by themselves. If some teachers would still lack in confidence to manage a programming activity, can invite a professional workshop leader or ask help from their community. Github hosts thousands of interesting projects, teachers can easily get in touch with other projects and software applications beside The Diorama Project.

**VI. CONCLUSION**
In this paper the development of a new education tool for primary schools was described. Four user tests with nearly 40 children, led to a project that not only supports STEAM disciplines, but many 21st century skills. Multiple prototypes and project plans were tested. The Diorama Project is a series of seven transdisciplinary workshops in which children learn the basics of coding electronics, practise teamwork skills and spatial thinking. Besides, it triggers their imagination while they use writing and speaking competencies in a fun and meaningful way. Gender equality is one of the project’s strengths, since it starts from storytelling and crafting – activities that both boys and girls are familiar with. The Diorama Project is open source available for every educator or
maker worldwide. All information for teachers is easily accessible on the Diorama Github page.

VII. FUTURE WORK

This project will be continued over the next year. First, the instructions booklets and teachers’ guide should be finalized and validated by teachers and pupils. The potential of the project in other contexts will be analysed and tested. A business plan will be written to sell and rent the Diorama Kits. Hopefully, similar projects can be developed in the near future.

ACKNOWLEDGEMENTS

I would like to thank Maria-Cristina Ciocci for her invaluable comments and encouragement during my Master’s thesis. I am grateful for the insights and support of my supervisors, Jelle Saldien and Xi Li, and the enthusiasm and feedback of all children who took part in the development of this project.

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Ontwikkeling van een tastbaar medium om STEAM onderwijs aan te moedigen met storytelling en elektronica

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Kernwoorden STEAM onderwijs, 21e eeuwse vaardigheden, lesmateriaal, DIY elektronica, storytelling

I. INTRODUCTIE

Als gevolg van de snelle ontwikkelingen in informatie- en communicatietechnologieën (ICT), ondergaat onze samenleving grote economische en sociale verandering die een enorme impact hebben op onze manier van werken, leven en leren. Media zijn alomtegenwoordig en mensen maken er voortdurend gebruik van [1], [2].


II. ONDERZOEK

A. 21st Century Skills

Terwijl de industriële samenleving van de vorige eeuw gericht was op massaconsumptie [5], wordt de moderne samenleving door velen gezien als een ‘kennismaatschappij’ [6]-[8], waarbij volgens Anderson verwezen wordt naar economische systemen waarin ideeën of kennis fungeren als grondstoffen [6]. Naast de dynamische veranderingen in het soort jobs in de kennismaatschappij [9], ervaart onze samenleving ook de uitdaging om jongeren te onderwijzen voor jobs die nog niet bestaan [1], [7]. Deze nieuwe jobs hebben dezelfde kerntaken waarvoor een andere groep van vaardigheden en competenties nodig is, vaak ’21st century skills’, of ’21e eeuwse vaardigheden’, genoemd.

Er zijn al vele studies gedaan om een definitie vast te leggen van dé ‘21st century skills’ [1], [6], [7]. In 2015 deed het WEF een gedetailleerde analyse van de literatuur om te bepalen wat zij beschouwen als de waardevolste competenties voor deze eeuw. Hoewel 21e eeuwse vaardigheden op tal van manier gegroepeerd worden, en verschillende terminologieën worden gebruikt, vonden ze -in overeenstemming met de conclusies van eerdere studies- de zestien meest kritische 21st century skills. Die vaardigheden zijn weergegeven in Figuur 1 [3].

B. Onderwijs van de 21st eeuw

21e eeuwse vaardigheden kunnen nieuwe vakken op zichzelf of nieuwe inhoud in traditionele vakken worden. De meeste van deze vaardigheden zijn echter niet direct gekoppeld aan één specifiek vakgebied, maar relevant in vele vakgebieden [11]. Het zou dus een betere aanpak zijn om ze integreren als vakoverschrijdende competenties in projecten en creatieve activiteiten.

1) Project-based learning

Project-based learning, oftewel projectmatig werken, is een educatieve aanpak waarbij het leerproces georganiseerd wordt in projecten. Het bevordert de link tussen vakken en is opgebouwd rond transversale thema’s die aangepast kunnen worden aan het niveau van de leerlingen, de leersituatie en hedendaagse maatschappelijke vraagstukken. Op deze manier
worden leerlingen aangemoedigd om actief te leren. Doordat maken, doen en leren onlosmakelijk met verbonden zijn, is het belangrijk dat leerlingen tijdens projectmatig werken de vrijheid krijgen om dingen te maken. Hun kennis wordt opgebouwd door het leerproces dat ze doorgaan tijdens het creatieproces [10].

Uitdagende vraagstukken en opdrachten vragen niet alleen om ontwerpmomenten, probleemoplossend denken en het maken van beslissingen, maar ook de actief betrokkenheid van leerlingen voor een lange tijd. Er zijn verschillende factoren die bepalen of leerlingen al dan niet enthousiast deelnemen aan een project. Naast de nodige uitdaging, zullen jongeren ook meer gemotiveerd zijn als ze een project zelf waardevol vinden. Gevarieerde taken en nieuwe elementen, maar ook vrijheid in de manier van werken, stimuleren hen om actief deel te nemen. Ze houden er ook vooral van om in groep te werken [11]. Communiceren, het bespreken van ideeën en het werken naar een gemeenschappelijk doel is cruciaal tijdens projecten.

2) Spelenderwijs en creatief leren

Een andere manier om leerlingen te betrekken in het leerproces is het gebruik van spelelementen. Door te combineren wat kinderen moeten leren en wat ze voor hun plezier doen, zullen ze fijnere leerervaringen overhouden [12]. Zo ontwikkelen ze creatieve denkpatronen die belangrijk zijn voor vele vakgebieden, maar vooral nuttig zijn tijdens het leren van wetenschappen en techniek [13]. Ferrari, Cachia en Punj [14] hebben tijdens onderzoek vastgesteld dat creativiteit en innovatie sterk verband houden met kennis en leren. Creativiteit wordt gezien als een essentiële vaardigheid die leidt tot de verwerving van kennis en het opbouwen van een persoonlijke mening.


3) De rol van technologie


Toch is het gebruik van technologie in de klas niet altijd even effectief als men zou denken. Het doel van technologie is het leerproces ondersteunen, maar ICT en andere technologische media kunnen alleen bijdragen wanneer ze effectief gebruikt worden als leermiddelen, en niet wanneer het gebruik van de technologie het doel op zich is. Daarbovenop zal technologie enkel de leerervaringen van kinderen verrijken als ze geschikt is voor hun leeftijd en vaardighedsniveau.

4) De rol van leerkrachten

De implementatie van nieuwe vaardigheden en nieuwe onderwijsstrategieën, maar ook het gebruik van technologie in de klas, is enorme uitdagingen voor leerkrachten. Om mee te kunnen doen in deze educatieve veranderingen, moeten leerkrachten zich competent voelen en waarderen wat ze onderwijzen [10], [16]. Ze zouden voldoende tijd moeten spenderen aan het aanmoedigen van hun leerlingen, maar er wordt ook van hen verwacht dat ze zelf alle vaardigheden en kennis bezitten [19]. Om deze theorie in praktijk te brengen, moeten leerkrachten ondersteund worden door educatieve hulpmiddelen [2], [4].

Verder moet er ook bijzondere aandacht besteed worden aan de traditionele gedachtegang van leerkrachten. Ze zijn het gewoont om meer nadruk te leggen op het eindresultaat en juiste antwoorden, in plaats van het begrijpen van concepten en het leerproces zelf. De handboeken, het strakke lesschema en de klasactiviteiten die leerkrachten gewoon zijn te volgen, ontmoedigen het nemen van risico’s en intensieve betrokkenheid bij het uitvoeren van projecten [10]. Daardoor kan de implementatie van 21e eeuwse vaardigheden door projectmatig werken, creatief leren en ‘learning by doing’ enkel werken als leerkrachten bereid zijn om hun opvattingen over leren en lesgeven aan te stellen.

C. STEAM onderwijs

Een opkomende 21ste eeuwse aanpak van leren is STEAM onderwijs. Volgens Georgette Yakman [20] staat STEAM voor “Wetenschappen (Science) en technologie (Technology) geïnterpreteerd door ingenieurswetenschappen (Engineering) & kunst (Arts), begrepen met de elementen van wiskunde (Mathematics)”. Hoewel tegenstanders denken dat kunst misplaatst is in dit acroniem, geloven veel onderwijzers dat het juist cruciaal is om STEM vaardigheden te ondersteunen [21]. Kunst, in al zijn vormen, verbreekt leerlingen hun horizon, moedigt hen aan om hun verbeelding te gebruiken en hun intuïtie te volgen. Albert Einstein, verklaarde bijvoorbeeld dat hij intuitief werkte voordat hij zich met logica uitdrukte, en muziek was daarbij zijn gids naar nieuwe en creatieve oplossingen [22].

III. MINITHEATER CONCEPT

Om kinderen (9-12 jaar) kennis te laten maken met elektronica en programmeren, werd een draaiend minitheater ontwikkeld tijdens deze masterproef. Het staat aan de basis van een langdurig project waarin leerlingen verschillende STEAM-georiënteerde activiteiten doorlopen op een leuke en tastbare manier. Het minitheater wordt geleverd als een constructie pakket met vier lege podiumhoeken. In groepjes van drie tot vijf leerlingen, maken de kinderen een mini-theaterstuk door het minitheater te bouwen (engineering), het script te schrijven en op te nemen (woordkunst, ICT) en de podiumhoeken, personages en attributen te knutselen (beeldende kunst, engineering). Uiteindelijk gebruiken ze Microduino mCookie programmeerbare modules [26] om hun theater tot leven te brengen (technologie, wiskunde).

Het project omvat ook andere 21ste-eeuwse vaardigheden, eerder beschreven in Figuur 1, zoals kritisch denken, creativiteit, communiceren en samenwerken. Daarnaast wordt er tijdens het project ook doorzettingsvermogen, leiderschap en initiatief verwacht van leerlingen om hun doel bereiken.

Taal is een ander hoofddoeldeel van het project. Door een verhaal te verzinnen voor hun minitheater, verrijken kinderen hun woordenschat, verbeteren ze schrijf- en communicatievaardigheden en wordt hun verbeelding gestimuleerd. Het project moedigt hen aan om samen te werken en ideeën, concepten en ervaringen te delen met elkaar. Daarbovenop heet onderzoek aangetoond dat meisjes meer interesse tonen in leren programmeren als het gebruikt wordt met het doel om een verhaal te vertellen [27].

Op dit moment is er vaak een genderverschil te merken in STEM disciplines. Jongens zijn meer vertrouwd met bouwspeelgoed (zoals LEGO), auto’s, robots en wetenschappelijke onderwerpen [28]. LEGO wordt vaak gebruikt in ingenieurslessen en vele educatieve middelen om te leren programmeren zijn robots. Als gevolg hiervan, voelen jongens zich meer zelfzeker wanneer ze deelnemen aan STEM activiteiten. Het minitheater concept heeft een andere aanpak; zowel jongens als meisjes hebben al verhalen al zelf verhalen geschreven en naar verhalen geluisterd. Ze hebben ook al meer vaak geknutseld sinds de kleuterklas. Daarom streeft dit project gendergelijkheid na en stimuleert zowel jongens als meisjes om actief deel te nemen in het hele project.

Ten slotte moet een STEAM project ook leuk zijn. Het minitheater moedigt de creativiteit en verbeelding van kinderen aan. Door een storyboard te maken, geluid op te nemen, te knutselen en te programmeren zal elke groep een uniek resultaat neerzetten dat hun persoonlijkheid en talenten weerspiegelt. Uiteindelijk is het leren van waardevolle vaardigheden en competenties dan wel het potentieel van deelnemers tijdens het maken van het minitheater bepalen, was het doel van elke gebruikerstest.

B. Ontwerpproces

In totaal werden vier iteratieve gebruikerstesten uitgevoerd tijdens het ontwerpproces. Diverse projectplannen en prototypes werden getest. De problemen bij gebruiksgemak identificeren, kwalitatieve gegevens verzamelen en de tevredenheid van de deelnemers tijdens het maken van het minitheater bepalen, was het doel van elke gebruikerstest.

1) Gebruikerstest 1

Er werd een reeks van wekelijkse workshops georganiseerd om het potentieel van het minitheater tijdens spreekbeurten te analyseren. Het project bestond uit vier naschoolse workshops die elk twee uur duurden. Er werden twee projecten in dezelfde week op verschillende locaties gestart. Op basis van de waarnemingen tijdens workshop op woensdag werd de workshop op zaterdag meteen aangepast. Tien kinderen van 9 tot 12 jaar namen deel aan de test.

In team van 3 tot 4 leden, verzamelden de kinderen informatie over hun onderwerp (Figuur 2), knutselden de podiumhoeken van hun minitheater en namen de tekst op. Daarna maakten ze kennis met de Arduino IDE (Integrated development environment) en gaven ze een presentatie met hun minitheater voor hun ouders, broers en zussen.

IV. PRODUCT & PROJECT ONTWIKKELING

A. Methodologie


B. Ontwerpproces

In totaal werden vier iteratieve gebruikerstesten uitgevoerd tijdens het ontwerpproces. Diverse projectplannen en prototypes werden getest. De problemen bij gebruiksgemak identificeren, kwalitatieve gegevens verzamelen en de tevredenheid van de deelnemers tijdens het maken van het minitheater bepalen, was het doel van elke gebruikerstest.

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Figuur 2 Deelnemers verzamelen informatie

Figuur 3 Knutselactiviteit

2) Gebruikerstest 2

In samenwerking met het vijfde leerjaar (10-11 jaar oud) van een plaatselijke basisschool werd een tweede minitheater project georganiseerd. Tien meisjes en elf jongens namen deel aan een gebruikerstest van drie uur. Ze maakten teams met vier tot vijf leden.
De leraar vroeg aan iedere groep om na te denken over een fictief verhaal voor hun minitheater. Ze leidde de activiteit waarin de kinderen hun verhaal opschreven. Vervolgens namen de kinderen geluid op en knutselden ze onder toezicht van de ontwerper. Programmeren zou in een latere workshop gedaan worden.

3) Gebruikerstest 3
Een kleine klas van het zesde leerjaar (11 tot 13 jaar oud) werd uitgenodigd voor een minitheater workshop in de bibliotheek. De workshop duurde een volledige schooldag (5 uur). Vier meisjes en drie jongens namen deel aan de test. Er werd van de kinderen gevraagd om hun verhaal op een boek te baseren dat ze uit de bibliotheek mochten kiezien. Aangezien de tijd beperkt was, werd voorgesteld om een prentenboek te kiezen. Ze deden alle activiteiten van het project, inclusief programmeren met een nieuw visueel programmeerplatform.

1) Gebruikerstest 4
De laatste workshop werd georganiseerd met dezelfde groep kinderen die deelnamen aan gebruikerstest 2. Het hoofddoel van deze workshop was het leren programmeren met de nieuwe visuele programmeeromgeving (Figuur 4). Elke groep kreeg één laptop.

Figuur 4 Deelnemers tijdens de programmeerworkshop
De workshop duurde opnieuw drie uur. De teams mochten ook verder knutselen aan hun minitheater tijdens deze workshop. Het project eindigde met een eindpresentatie van alle minitheaters.

C. Bevindingen

Na elke gebruikerstest werden wijzigingen aangebracht aan het ontwerp van het minitheater. Het eerste minitheater was een eenvoudige kartonnen constructie waarbij de servomotor onder de podiumentoek zat. Later werden twee tandwielen toegevoegd en andere materialen gebruikt. Er werden slechts enkel kleine wijzigingen aangebracht aan de vorm van de kartonnen podiumentoeken. Kinderen vonden het fijn dat ze de hoeken uit elkaar konden halen tijdens het knutselen.

Het project was het meest waardevol als het werd georganiseerd in meerdere workshops over een aantal weken. In dit geval kunnen de kinderen nog tijd om na te denken over hun werk terwijl ze het aan het maken zijn. Ze kunnen nog aanpassingen doen voor het project is afgerond.

Het minitheater werkt het best in de context waarbij kinderen zelf een verhaal mogen vertellen. Ze kunnen een verhaal verzinnen, een sprookje vertellen of een boek namaken; de mogelijkheden zijn eindeloos. Uit de gegevens van de vragenlijst blijkt dat het minitheater een positieve invloed heeft op de houdingen van kinderen tegenover taal en schrijven (Tabel 1). Informatieve onderwerpen zijn echter minder geschikt voor dit project, tenzij ze op een verhalende manier gebracht worden.

Tabel 1 Vragenlijst gegevens over taal en verhalen schrijven

| Hou je van taal en verhalen schrijven? | 11 | 5 | 3 |
| Vond je het fijn om een verhaal te schrijven voor jullie minitheater | 19 | 0 | 0 |

Geluid opnemen is een eerder ongewone activiteit voor scholen, maar kinderen vinden het geweldig om te doen. Terwijl ze de computer op een nuttige manier gebruiken, oefenen ze hun spreekvaardigheid, inleven in een personage en wordt hun zelfvertrouwen gestimuleerd.

Het knutselen van de podiumhoeken is bij verre de favoriete activiteit van de kinderen (Figuur 5). Het vereist teamwork en stimuleert ruimtelijk denken, wat beiden belangrijke vaardigheden zijn om te werken in een technologie of ingenieurscontext. Knutselmateriaal in alle vormen, zoals recyclebaar materiaal of kleine dingen uit de keuken, kunnen dan weer de creativiteit stimuleren.

Figuur 5 Vragenlijst resultaten voor favoriete activiteit
Observaties toonden aan dat kinderen moeite hebben met de syntax van Arduino’s C-gebaseerde programmeertaal. Om aan de behoeften van het minitheater project te voldoen, werden nieuwe visuele blokken ontwikkeld voor BlockyArduino, een visueel programmeerplatform [29]. Daardoor kan het project logisch denken bij kinderen stimuleren zonder het gedoe van het vergeten van een puntkomma of haakjes.

V. ET DIORAMA PROJECT
Het eindproject dat voorgesteld wordt in deze thesis heet Het Diorama Project. Het is een reeks van transdisciplinaire workshops waarin vertrouwde schoolvakken, zoals taal en kunst, worden gecombineerd met nieuwe onderwerpen, zoals het programmeren en elektronica, om een tafeltheater (figuur 6) te maken. Kinderen werken samen om een verhaal te schrijven, op te nemen en te knutselen. Programmeerbare
elektronica laat hun theaterstuk tot leven komen. Tijdens de workshops, ontwikkelen kinderen waardevolle 21e eeuwse vaardigheden en kennis op een meer leuke en tastbare manier.

![The Diorama Project](image)

**A. Projectplan**

Het project bestaat uit een reeks van activiteiten die onafhankelijk van elkaar georganiseerd kunnen worden. Leerkrachten zien zelf wanneer hun Diorama Project begint en eindigt, of ze het spreiden over een hele maand of slechts een week. Een open source-platform biedt hen alle informatie om alle workshops zelf te organiseren, of ze kunnen hulp vragen van mensen die meer vertrouwd zijn met informatica en programmering.

Hoewel leraren vrij zijn om de workshops te plannen op basis van hun eigen schema, hebben gebruikerstesten aangetoond dat het aan te bevelen is om de volgorde hieronder te volgen.

1) *Story writing (verhalen schrijven)*

**Story writing** begint met een brainstorm over alle soorten verhalen die kinderen zouden kunnen vertellen. Naar welke verhalen luisteren ze graag? Hebben ze al eens een toneelstuk gezien? Kan bekende verhalen worden veranderd? Alles wat ze zich kunt voorstellen, kunnen ze ook schrijven. Vervolgens kiest elk team één van verhaal uit de brainstorm voor hun minitheater. Ze leren over storyboards en de basiselementen van een verhaal. Tot slot, schrijven ze het script van hun verhaal. De activiteit duurt ongeveer 1,5 uur.

2) *Knutselen*

Voordat ze beginnen te knutselen, herberijkt elk team een hun script en storyboard. Samen maken ze een plan, zodat iedereen weet wat elk teamlid gaat maken. Idealiter wordt dit een paar dagen voor het knutselen gedaan, zodat leerlingen extra knutselmateriaal voor hun minitheater kunnen meebrengen. De teams mogen ongeveer twee uur knutselen, maar het minitheater mag nog niet klaar zijn na deze activiteit.

3) *Geluid opnemen*

Deze workshop begint met het luisteren naar geluidsoptnames van theaterstukken, animatiefilms, verhalen en dialogen. Leerlingen horen dat de personages verschillende stemmen, humeur en dialecten hebben. Dit is woordkunst en voice acting. Het is belangrijk dat kinderen zich leren inleven in hun personage en het intonatie gebruiken tijdens het spreken. Nadat ze even geoeufd hebben, kunnen ze hun theaterstuk opnemen met een voice recording applicatie, zoals de Online Voice Recorder van 123apps (http://online-voice-recorder.com/). Deze activiteit zal ongeveer 1,5 uur duren.

4) *Knutselen*

Omdat ze hun verhalen al geschreven en opgenomen hebben, hebben de leerlingen nu een beter idee van wat ze willen maken. Wanneer ze mogen verder knutselen, kunnen ze nieuwe ideeën toevoegen, aanpassingen maken, verbeteren wat ze al gemaakt had, en feedback geven aan hun klasgenoten. Alle podiumhoeken zouden af moeten zijn aan het einde van deze workshop (1,5 uur).

5) *Programmeren*

Alles is klaar, nu moeten ze het alleen maar tot leven brengen met de elektronische modules. Eerst volgen de kinderen de instructies om de programmeromgeving te leren gebruiken. Door dit te doen, bekomen ze een basis diorama dat kan draaien en geluid spelen. Vervolgens kunnen ze kiezen uit een lijst van functies waarmee ze licht, meer knoppen of extra geluiden kunnen toevoegen. Door specifieke instructies te volgen, verbetert elke groep zijn theaterstuk met unieke eigenschappen. Deze activiteit zal minstens drie uur duren, maar afhankelijk van de interesse van de leerlingen en de tijd dat de leraar ter beschikking heeft, kan de workshop worden verlengd.

6) *Presentatie*

Elk team presenteert hun theaterstuk aan de leerkracht en klasgenoten. Zij krijgen de kans om nuttige feedback te geven.

7) *Filmen en bewerken*

Na de presentaties, kan deze optionele workshop worden toegevoegd. De kinderen kunnen een camera of telefoon gebruiken om hun theaterstuk te filmen. Vervolgens gebruiken ze een eenvoudige video-editor, zoals Wondershare Filmora, om hun verhaal te verrijken met tekst, visuele effecten en geluidsEffects, of het volume en de helderheid aan te passen. Uiteindelijk kan de video naar de diorama platform verzonden worden en worden gedeeld op de schoolwebsite.

**B. Diorama Kit**

Om de workshops te organiseren, is een ondersteunend pakket ontwikkeld. Elk team van 3 tot 5 leerlingen gebruikt één Diorama Kit. Daarin zit:

- Instructieboekjes voor elke activiteit;
- Een microfoon om geluid op te nemen;
- Microduino microCookie modules;
- Alle onderdelen om het minitheater te monteren.

Het minitheater is een modulair bouwpakket dat kinderen de vrijheid geeft om verschillende constructies voor hun minitheater te bouwen. Alle onderdelen van de kit zijn ofwel 3D geprint van PLA of gelaserout uit 3mm PMMA platen. Vele materialen, zoals multiplex, MDF en karton, zijn verkrijgbaar in 3 mm platen, dus leerlingen en leerkrachten kunnen gemakkelijk extra onderdelen maken om zelf hun minitheaters uit te breiden.

De kit is zodanig ontworpen dat de vier podiumhoeken ook vervangen kunnen worden door twee of drie podiumhoeken. De hoeken zijn niet inbegrepen in de diorama kit. Kinderen kunnen ze zelf uit een kartonnen plaat knippen. Daardoor kunnen leerkrachten de diorama kits zo vaak hergebruiken als ze willen.

Bovendien zijn alle productie-bestanden open source. Scholen, workshop organisatoren en makers van over de hele
wereld kunnen een laser cutter of andere productietechnieken gebruiken - zelfs een breukmesje en wat geduld is voldoende - om het minitheater zelf te maken. Ze kunnen ook gemakkelijk aanpassingen doen of gebruik maken van andere elektronische modules.

C. Visuele programmeerplatform

Voor dit project worden Microduino Mcookie modules gebruikt om het minitheater te besturen. Kinderen kunnen deze modules met Blocky4Arduino (figuur 7) programmeren. Dit is een online visuele programmeeromgeving voor Arduino, ontwikkeld door Ingegno. De visuele interface is kleurrijk, eenvoudig te gebruiken en toegankelijk voor kinderen van alle programmeerniveaus.

D. Online leerkrachtenhandleiding


VI. CONCLUSIE

In deze paper werd de ontwikkeling van een nieuw didactisch hulpmiddel voor het basisonderwijs beschreven. Vijf gebruikerstesten met bijna 40 kinderen, leidde tot een project dat niet alleen STEAM disciplines ondersteunt, maar vele 21st century skills. Meerdere prototypes en projectplannen werden getest. Het Diorama Project is een reeks van zeven transdisciplinaire workshops waarin kinderen de basissprincipes van het programmeren van elektronica leren, en teamwork vaardigheden en ruimtelijk denken oefenen. Daarnaast, stimuleert het hun fantasie, terwijl ze gebruik maken van schrijf- en spreekvaardigheden op een leuke en zinvolle manier. Gendergelijkheid is een van de sterke punten van het project, omdat het vertrek van storytelling en knutselen - activiteiten waarmee zowel jongens als meisjes vertrouwd zijn. Het Diorama Project is open source beschikbaar voor iedere onderwijzer of maker wereldwijd. Alle informatie voor leerkrachten is gemakkelijk toegankelijk op de Diorama Github pagina.

VII. TOEKENSTVISIE

Dit project zal worden voortgezet in het komende jaar. Eerst moeten de instructieboekjes en leerkrachtenhandleiding worden afgewerkt en gevalideerd worden door leerkrachten en leerlingen. Ook het potentieel van het project in andere contexten zal worden geanalyseerd en getest. Een businessplan zal geschreven worden over de mogelijkheid om de Diorama Kits te verkopen en te verhuren. Hopelijk kunnen er nog vergelijkbare projecten worden ontwikkeld in de nabije toekomst.

DANKwoord

Ik zou graag Maria-Cristina Ciocci bedanken voor haar waardevolle opmerkingen en aanmoediging tijdens mijn masterproef. Ik ben ook dankbaar voor het inzicht en de steun van mijn promotoren, Jelle Saldien en Xi Li, en het enthousiasme en de feedback van alle kinderen die hebben deelgenomen aan de ontwikkeling van dit project.

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1. **INTRODUCTION**

1.1. **RESEARCH QUESTION**

In the spring of 2015 I met Tiki Wang, CEO and co-founder of Microduino, in China. His company just announced a brand new electronic kit on Kickstarter. Impressed by the usability and functionalities of these smart modules, I imagined the great potential it could have to make children excited about electronics and coding. We decided to collaborate and develop a product with educational relevance. That was the start of this Master’s thesis.

1.2. **PROJECT PARTNERS**

1.2.1. Microduino

Microduino is an open source hardware company that produces one of world’s smallest series of Arduino-compatible smart modules. Over the last four years, Microduino has grown into a company of 50 across the U.S. and China. Its headquarter is located in Beijing where they work closely together with some of China’s best universities. Microduino has already developed more than 50 stackable modules and 30 sensors to support a growing community of makers, designers, engineers, parents and children worldwide [1].

Currently, Microduino’s team is mainly organising workshops for Chinese children and students, but aims to share and translate their projects to reach more children, schools and educators all around the globe in the near future. Microduino mCookie is Microduino’s latest product.

**mCookie**

Microduino mCookies are stackable modules that snap together magnetically with magnets hidden in the plastic fixators on each side. If they aren’t angled correctly, the modules will reject to snap
together. The spring pin connection inside mCookie provides rugged surface-to-surface connection between circuit boards. There is no need for soldering, which makes it easy for children and beginners to enhance their projects with electronics. Microduino mCookie is also LEGO compatibility. The modules can be stacked on any LEGO creation. Besides, mCookie modules are Arduino-compatible, which means they can be programmed in the Arduino IDE. Microduino is also working on a visual programming language, called Mixly, which is based on Google’s open source library Blockly.

There are already nearly fifteen different mCookies available that can be combined with lots of sensors, motors, LEDs and other accessories. The main competitors for Microduino mCookie are Do It Yourself hardware producers Genuino/Arduino and LittleBits. Table 1 shows a comparison of the three competitors in June 2016.

Microduino’s team provided me a bunch of mCookies to research the potential of their electronic modules in educational projects for children.
Table 1 Competitors in DIY electronics

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<tr>
<td>Core module</td>
<td>mCookie USBTTL €12,60</td>
<td>Genuino Micro €18,00</td>
<td>littleBits Arduino €44,99</td>
</tr>
<tr>
<td>Price</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection</td>
<td>Magnetically stackable, accessories connect with wires and connectors</td>
<td>Wiring with jumper wires</td>
<td>Magnetically connectable behind each other</td>
</tr>
<tr>
<td>Lego compatible</td>
<td>Yes (included in kit)</td>
<td>No</td>
<td>Yes, by brick adapters (€13,99)</td>
</tr>
<tr>
<td>Programming platform</td>
<td>Arduino, Mixly</td>
<td>Arduino, Scratch etc.</td>
<td>Not necessary, Arduino, Scratch</td>
</tr>
<tr>
<td>Power</td>
<td>Batteries, USB, LiPo battery</td>
<td>USB, batteries</td>
<td>9-volt battery, USB</td>
</tr>
</tbody>
</table>

1.2.2. Ingegno

I have been working closely together with Ingegno [5]. This is a Belgian STEM academy, organising workshops and after school activities to enthral children with science and technology. The organisation is found by Maria-Cristina Ciocci, a mathematician with a fiery passion for technology. Her workshops stimulate primary schools to use educational technology, robotics and toys in teaching of science subjects. I have been assisting her during workshops and weekly activities since last year. In this way, I got familiar with technology education for children.

1.3. TARGET AUDIENCE

This project is focused on children in the 4th, 5th and 6th grade of primary school (age 9-12), since it is commonly agreed that children are able to start programming and experimenting with electronics at this age.

Giving children the right education to prosper in the 21st century is a major challenge for policy makers and educators worldwide. Even though all user tests were organised with Belgian children and school, this project aims to fit in all kinds of education systems and standards.
2. RESEARCH

The attention and investment for ICT and sciences education is increasing significantly. The importance of these subjects is immense, regarding the technological development our society is going through. Nevertheless, the value of creative and social skills should not be underestimated either. How can we equip young people with useful skills and competencies which allow them to actively and effectively take part in a globalised society? In this chapter, the findings of researchers and experts about the crucial changes in education systems are highlighted.

2.1. 21ST CENTURY SKILLS

As a result of the rapid development of information and communication technologies (ICT), our society undergoes major economic and social changes that have an enormous impact on the way people work, live and learn. Media are omnipresent and people make constantly use of it [6], [7]. While the industrial society of the last century aimed at mass consumption focusing on motorization [8], the modern society is by many seen as a ‘knowledge society’ [9]–[11] which refers to “economic systems where ideas or knowledge function as commodities”, according to Anderson [9]. In fact, Masuda already believed that growing information and knowledge would lead to “a society in which the cognitive creativity of the individual flourishes throughout society” ([8], p.147). This is consistent with the findings of Levy and Murnane [12] who argue that the exchange of information is no longer only important for many jobs, but also the particular interpretation of information. Beside the dynamic changes in the types of jobs demanded by the knowledge society [13], our society also experiences the challenges to educate young people for jobs that don’t exist yet [7], [10]. These new jobs have similar key tasks that require a different set of skills and competencies, often referred to as 21st century skills, since they are more related to “the needs of the emerging models of economic and social development than with those of the past century” according to Ananiadou and Claro [14].

Many studies have been done to define what we should consider to be the ‘21st century skills’ [7], [9], [10]. In 2015, the World Economic Forum (WEF) undertook a detailed analysis of research literature to define what they consider to be valuable competencies for this century. Although 21st century skills are categorised and grouped in numerous ways and various terminologies are used, they found in line with the conclusions from previous studies the sixteen most critical 21st century skills as shown in Figure 2 [15].
Further, the importance of ICT is emphasised by many frameworks [7]. Its rapid development requires a whole new set of ICT literacy competences that surpass the current use of ICT tools and applications.

2.2. 21ST CENTURY EDUCATION

Since the recent developments have changed our workspace and lifestyle, education systems should have been revised as well. WEF’s study [15] of nearly hundred countries, however, reveals that all too often pupils are not attaining these sixteen 21st-century skills. Policy makers and educators experience major challenges to develop a curriculum that’s relevant to this century. Voogt and Roblin [7] noted that most frameworks typically address three key issues concerning the implementation of 21st century: “the place of these competences in the school curriculum, the role of teachers and teacher professional development, and the involvement of various stakeholders from both the public as well as the private sector.”
Completely changing a curriculum that worked fine for decades, is perhaps the most complex and challenging part of the implementation. Nevertheless, education is seen as central in mastering all 21st century competencies. WEF [15] divided these skills into three broad categories:

- **Foundational literacies**, including literacy and numeracy, represent how pupils apply skills to everyday tasks. They have been the traditional focus of education worldwide. Until now, understanding these skills was sufficient for entering the job market. For young people this is just one part of the education they need to prosper in the 21st century.

- **Competencies** describe how pupils approach complex challenges. In order to formulate innovative solutions for real life problems, pupils should be able to critically evaluate and convey knowledge, as well as using their creativity to answer questions and tackle problems.

- **Character qualities** describe how pupils approach their changing environment. In a globalized economy, skills as social and cultural awareness, leadership and adaptability are getting more important than ever before.

21st century skills can be added as new subjects or new content within traditional subjects. However, most of them are not directly linked to a specific field but relevant across many fields [16]. Integrating them as cross-curricular competences in projects and creative activities is a better approach.

### 2.3. INNOVATIVE TEACHING

#### 2.3.1. Project-based learning

Project-based learning, also referred to as PBL, is an educational approach where learning is organised around projects. It promotes links among subjects and is built around transversal themes, adaptable to different types of learners, learning situations and contemporary societal issues. In this way, pupils are encouraged to learn actively. Since creating, doing and learning are inextricably related, giving pupils the freedom to generate artefacts is a critical component of project-based learning. Their knowledge is generated through the process of constructing things. Moreover, artefacts, such as models, videos, applications and products, can be shared and critiqued, allowing others to provide feedback [17].

Challenging problems require not only design thinking, problem-solving and decision making, but also active engagement over a long period of time. Project-based education can only work when "projects are designed in such a way that, with teacher support, they marshal, generate, and sustain student
motivation and thoughtfulness." [17] There are several factors affecting whether or not pupils enthusiastically take part in a project. Besides being challenged, young people are more motivated when projects have value to them. Varied tasks and novel elements, as well as freedom in working method, encourage them to participate actively. They also particularly enjoy working in teams and making artefacts as a final result of the project [18]. Even though teamwork can be fun, without the right skills pupils may not benefit from it. Collaborative work requires them to respect each other’s abilities and opinions. Communicating, discussing ideas and working towards a common goal is essential. From a young age, children should get the opportunity to practice these teamwork skills by participating in projects and hands-on activities.

2.3.2. Playful and creative learning

Another way to engage pupils, especially children, is the inclusion of play in the learning process. By combining what children learn and what they do for fun, exciting learning experiences can occur [19]. They develop creative thinking techniques that are important to many fields, but particularly useful for learning science and engineering [20]. Ferrari, Cachia and Puni [21] have identified that creativity and innovation have strong links with knowledge and learning. Creativity can enhance the learning process in many ways. Children creating mnemonics to remember European countries and capitals, is just one example of creative thinking. This form of learning favours understanding over memorisation. Therefore, creativity is seen as an essential skill that leads to knowledge creation and the construction of personal meaning [21].

Tangible mediums as learning tools also benefit the learning process. Resnick’s [22] research group organized Playful Invention and Exploration (PIE) workshops in museums. They found that especially familiar objects used in unfamiliar ways can spark children’s interest in learning new subject matter. A workshop with food as musical instruments, for example, let children explore the resistance of different substances. Similarly, Johnson and Thomas [19] used conductive dough to teach children about electronic circuits. They all noticed that children were more comfortable experimenting and exploring while playing with familiar materials. At the same time, they were more triggered when unexpected things happened with these objects. A PIE workshop leader explained: “The familiar doing the unfamiliar stops you in your tracks, it jars you to want to know more.” [22]

2.4. THE ROLE OF TECHNOLOGY

As mentioned before, technological developments are influencing our society
and the competencies pupils should master to actively take part in it. Therefore, it is not surprising that most of these competencies can either be supported or enhanced by information and communications technologies (ICT) [14]. For many young people, schools are the only place where they can learn about and with ICT. On top of that, the use of technology can expand children’s understanding of traditional subjects, such as literacy, science and mathematics. First, teachers and books were the only key sources of information, but the Internet has changed it drastically. Technologies can also foster creative learning and innovative teaching [21], [23]. After all, like their pupils, teachers also benefit from the greater reliance on technology. It gives them the opportunity to reconsider how courses and learning activities are organised [17], [24]. Via networks forums on the Internet teachers can find examples of how others have implemented projects. They can share ideas and support each other with valuable information. Further, multimedia, such as video and animation can be used during class to explain complicated concepts. Regarding the rapid development of virtual reality headsets and applications, technology has the potential to give teaching and learning a whole new dimension.

However, technology in the classroom isn’t always as effective as we may think. The purpose of technology is to facilitate learning, but ICT and other technological mediums can only be relevant when they are used as learning tools, and not just for the sake of using technology. Using it at an extremely high level or in an inefficient way, may even hinder the learning process [25], [26]. Further, technology will only enhance the learning experience when it suits the age and the proficiency level of the pupils. When tools are too difficult to learn, pupils lose interest in the project or subject matter. The current generation of pupils has been growing up with technology. Computers, tablets and smartphones are part of their daily lives. They constantly learn to use new applications and tools by trying, using and exploring it. Everything is expected to work properly and fast. Since they are experts in using computers and the Internet, you would expect that young people learn better through online courses, but the opposite is true. They enjoy being in class with their peers and the social interaction that comes with it. Classmates, and definitely teachers, enrich their learning process in a way technology can’t. In 2005, McNeely [25] already stated: “Using technology only enhances the hands-on experience; it does not –and cannot- replace human interaction.”

2.5. THE ROLE OF TEACHERS

The implementation of new competencies and new education strategies, such as interdisciplinary projects, but also the
use of technology in the classroom, are major challenges for teachers. To engage in this educational change, teachers need to feel competent and value what they are teaching [14], [17]. They should spend sufficient time on supporting their pupils and are also expected to have mastered all the skills and knowledge themselves [16]. Most teachers, however, experience trouble applying 21st century skills in their classrooms. For instance, research showed that American primary school teachers often have inadequate knowledge of science and understanding of inquiry-based science to explain natural phenomena and real-world situations [27], [28]. Schools indicate that they feel the need for more time, teacher training and ready-for-use lesson materials. Providing teachers with clear educational tools for guidance, is necessary to innovate and bring theories into practice [6], [29].

As argued before, technology can support teachers in the education process. Nevertheless, not all teachers make sufficient use of new tools and content. Classrooms can be equipped with smart objects, such as an interactive whiteboard and computers, but if teachers are unwilling to use them, they won’t improve the teaching and learning performance. Teachers don’t think that these technologies are useless, but their low level of new media fluency discourages them to operate and actively use them [24], [26]. This shows again that teacher training will be critical to pursue 21st century education.

In addition to the improvement of ICT pedagogical skills, special attention should be paid to the traditional mindset of teachers. Teachers are likely to put more emphasis on grades and right answers than understanding concepts and the learning process itself. The textbooks, tight schedule and whole-class activities that teachers are used to stick to, discourage risk taking and intense engagement in doing projects [17]. Dede [10] noted that “troubleshooting systems and applications” is seen as one of the key subskills of ICT Literacy by The International Society for Technology in Education (ISTE), but “pupils seldom get the opportunity to learn "troubleshooting" because teachers instinctively don’t ever want problems to emerge in an instructional situation.” The implementation of 21st century skills through project-based learning, creative learning and learning by doing strategies can only work when teachers are willing to rethink their beliefs about learning and teaching. By organising projects, pupils will work more autonomously. Teachers can spend more time supporting individuals and small groups of pupils and less on whole class teaching [16]. Finally, standardized testing models should make place for an assessment procedure that values the process of learning by applying and understanding 21st century competences.
2.6. ASSESSMENT OF 21ST CENTURY SKILLS

People don’t all learn in the same way. Some can easily memorise facts, while others learn best through visual and hands-on interaction. Current assessment methods mostly focus on the measurement of discrete knowledge. With the result that the first group of people are identified as “intelligent”, since they get good grades on pencil and paper tests. The level of intelligence of people that learn by doing, however, is highly underestimated by these traditional testing techniques. Nevertheless, designing, building and programming invoke knowledge and intelligences as well. Children that usually have low scores can suddenly be the experts of the class during a hands-on project [30]. Obviously, present assessment models are not suitable to assess interdisciplinary projects involving 21st century skills [31]. In 2009, Ananiadou and Claro [14] conducted a questionnaire study to obtain information on whether or how OECD countries teach and assess 21st century skills. One of their key findings was that

"there are virtually no clear (formative or summative) assessment policies for these skills. The only evaluation regarding their teaching is often left to external inspectors as part of their whole school audits."

Belgium (Flanders) is one of the examples having no assessment of 21st century skills. Since there are no guidelines or models from the Ministry, schools decide themselves how to achieve these cross-curricular objectives.

Voogt and Roblin’s analysis [7] of international frameworks regarding 21st century skills showed that only a few frameworks explicitly discuss how assessment of 21st century competences should be organised. They summarized the findings of the Assessment and Teaching of 21st century Skills (ATC21S) framework, as follow:

"The ATCS framework further describes the general characteristics that the assessment of 21st century competences should ideally have. According to this framework, assessments need to: (a) be aligned with the development of significant 21st century goals, (b) be adaptable and responsive to new developments, (c) be largely performance based, (d) provide productive and usable feedback for all intended users and contribute to capacity building of teachers and pupils, and (e) meet the general criteria for good assessments (i.e. be fair, technically sound, valid for purpose, and part of a comprehensive and well-aligned system of assessments at all levels of education)."

In general, there is the need to move from summative assessment towards formative assessment. This latter method monitors pupils’ progress by formal and
informal assessments along the learning process. It emphasizes qualitative feedback for pupils and teachers. It also includes self and peer assessment which proved to have many benefits for the learning process [32].

Several initiatives have been set up around the world to innovate the current assessment procedures to a system that proves pupils have mastered the competencies to prosper in the knowledge society. However, many are still at an early stage. Much more research and development must be done before real change will happen.

2.7. STEM EDUCATION

"Science" is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world..."

- President Barack Obama
23 March 2015

STEM is a well-known, international acronym referring to Science, Technology, Engineering, and Mathematics. Instead of compartmentalizing the four disciplines as is done in traditional school subjects of mathematics, chemistry and physics, STEM combines them to give each of them a meaning in a broader context [33], [34]. STEM projects encourage pupils to apply mathematical, scientific and technological insights and concepts to create solutions to complex questions and real-world problems. Its interdisciplinary nature reflects the challenges engineers face daily when developing new systems and products. Without a good understanding of various science disciplines, math and technology, they wouldn't succeed [30], [35]. Despite its importance, engineering as a field of study is often forgotten by teachers. Yet, it entails hands-on work, something children enjoy most in their education. Engineering reaches even further than the STEM disciplines. While working on a project, pupils also need reading, writing and communication skills, leadership and many more 21st century competences. It is understandable, however, that primary school teachers have difficulties to bring engineering into the classroom when they don't have the tools to do so. Functional and educational toolsets developed for pupils and teachers, can be of great support.

2.8. STEAM EDUCATION

In 2005, Prensky [36] wrote that "every single student we teach has something in his or her life that’s really engaging – something that they do, that they are good at, something that has an engaging, creative component to it". Yet creativity is exactly the component that is often overlooked. Nobody would deny that
STEM education and STEM skills are crucial to our society, but many educators notice that it is missing a creativity-related segment [37]. Therefore, to show that arts education is of equal importance, an A is added to the acronym, making it into STEAM.

According to Georgette Yakman [38], STEAM stands for “Science and Technology interpreted through Engineering & the Arts, all understood with elements of Mathematics”, shown in the STEAM Pyramid (Figure 3). Arts, in all its forms, helps pupils to broaden their horizons, to combine knowledge of different disciplines, to be inspired by each other, to keep trying after failing, to imagine the impossible and to aspire to innovate. Would people have appreciated the technological features of Apple products without their unique visual looks, the ease and beauty of their interface design and their convincing talks and elegant advertisement? S, T, E or M may be magnificent, but without the “A”, there would just be no outlet for it [37].

![Figure 3 STEAM Pyramid by Yakman [38]](image-url)
Discussion has arisen among museums about Leonardo da Vinci. Was this genius man an artist or a scientist? In our modern age, it seems impossible to be a great artist and scientist at the same time. Our knowledge of the world has increased so much that it suppresses the imagination of many people. The work of Da Vinci, however, proves that he needed science to create artistic masterpieces, and used art to document his inventions and anatomical drawings [39]. Albert Einstein believed that “the greatest scientists are artists as well.” Besides his work as a scientist he had a passion for playing the violin and the piano. “When I examine myself and my methods of thought, I come close to the conclusion that the gift of imagination has meant more to me than any talent for absorbing absolute knowledge*, he explained to a friend [40, pp. 245, 22]. He worked intuitively before he expressed himself logically, having music as his guide to new and creative solutions. “The theory of relativity occurred to me by intuition, and music is the driving force behind this intuition. My parents had me study the violin from the time I was six. My new discovery is the result of musical perception” [41, p. 90]. With this, Einstein shows again how art can have a positive influence on science and mathematics, but also engineering and technology. STEM education is basically logic driven learning, but if STEAM can stimulate children to use their imagination and feel confident to follow their intuition, more great inventions are ahead of us.

2.9. STEM AND STEAM IN PRIMARY SCHOOLS

Primary school is a good starting point to introduce STEM and STEAM education. Its instructions and outcome, however, will – and should – be different from secondary level education. A child’s learning process benefits from interaction with tangible objects. Although computer are useful education tools as well, interaction with physical objects trains motor skills and encourages collaborative play such as competition and cooperation [42], [43]. This way of playful learning, enables children to gain knowledge and actively practice valuable skills while having fun [19]. According to Rogers and Portsmore [30],

*elementary school students are capable of beginning to learn about important physics concepts (friction, forces, etc.), programming concepts (go to statements, wait statements, etc.), and math concepts (reading graphs, modelling, decimal numbers, etc.) much earlier than expected when represented in the context of engineering design projects.*

Unfortunately, STEM disciplines usually aren’t priority in primary school. This attitude causes that pupils have a hard
More and more private companies focus on the development of tangible educational toolsets and materials. Time understanding the importance of STEM subjects and the careers it can lead to. Tytler [44] analysed multiply studies showing that the majority of children decide whether to choose a STEM related career before the age of 14, based on early experiences. Engaging older children becomes progressively harder. Hence, primary school education has a crucial impact on children’s future professions – and their impact on the future.

2.10. COMPETITORS IN EDUCATIONAL TOOLSETS

The need for good educational support was mentioned multiple time in the previous sections. Recently, more and more private companies focus on the development of tangible educational toolsets and materials to encourage 21st century teaching and learning through STE(A)M education. A short review is given of prominent competitors focused on the field of electronics and primary school children.

Table 2 Competitors in educational STEAM toolsets compared in duration and price

<table>
<thead>
<tr>
<th>Toolset</th>
<th>Age</th>
<th>Size</th>
<th>Duration</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEGO Education WeDo 2.0 Classroom Pack [45]</td>
<td>7+</td>
<td>16 pupils</td>
<td>40+ hours</td>
<td>€1217,37</td>
</tr>
<tr>
<td>littleBits STEAM Education Classroom Pack [46]</td>
<td>8-14</td>
<td>16 pupils</td>
<td>16+ hours</td>
<td>€1399,96</td>
</tr>
<tr>
<td>Bare Conductive Workshop Pack [47]</td>
<td>12+</td>
<td>15-20 pupils</td>
<td>8+ hours</td>
<td>€478,10</td>
</tr>
<tr>
<td>Chibitronics Circuit Sticker Classroom Pack [48]</td>
<td>8-10</td>
<td>30 pupils</td>
<td>2 hours</td>
<td>€98,66</td>
</tr>
</tbody>
</table>
LEGO Education WeDo 2.0
LEGO Education has various classroom sets to promote STEM education and 21st century skills. WeDo 2.0 Classroom Packs [45] are a combination of LEGO bricks, sensors and motors, child-friendly visual programming software and lots of projects to enhance pupils’ skills in science, technology, engineering and coding. It includes all educational support, from step-by-step instructions for pupils, to fully integrated assessment tools and an e-learning program for teachers.

littleBits
littleBits [46] is a system of small circuit boards that snap together with magnets without soldering, wiring or programming. Each electronic module has one unique function (light, sound, sensors, buttons) that can be combined to easily make large circuits. littleBits’ STEAM Education Classroom pack aims to engage pupils with electronics, to think creatively and practice problem solving skills. Educators can use the Teacher’s Guide as a supporting document – no experience is needed. The challenges are linked to NGSS and the Common Core standards of the United States.

Bare Conductive
The Bare Conductive Touch Board [47] is an Arduino-compatible microcontroller with the ability to turn almost any material or surface into a touch or proximity sensor. It comes preprogrammed as an MP3 player, but by changing the code it can have other outputs as well. Bare Conductive’s Electric Paint is conductive paint to paint circuits and sensors. The Workshop Pack introduces pupils to circuits - and optionally programming- to make their projects come alive. It is supplemented by online available lesson plans and templates.

Chibitronics
Chibitronics’ circuit stickers [48] are adhesive LED stickers that can be combined with conductive tape to draw circuits on paper or other crafts. With the Circuit Sticker Classroom Pack teachers can introduce pupils to simple electronics concepts, such as parallel and series circuits while making interactive artworks. Chibitronics provides lesson plans online with templates, instructions and references to ISTE and NGSS standards.
3. CONCEPT DEVELOPMENT

3.1. FIELD RESEARCH

No matter how valuable an education tool or STEAM project can be for a child’s future, if educators are incapable of teaching or assessing it, or regard it as irrelevant, too expensive or time-consuming, it is unlikely to have any impact. To get a better understanding of the current situation concerning 21st century skills and education in Belgian primary schools, several people were interviewed. The key findings of these interviews are:

- Primary school head teacher Jelle Jacobs pointed out that projects work best when they are related to the thoughts and interests of children. They get triggered by what happens around them.

- Mark Vandeweyer, head coordinator of a Lego Education Innovation Studio, adapted the Lego Education program to Belgian curriculum goals. He emphasizes the aspects that can make or break a STEM project: (a) the time available to work on the project, (b) the number of pupils in a class group to work individual or in teams (c) the prior knowledge of pupils and teachers about the subject and how the project can extend it, (d) the equipment that must be available to accomplish the project and (e) the access to Internet and other multi-media devices that are required for the project. Further, he notes that instructions must be clear and understandable for children.

Similar to the findings in chapter 1, both men indicate that Belgian teachers usually have limited knowledge about STEM topics and new technologies. They will rather avoid organising interdisciplinary projects and teaching new subjects which are not interesting or complicated to them. However, when they get clear instructions and background information or a preliminary teachers training, teachers will be more confident to give it a try.

Another criterion to keep in mind, is the limited budget of primary schools. A project should either be reusable or use resources that are already available in the classroom. Schools, organizations or city governments often put resources together to buy new educational tools. The toolkits move from school to school and are used by multiple classes.

Further, STEAM education can head in many directions. The focus often varies, depending on the technologies that are used. Since this thesis project is organised in cooperation with Microduino, the mCookies modules should have a prominent place in the project.

During the idea generation, different project types were considered. Toolkits can be designed to teach a variety of short independent project. The LEGO Education Packs and littleBits STEAM
Education Pack are examples of this approach. The projects usually don’t take longer than several hours, so pupils are more likely to stay concentrated and engaged and results are quickly visible. Another way to teach pupils diverse skills and knowledge is organising one interdisciplinary project which pupils work on over several days of weeks. As they gain knowledge about the different aspects, the project results get more advanced. It gives pupils the chance to reflect on their work and adjust it before the project is done. Even though the learning process is more important than the results, pupils also feel prouder after finishing a long term project. After all, the things that linger after they’ve forgotten what a teacher taught, are the achievements that were meaningful to them, and the hands-on investigations that they did to accomplish them.

Keeping these restrictions and advice in mind, many concept ideas were created. The concept explained in the next section, had clearly the most potential to become a challenging STEAM project, connecting electronics and programming with creativity.

### 3.2. A SMART MINI-THEATRE

Children feel more confident to learn new things, like programming, while experimenting with familiar objects (see 2.3.2. Playful and creative learning). Since mCookies are compatible with LEGO, a project combining them would be an obvious and simple solution. LEGO bricks, however, are rather expensive and children need a lot of them to create freely. Schools are on a limited budget, so another building material, which is cheap and available to nearly all schools worldwide, was chosen for this project: crafting supplies.

As a child, I really enjoyed tinkering and crafting with my friends. Every year, we made a handcrafted puppet show for our classmates. As an engineering student surrounded by technology, I imagined what it would have been like if we had electronics to enhance our mini-theatre. Inspired by this idea, I explored the possibilities of a smart mini-theatre as a STEAM project. It could be a unique, enriching concept to introduce children to electronics and programming in a fun and tangible way. The mini-theatre project would consist of theatre construction kits including Microduino’s mCookie modules, instructions for teachers and pupils and an online sharing platform. Each group of three to five children uses one mini-theatre kit to build a play together.

The process of creating a table top mini-theatre is a long-term project that fits perfectly in the interdisciplinary approach of STEAM education. By letting characters pop up on stage and backgrounds change automatically, children practice engineering and technical skills. Crafting the stages, props and characters is visual art, but is not the only artistic skill that is involved in creating a theatre show.
Children also practice spoken word, such as articulation and intonation. By recording the dialogues, the mini-theatre gets more attractive and pupils improve ICT skills. Programming the sequence of the story, involves logical thinking and math.

Besides STEAM subjects, literacy is another major component of the project. By inventing a story for their mini-theatre, children enrich their vocabulary, improve writing and communication skills and stimulate their imagination. It encourages pupils to collaborate and share ideas, concepts and experiences. Besides, research has shown that girls show more interest in learning computer programming when it is used for the purpose of storytelling [49]. It enhances their stories and allows girls to share them with friends and classmates. Plus, the results of a first programming lesson are often difficult to appreciate for non-programmers. Stories, however, can be enjoyed by anyone.

In programming classes and STEM disciplines in general, a gender difference is often noticed. Boys are more familiar with construction toys, cars, robots and science topics [50]. Rogers found that girls have less experience building with LEGO than their male classmates have [30]. LEGO is commonly used in engineering classes and many educational tools for programming are robots. As a result, boys feel more confident and courageous when taking part in STEM activities. The mini-theatre concept is totally different. All children, either boys or girls, have written and listened to stories before. They also have taken part in tinkering and crafting activities since kindergarten. Hence, this project strives to be gender equal and stimulate both boys and girls to actively take part in the whole process of making.

Further, the project integrates many 21st century skills. The four competencies of WEF’s model (critical thinking, creativity, communication and collaboration) shown in Figure 2 are strongly encouraged. Besides, a long-term project also requires pupils to show persistence, leadership and take initiative to reach their goal.

Finally, a STEAM project should be fun. The mini-theatre fosters imagination and creativity of children. By storyboarding, sound recording, tinkering and programming, every group will finish with a unique product that reflects their personality and abilities. After all, learning valuable skills and competencies, is the project’s goal, but showing a magnificent theatre play is the ultimate goal of children.

3.3. IDEA GENERATION

The idea of telling a story with crafting materials is not new. Making dioramas and theatres in shoeboxes is a common activity in primary schools (Figure 4). However, the use of DIY electronics to control the story, is quite new.
There are many opportunities to integrate electronics, such as mCookies, in a storytelling machine. During a more detailed idea generation of the tangible mini-theatre, a lot of ideas came up for the usage of electronics. Besides controlling light and sound, it could move characters on stage, let them disappear or change the background during the play.

Thinking of a real theatre and a puppet theatre, the stage itself is usually static, like a box or a room in which decoration and characters are placed. Anyhow, for some musicals or theatre productions a revolving stage is created. It is a platform that rotates to speed up the change of a scene during a play.

This concept led to the idea of moving away from the typical box-shaped theatre. A revolving mini-theatre has the advantage of creating up to four unique theatre stages, which gives children the possibility to design and build the decor as a team or individually.

The integration of electronics can result in great projects, but by adding up features, complexity will increase as well. Since most children have never used electronics or programmed before, the mini-theatre shouldn't be too overwhelming, though be open-ended and challenging for them. Three features were selected:

- a servo motor to rotate the platform
- sound modules, including an amplifier and speakers to play recorded dialogues and sounds
- NeoPixel LEDs in and around the stages

This combination of motion, sound and light gives pupils the freedom to create both simple and advanced plays.

3.4. CONCEPT GENERATION

There are various options for teachers to connect the mini-theatre to topics covered in class. This can reach from making a play about a historic event or natural phenomena, to learning about theatre and spoken word. Pupils can
CHAPTER 3
CONCEPT DEVELOPMENT

By rebuilding the theatre play, children automatically think about the meaning of it. For instance, a theatre play that they attended with school. When a theatre maker heard about the mini-theatre concept, he explained that it could be a useful tool for children to reflect on their abstract theatre plays. By rebuilding the play, children automatically think about the meaning of it. The same could be done with a book that they have read. Teachers can also let pupils use the computer to do research about their subject matter or even take them on a trip to the local library or maker space.

Depending on the choice of the teacher, the mini-theatre could be narrative, informative or a combination of both. Children could create stories from their own imagination, or rebuild and adapt well-known stories, like fairy tales. They could also talk about relevant events and experiences, such as a wedding they attended, a field trip or a summer camp. Beside these narrative topics, teachers could ask pupils to use it for their show and tell presentation or to visualize an article they read in the newspaper. The possibilities are endless. During the user tests, described in the next chapter, several contexts for the project are tested by children.

3.5. CONCEPT TESTING

Prior to the further development of the project, children’s response to the project idea was evaluated. Four girls of age 9 to 10 were invited to tinker a mini-theatre according to the following schedule:

1. Introduction to sound recording and Microduino’s electronic modules
2. Brainstorm for a story idea
3. Sketch the scenes on paper and divide the work
4. Tinker the stages
5. Write the story
6. Record the story
7. Test the electronics
8. Play

An early prototype, including four separate stages connected to a base and a servo motor, was used during the workshop. Since there wasn’t developed an appropriate programming plan yet, programming was not integrated in the workshop. The girls could operate the motor and the audio with buttons to rotate it clockwise and counter clockwise, play sound and pause it.

There was no restriction on the type of story the children could tell with the mini-theatre. It could be informative (e.g. a story they heard about in the news or a presentation in school) or narrative (e.g. an invented story or a well-known children’s story). In this way, their brainstorm ideas and preferences could
be observed. The girls clearly preferred telling a fairy tale. They listed numerous stories and finally voted to make 'The Three Little Pigs'. The process of writing and tinkering is shown in Figure 6.

The test took one afternoon. The facilitator observed the children's actions and behaviour. A detailed observation report is added to Appendix 1. In conclusion, the children reacted positive to the project concept and most of them engagingly completed all steps. They felt confident, yet challenged while tinkering three-dimensional characters and props. Triggered to find a solution to connect everything to the stages, they inspired each other and worked together as a group. Recording sound was new to them, but they truly enjoyed it. To succeed, they had to be concentrated and take part actively in the dialogues. Even though teamwork was challenging sometimes (especially while using the computer), with some help of the facilitator from time to time, they were able to solve disputes and proudly finished the very first mini-theatre by the end of the day.
3.6. STORYTELLING BENCHMARKS

LEGO Education StoryStarter
The StoryStarter of LEGO Education [51] is a playful learning tool for primary school children (age 7-11) to develop strong language and literacy skills by using storytelling. Pupils work together to create and build stories with LEGO building plates, bricks and figures. The scenes that they create become the foundation for writing, sharing and listening. One StoryStarter Brick set contains all the elements to equip up to five pupils, including a StoryStarter spinner. This tool aims to enhance children’s creativity and injects variation into the story-making process. Finally, pupils can use the StoryVisualizer Software to write their stories and upload photos they’ve taken of their modules. LEGO Education provides a full curriculum pack for teachers, including curriculum standards and lesson plans.

Pinbox 3000
Pinbox 3000 [52] is a table top pinball machine made out of cardboard. After pupils have assembled the pinball machine, they can customize their play boards with crafting supplies. By adding electronics, like lights and buzzers, the Pinbox 3000 becomes even more interactive and playful. Educators can use it in their STEAM lessons to teach pupils about design, engineering, electronics and even storytelling. Pupils are challenged to tell a story through the elements that they add on the play board. Pinbox 3000 contains documentation for teachers, including curriculum suggestions, design templates and exercises.

StoryJumper
StoryJumper [53] is a free web-based tool for pupils to create online books. Besides the ability to write a story on digital pages, the application includes many background scenes, props and characters to visualize the story. Pupils can also upload their own photos and images. Finished stories can be viewed on a computer or interactive whiteboard in the classroom, but can also be printed off on paper or purchased as a real book. The website provides a workbook for teaching pupils the creative writing process. After completing the worksheets, pupils have complete story arcs that they can develop into rich, detailed stories with the online application.
Scratch

Beside StoryJumper there are many more digital storytelling tools available online. Most of them are limited in use or don’t look attractive to children. With visual programming language Scratch [54] pupils can easily create animations, games, interactive art and music. Users can program and design objects and background, which makes Scratch a great tool for digital storytelling. Depending on their programming skills, pupils can make simple or advanced animations of their stories.

Comparing the mini-theatre to the benchmarks:

Based on Internet research and own intuition the mini-theatre concept is compared to these storytelling benchmarks in the table 3.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Creativity</th>
<th>Storytelling potential</th>
<th>STEM-related</th>
<th>Tangibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-theatre</td>
<td>★★★★☆</td>
<td>★★★★★</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Lego Education StoryStarter [51]</td>
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<td>★★★★★</td>
<td>no</td>
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<tr>
<td>Pinbox 3000 [52]</td>
<td>★★★★☆</td>
<td>★★</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>StoryJumper [53]</td>
<td>★★</td>
<td>★★★★</td>
<td>no</td>
<td>sometimes</td>
</tr>
<tr>
<td>Scratch [54]</td>
<td>★★</td>
<td>★★</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>
4. PRODUCT & PROJECT DEVELOPMENT

4.1. METHODOLOGY

So far, the project’s development was mainly influenced by scientific research and teachers’ requirements. Nevertheless, children should have an important stake in the design process, since they are the principal users. Therefore, the experience of children with the product took a central place in its development. This design approach is called user-centered design (UCD). It describes a design methodology in which end-users, in this case children of age 9-12, influence how the design takes shape. There are various methods to involve users in the design process, reaching from simply consulting users about their needs to usability testing, or even letting them participate as co-designers during the development of the product [55].

Regarding Figure 8, to take the STEAM project from a concept to a ready-to-launch product, the design should go through an iteration process based upon user testing. The design can only get more detailed and satisfying when users are involved throughout the whole process of designing. Therefore, usability tests were organized frequently during the entire design of the tangible medium and the content development of the project. According to Dumas and Redish [56] a usability test has five typical characteristics:

- Improving the usability of the product is the main goal.
- The participants must represent real users.
- The participants should accomplish real tasks.
- An observer records what participants do and say during the test.
- The obtained data should be analysed to fix problems.

All the usability tests that took place are described throughout this chapter. The goal was to develop a STEAM-oriented project in which children can learn valuable skills and knowledge in an enjoyable way, regardless of education standards and other influencers.
4.2. USER TEST 1: AWESOME PRESENTATION MAKER

4.2.1. Prototype

The prototype for this user test was cut out of cardboard sheets.

Four separate, foldable stages on which pupils can tinker their story

A sheet with cut-outs on which the stages can be fixed

A 3D-printed piece shaped like an upturned table that connects the stages to the servo motor

The base in which the servo motor is inserted. The concept test had shown that the previous prototype was unstable. This base has some upright sides to support the stages and prevent them from tipping over. Support on all sides, however, would cause too much friction.
4.2.2. Workshops

The previously described prototype was tested in a series of weekly workshops with children. The workshops were organised to study the potential of the mini-theatre in a show and tell presentation. The project consisted of four afterschool workshops, which lasted two hours each. Two projects started in the same week at different locations. In this way, the feedback of the workshops organised on Wednesday, could immediately be implemented in the workshops taking place on Saturday.

The projects were planned according to the schedule below:

Workshop 1:
- short introduction of the project
- brainstorm and choosing a topic
- research information about the topic on the Internet

Workshop 2:
- writing the script of the presentation
- tinkering

Workshop 3:
- tinkering
- sound recording
- programming

Workshop 4:
- reflect and make adjustments
- give a presentation for parents and siblings

The Wednesday project had four participants; the Saturday project six. They were all 10 to 12 years old. In total the children represented four different primary schools from the same town. They were split in groups from three to four children. Both projects were led by me, further referred to as the ‘facilitator’. Detailed observation reports can be found in Appendix 1.

The instructions were bundled in a design booklet with fill-in templates, presented in Appendix 2. To avoid arguments about who could operate the computer or write the text, three leadership functions were added to the project. The “project manager” was responsible for the design booklet, the “material manager” took care of all the supplies and the “computer manager” was in charge of the computers or the laptop. Every leadership function was given to another team member every week.

4.2.3. Observation Findings

The Wednesday group started with a brainstorm to find a suitable topic for their show and tell presentation. They wrote down a lot of topics, but most were not relevant. They finally decided to make
a mini-theatre about ‘comedy films’. Unfortunately, they couldn’t find much information on the Internet about the history of comedy films or the best comedy films ever made. Therefore, another strategy was used in the Saturday groups. The facilitator had selected four short videos about global warming from a news website for children. By watching the videos, the participants got information to fill in a template in their design booklets. This was a better structure for children who are unfamiliar with show and tell presentations.

During the second workshop the children wanted to do something active, so they started tinkering the stages. All children decided to tinker one stage individually first and help other team members or tinker the fourth stage together, afterwards.

It was remarkable that a lot of participants only stuck paper shapes on the sides of the stages, instead of making 3D characters and props. Spatial abilities, however, is an important skill for working in technology and engineering contexts [57]. The mini-theatre, however, should stimulate children to be inventive with materials by bending and folding shapes and materials to three dimensional objects. Providing crafting supplies in all shapes and forms, like small household items, can motivate children to use the space that each stage provides. Examples of previously made mini-theatres can inspire them as well.

Writing the text of their presentation was the most difficult - and least pleasant – activity for nearly all children. Especially the groups of the Saturday project...
struggled with summarizing the information about global warming, even though they had written lists of causes, consequences and solutions in their design booklets. Every team member was asked to write a part of the text according to the stage that he or she had tinkered. It would have been better to let the children work together in pairs. In this way, they could have helped and learned from each other.

Changing the focus to storytelling again, would be another option to address this issue. Instead of making a traditional show and tell presentation, children write a fictive story, using the information that they find about a topic. Teachers can make a list of words or facts that pupils should use in their story.

In contrast to the findings of the concept test, sound recording was not an exciting activity. There weren’t any dialogues, funny voices or sounds to be recorded. As a result, the presentation of the mini-theatres was rather boring for its audience. Again, a storytelling approach would be better.

Also programming didn’t work out well. The code was prewritten in the Arduino IDE. The children only had to copy some lines from a print-out. They didn’t learn much about coding or logical thinking. The mini-theatre should be an exciting, first introduction to the basics of programming. To achieve this goal, a visual programming platform that is suitable for the target group and the project, should be made.

The project didn’t go according to plan either. Activities got switched over workshops, because research took longer and the children wanted to start tinkering as soon as possible. A better project plan would be: research, writing, tinkering, recording, tinkering, programming, presenting. In this way, there is time for the team to reflect on the written part while tinkering, or the tinkering while recording, and still make adjustments.

Finally, it should be mentioned that most participants were filming or taking

Instead of making a traditional show and tell presentation, children better write a fictive story, using the information that they can find about a topic.
pictures during presentation of their mini-theatre, to show it to their friends and family. Filming and video-editing would be a great optional activity for the mini-theatre project. The project video could be shared online on the mini-theatre platform and the school website.

4.3. USER TEST 2: CLASSROOM WORKSHOP

4.3.1. Prototype

For the next user test some changes were made to the prototype. The previous workshops showed that the design of the stages worked well for children. The ability to take the stages apart, is a major advantage. For instance, while one team member has still flattened a stage to paint it, other team member can already stick the sides of another stage together to put props in it. Pupils can put the four stages together in the cardboard plate, take it apart again and reposition them as many times as they want.

A disadvantage of the previous prototype, however, was its inability to test it without connecting a servo motor. Children like to spin the mini-theatre while working on the project, but they can't until the code is written. To solve this problem, the central servo motor was replaced by an axis and gears were added to the new prototype.

Various gear mechanisms were considered. Even though several options were smaller or looked better, a simple, yet educational composition was chosen. Both gears are placed next to each other to emphasize their difference in size, rotational direction and speed. The gear on top of the servo motor is exactly five times smaller than the gear in which the stages are placed. Since the bigger gear
rotates slower than the servo, it is easier for children to set the right variable to make the mini-theatre revolve exactly 90° after every scene.

The prototype was laser cut of cardboard boxes, because it was the cheapest, fastest and most environmental material available. All components could be connected without glue or tape.

Children usually learn about gears in mechanical devices at the age of 10 [58]. Therefore, the mini-theatre creates the perfect opportunity for teachers to teach (again) about the concept of gears.
4.3.2. Workshop

A mini-theatre project was organised with the 5th grade (age 10-11) of a local primary school. Ten girls and eleven boys took part in the user test. They made teams of four to five members. The teacher asked each group to think of a fictive story for their mini-theatre. Three groups chose a fairy tale, one group wrote the story of a musical they had seen and the fifth group invented a story taking place in the world of Minecraft. The children could write their scripts during language class before the workshop started. Next, I came to their classroom to lead the sound recording and tinkering activities. The instruction booklet for sound recording is added to Appendix 2. The workshop took about three hours. Programming would be done in a later workshop.

4.3.3. Observation findings

Leaving some days between inventing a story, writing it down and recording it, gave the pupils the chance to iterate on their stories. The teacher noticed that one group even decided to write a new story after school time.

The pupils showed more engagement during the sound recording activity than the children of the previous user tests. For example, a boy imitated the voice of a grandmother and some girls were singing musical songs. Most children empathised with their characters. Hereby, it was confirmed again that the mini-theatre project is more suitable for storytelling than show and tell presentations. Since five groups of children were recording at the same, there was a lot of background noise on the recording. External microphones would be useful in this situation.

The teacher had asked each group to bring some crafting supplies with them. In doing so, the children had considered how they would make their stages. The facilitator and the teacher also provided all kind of crafting supplies, including recycled materials and small household items. Many children made three dimensional characters and props, using wine corks, foam balls, matchboxes, PlayMais and cardboard.

Unlike the children in the previous user tests, most pupils worked together as a team during the tinkering activity. Some team members made the characters, some other took care of the background, yet another team member built the props.
or put everything together. This approach was unexpected, but resulted in great teamwork and should be encouraged.

Figure 15 Pupils use all kind of crafting materials to tinker characters and props

4.3.4. Questionnaire analysis

After the workshop 19 children (10 boys and 9 girls) filled in a questionnaire. First, several questions were asked about their experience with language course, storytelling and tinkering in general. Next, the participants could rate the project’s activities and teamwork. For each question five emoticons were listed, from very happy to very sad. The participants could mark them to indicate their feelings about an activity. In the analysis of the results, these emoticons were linked to a number from zero to ten. 8 and 10 stand for enjoyment. 0, 2 and 4 indicate sadness or boredom. 6 means that the participant was okay with the situation, but felt neither happy nor sad doing it. The emoticons and their corresponding scores, are shown in Figure 16. The questionnaire and its results are presented in Appendix 3.

Figure 16 Emoticons in the questionnaire

Language and storytelling

- 8 out of 19 pupils don’t enjoy language course and writing stories (score 0-6), but all 19 pupils indicate that they enjoyed writing a story for their mini-theatre.

- Almost all pupils point out that they helped their teammates during the story writing activity. Most comments emphasize that they worked together as a team.

- The questionnaire data reflects that all children truly enjoyed sound recording for their mini-theatre. Many children mention that it was funny and cool to imitate different voices. Someone wrote that it was also difficult sometimes.

all children indicate that they enjoyed sound recording
Conclusion
The results of the questionnaire show that the mini-theatre can have a positive impact on children's attitude towards languages and writing. In general, sound recording is engaging and fun activity, but some pupils will find it difficult. This is especially true for shy children and team members that don’t get along with each other. All the children of this class indicate that they like tinkering, which is rather unusual for their age. The pupils also state that they are able to make decisions as a team. These results are just an indication of the potential of the mini-theatre project. However, a larger audience from different schools, ages and backgrounds should be questioned to prove it.

4.4. USER TEST 3: STORYTELLING AT THE LIBRARY

4.4.1. Prototype
Until now, corrugated cardboard was used for all components of the mini-theatre. It is a cheap material and easy to get. The cardboard gears, however, were quickly damaged by some children. Simply making it in another material would cause new problems, so the decision was made to completely redesign the mini-theatre kit.

Tinkering
- All pupils, boys and girls, state that they like tinkering.
- Everybody enjoyed tinkering the mini-theatre. The comments show that it was a great experience.
- More than one fourth of all pupils point out that tinkering was their favourite part of the project.

Teamwork
- 10 out of 19 pupils indicate that their team decided together about the character they could play. Other students they decided for themselves, or one other team member or all other team members made the decision. Everybody was okay with playing their assigned character.
After the previous user test, the teacher had to store all the mini-theatre until the next activity. A little component was added to make the new prototypes stackable.

Since there were some battery issues when combining the servo motor with the audio modules, the new prototype uses two mCookie Core modules. By placing the mini-theatre in the middle of the table, a team can split in pairs and each take care of one part of the programming: audio or motion.

The new prototype was made of wood in order to increase its durability.

To make the mini-theatre reusable, the stages are not included anymore. Two wooden shapes that represent the bottom plate and the wall can be outlined on cardboard and cut by the pupils. In this way, they can make as many stages as necessary.

The central axis is replaced by a system in which the circle-shaped upper part of the prototype can be placed and rotate in the grooves of the lower part. The middle of the theatre is open for wires that connect LEDs on the stages to the mCookie modules.
4.4.2. Workshop

A small class of 6th graders (age 11-13) was invited for a mini-theatre workshop at the local library. The workshop covered an entire school day (5 hours). Four girls and three boys took part in the test. They went through all activities of the workshop, including programming with the new visual programming interface. Yet, this was only a pilot test, because the platform was brand new and the instruction were not ready yet. More information about the programming platform can be found in section 4.5 User test 4.

The children were asked to base their story on a book that they could choose from the library. Since the time was limited they were suggested to choose a picture book and build a mini-theatre play for the kindergarten of their school. The observation report of this workshop is included in Appendix 1.

4.4.3. Observation findings

The teacher divided the class in two teams. During the workshop, she often coordinated the work of one team. This behaviour influenced the teamwork and the results of this team. The team that didn’t get help, was unable to finish their mini-theatre. In the afternoon, some team members were less motivated. Splitting the project over different short workshops would still work better.

The pupils got some help during the scriptwriting activity. They had to think critically about story of the book, like “which scenes were the most important to make a short theatre play?”. A template with guiding questions about main characters and events, would be a good support.

Unexpectedly, one group struggled with sound recording. They were very critical for each other and made fun of every misspoken word. Since these children were older than the participants of the previous user tests, they cared more about their public image when their voices were recorded. By practicing and empathizing with their characters, however, they gained self-confidence.
Especially the boys enjoyed programming their mini-theatre. They were able to remake an example that the facilitator gave them. The instructions for the next user test should be made in such way that both genders feel equal and ready to start programming.

The prototype, however, turned out too big and didn’t work. Because of too much friction the gears got stuck and the mini-theatre didn’t rotate. The audio didn’t work flawless either.
4.5. USER TEST 4: PROGRAMMING AND REFLECTION

4.5.1. Visual programming interface

Previous tests showed that the mini-theatre was in need of a programming platform suitable for its target audience. For the average child computers and smartphones are fun tools. Education comes much later. Getting children excited about programming might take some doing, because logic needs a bit of time to develop. Imagination and creativity arrive first, therefore using creative tools to get children passionate about programming is important.

Microduino already started with the development of Mixly, a visual programming interface based on Blockly. Blockly is a recent open source project of Google, and one of a growing number of visual programming environments. It is similar to Scratch in its visual approach to drag and drop objects (script blocks) and understand the program flow. In the back end, it generates code (Python, JavaScript, Arduino, et cetera), but the children don’t have to know the syntax. They only have to provide the logic and assemble the blocks of the program. One of the differences with Scratch is that Blockly is meant to be adapted for different code generation cases. It however always retains most of the logic in a visual manner that children will need later on, when starting real programming. Other educational tools using Blockly are MIT’s App Inventor [59] to create applications for Android, and the Dot and Dash robots [60] by Wonder Workshop.

![Figure 20 Dot and Dash coding environment based on Blockly](image)

Mixly didn’t include all the blocks to control the rotation of the mini-theatre. Moreover, it was not available in Dutch yet. Ingegno offered to include the functions for the mini-theatre in the platform they were working on. They also adapted Blockly for the generation of Arduino code, creating Blockly4Arduino [61], a fork from ArduBlockly [62]. In Blockly4Arduino, blocks have been added to better visualize working with Arduino and Microduino parts. Care has been taken to keep the interface sufficiently simple for 10 year olds.

To initialize the mCookie modules, a link was made to the stackable nature of the tangible modules. Each module is represented by a block on the Blockly4Arduino platform. Children getting children excited about programming might take some doing, because logic needs a bit of time to develop.
should virtually stack the modules together before they start coding (Figure 21). The interface also shows the corresponding Arduino code, so children can see what happens behind the blocks. Next, the code can be directly uploaded to the mCookie Core module or copied to the Arduino IDE.

4.5.2. Workshop

A final workshop was organised with the same group of children that took part in user test 2. During the first workshop the teams recorded the sound of their mini-theatre and started tinkering the stages. Most groups didn’t finish yet, so they could continue their work in this workshop. The main focus of the workshop, however, was programming with the Blockly4Arduino platform. Each group could use one laptop. Since the latest prototype didn’t meet its expectations, the previous prototype in cardboard was used again for this workshop.

The instruction booklet is included in Appendix 2. The workshop lasted for three hours again. The observation report is Report 6 in Appendix 1. The project ended with a final presentation of all mini-theatres.

4.5.3. Observation findings

The pupils were very motivated during the programming activity. Now and then, arguments arose among teammates, but in general they all worked together as a team and used the instruction booklet.
actively. Every group was able to make the code to rotate the mini-theatre exactly 90 degrees at a time. Even though some computer issues occurred during the workshop, the children stayed calm and engaged.

All children were excited when they could continue tinkering the stages of their mini-theatres. Even the teams that finished their mini-theatre during the first workshop, were making adjustments to their props and characters. This suggests again that is it better to organise two short activities, so children can overthink their work and have the time to improve it if they want.
4.5.4. Questionnaire analysis

The day after the workshop the children filled in a short questionnaire. The questions were similar to the previous questionnaire, but focused on programming and all activities in general. The same emoticons were used to gauge their feelings about the project. The questionnaire and its results are included in Appendix 3.

**Programming**

- 7 boys and 1 girl indicate that they have programmed before. Only one of them writes that he often writes code. The others have made a drone, robot, Scratch project or forgot what the project was about.
- All children give a high score for enjoyment of programming. Comments show that it was quite difficult, but they liked doing it.
- Almost everybody indicates that they could support their team during the programming activity. Comments show that most teams divided the work and everybody helped somehow.

**Project as a whole**

- 5 children state that programming was the most difficult part of the project. Others say nothing was really difficult. Some children also experienced difficulties with tinkering (3), using the computer (1) or managing the presentation (1). Four didn’t answer the question.
- Most pupils chose tinkering or sound recording as their favourite activity. Three children wrote everything was fun. One girl states that using the computer was the most enjoyable activity, but nobody chose programming.
- Of all pupils who answered the question: “What was difficult for you?”, a third of them wrote programming. Remarkably, 11 of 19 pupils also particularly state that they learned programming during the workshop.
- All children would like to redo the project. If they got a second chance to make the mini-theatre, most of them wouldn’t make significant changes to it. Some say they would choose another story.
Conclusion
The mini-theatre was an enjoyable, yet educational project for all pupils. Programming is a rather uncommon activity in the classroom, but when it is placed in a meaningful context, children really enjoy doing it. As expected, tinkering was their favourite part of the project. It is the most hands-on activity. Children can create freely, be part of a team – and get the chance to use a glue gun. Even though some children indicate that tinkering was also challenging for them, they still enjoyed it. Nevertheless, these results are just a presumption of the success of this mini-theatre project. More classes should take part in it to get reliable results.

4.6. CONCLUSION
During its development, the mini-theatre project was tested by nearly 40 children. In 5 workshops they made 10 different mini-theatres. It led to an iterative process in which every prototype and various project plans were tested.

The project has the most value when it is organised in multiple workshops over several weeks. In this case, children can reflect on their work during the process of making it. They can still make adjustments before the project is finished.

The mini-theatre project works best in a storytelling context. Children can invent their own story, tell a fairy tale, remake a book; the possibilities are endless. Informative topics, however, are less suitable for this project, unless they are addressed in a storytelling manner. Even children who usually don’t like language classes, enjoy story writing for the mini-theatre. An introduction to storyboarding and the typical elements of a story (main characters and events) would be useful.

Sound recording definitely adds value to the project. It is not difficult, but an unusual activity in the classroom and children think it’s great. While they are using the computer in a purposeful way, they practice speaking skills, empathise with their character and gain self-confidence.

Tinkering the stages of the mini-theatre is by far children’s favourite part of the project. It requires teamwork and stimulates spatial thinking, which are both important skills for working in technology and engineering contexts. Crafting supplies, like recycled materials and little household items of all shapes, can encourage creativity.

A new part of the visual programming platform Blockly4Arduino was developed to meet the needs of the mini-theatre project. The visual interface is colourful, easy to use and accessible for children of all programming levels.

The mini-theatre building kit went through several iterations. Every
Prototype was tested by at least seven children. Improvements were made, but the latest iteration turned out wrong. It didn’t work properly and was too big. The prototype will be revised until the final product works flawlessly.

Finally, during the user tests it became clear that children not only want to share their results with classmates, but also with friends, grandparents, siblings and the rest of the world. They are fond of filming their experiences, watching videos and YouTube vloggers. To react to this trend an extra activity can be added to the project: filming and video-editing. The presentation in class provides a valuable opportunity for feedback of their classmates. Each team can use this feedback to make small improvements before filming their theatre play. During computer class, children edit their videos and finally share it on the project’s platform and the school website. In this way they can show off with their mini-theatres and inspire children all over the world.
5. FINAL RESULT

5.1. THE DIORAMA PROJECT

The Diorama Project is a series of transdisciplinary workshops to foster STEAM education in primary schools. By combining familiar subjects, like languages and art, with new topics such as programming and electronics, children develop valuable skills and knowledge in a more fun and tangible way. Pupils team up to write, record and tinker a story. Programmable electronics let their theatre plays come alive. An open source platform provides all the information for teachers to organize the workshops by themselves. They can use it to share their experience and knowledge with colleagues worldwide.
5.1.1. Project plan

The project consists of a series of activities that can be organised independently of one another. Teachers choose when their Diorama Project starts and ends, if they spread the workshops over an entire month or all in one week. They can find all information in the teacher's guide online to coordinate the workshops all by themselves. Some teachers may still lack in confidence to organise a programming activity, since computer issues can always occur. In this case, they can invite someone of the Diorama Team to manage this workshop in their classroom. Of course, they can also ask help from pupils' parents or grandparents who are familiar with computer science and programming.

Every Diorama Project will start with an introduction video to trigger pupils' curiosity and engagement for the project. In the video, a mini-theatre is used to give an overview of all activities they will

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How this project got its name...

During its development, the project's name has changed several times. From 'Smart Mini-Theatre' to the 'Awesome Presentation Maker' and 'Story Teller', it was finally named The Diorama Project. This name was chosen because of the history of the word Diorama. Since the twentieth century, it refers to "a three-dimensional miniature or life-size scene in which figures, stuffed wildlife, or other objects are arranged in a naturalistic setting against a painted background" [64], but it hasn't always been a motionless museum piece. In 1822, Louis Daguerre, a French expert in lighting and scenic effects, invented the diorama theatre. It had almost the size of a small, modern cinema screen. The scenes were built of a series of painted linen panels arranged behind each other. An ingenious system of screens, shutters and skylights manipulated the direction of incoming sunlight to highlight particular paintings. With the result that the scene appeared to change naturally, like winter snow turning into summer meadow or a rainbow appearing after a storm. Later, sounds effects and even live performers were added. Because of their size, the screens couldn't move during the exhibition. To watch two short shows after each other, the auditorium was placed on a massive turning table, revolving the whole audience from one scene to the next [65].

As a tribute to Daguerre's wonderful invention, unfortunately forgotten over time, this project found its name, hoping that children will be inspired to shape the meaning of a 'diorama' in the 21st century.
participate in to build their own mini-theatre play. The video is full of inspiration, tinkering, sound recording and programming ideas that are all explained on the online platform. Children will be excited to get started!

Although teachers are free to plan the workshops according to their own schedule, it is recommended to follow the next order and timing.

1. **Story writing (1.5h)**
   Story writing starts with a brainstorm about all types of stories that children could tell. Which stories do they enjoy listening to? Have they ever seen a theatre play or a musical? Can famous stories be changed? What if Cinderella was a boy? Or what would a birthday party on the moon be like? Whatever they can imagine, they can write. Next, of all story ideas, each team can choose one for their mini-theatre. They learn about storyboarding and the basic elements of a story’s structure. Finally, they write the script of their story.

2. **Tinkering (2h)**
   Before they start tinkering, every team takes a look at their script and storyboard again. Together, they make a plan, so everybody knows what each member is going to make. The teacher could let the pupils do this some days before the tinkering activity, in case pupils want to bring extra crafting supplies for their mini-theatre. The teams start tinkering, but the stages shouldn’t be finished yet after this activity.

3. **Sound recording (1,5h)**
   This workshop starts by listening to audio clips of theatre plays, animation films, stories and dialogues. Pupils hear that some character have a very high voice, some others speak slow, some yell at each other, or use different dialects. This is the art of spoken word and voice acting. It is important that children empathise with their character and use intonation while speaking. After short practice, they record their play with the Online Voice Recorder by 123apps (http://online-voice-recorder.com/).

4. **Tinkering (1,5h)**
   Since they have already written and recorded their stories, pupils have a better understanding of what they want to make. They continue tinkering, implement new ideas, adjust and improve what they had made, and give feedback to their classmates. They should finish the stages at the end of this workshop.

5. **Programming (3h)**
   Everything is ready, now they only have to bring it alive with the mCookie modules. First, the children follow the instructions to get familiar with the programming interface. By doing this, they will end up with a basic diorama that can rotate and play sound. Next, they can choose from a list of features to add light, more buttons or extra sounds. By following specific
instructions, every group enhances their mini-theatre with unique features.

6. **Presentation (10 minutes/group)**
   Each team presents their play to their classmates and teacher. Classmates get the chance to say what they like about the diorama and provide useful feedback.

7. **Optional: Filming and editing (2h)**
   After their presentations, the teams got useful feedback. Teachers can choose how much time they are willing or able to give to the pupils to make small adjustments to their mini-theatres. Next, each group uses a camera or phone to film their play. They can film the theatre as a whole, or zoom in on characters and details. Afterwards, they use a simple video editor, like Wondershare’s Filmora Video Editor [63], to enrich their story with text, visual and sound effects, or adjust volume and brightness. Ultimately, the video is sent to the Diorama platform and shared on the school website.

5.1.2. **Diorama Kit**

Each team of three to five children gets a diorama kit, including

- Instruction booklets for every activity
- A microphone for the sound recording activity
- Microduino mCookie modules
- All parts to assemble the mini-theatre

Since the latest prototype didn’t work properly, a new modular building kit was designed. Its modularity gives children the freedom to build and rebuild many different constructions for the mini-theatre. All parts of the kit are produced by a laser cutter or 3D printer. The laser cut parts are made of PMMA, with a thickness of 3 mm. Besides being a durable material, PMMA is extremely smooth. The parts can slide over each other without friction obstructing its movement. Furthermore, many materials, such as plywood, MDF and cardboard are available in 3 mm, allowing pupils and teachers to create their own parts with a laser cutter at a local maker space or fab lab.
The kit is designed in such a way that the four stages could be replaced by either two or three stages as well. The stages are not included in the diorama kit. Children can cut them out of cardboard sheets by themselves. Hence, teachers can reuse the diorama kits as many times as they want.

Finally, the mini-theatre has some extra fun features for little, future engineers. Between the cardboard stages and the gears, I left about 1.5 cm space to put batteries for wind turbines and disco lights, or all kinds of small stuff that children would like to hide from their stages. Children may also want to get super creative and build more than four stages. They can easily extend their stories by connection multiple theatre kits together!

**Estimated costs**
Based on the price of the mCookie modules and the production cost of the prototype, the material cost of one Diorama Kit was estimated.

<table>
<thead>
<tr>
<th>Components</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microduino mCookie modules</td>
<td>€117</td>
</tr>
<tr>
<td>360° Servo Motor</td>
<td>€5</td>
</tr>
<tr>
<td>Microphone</td>
<td>€3</td>
</tr>
<tr>
<td>PMMA 60x45x3mm</td>
<td>€15</td>
</tr>
<tr>
<td>Laser cutting</td>
<td>€10</td>
</tr>
<tr>
<td>3D printing</td>
<td>€3</td>
</tr>
<tr>
<td>Printed instructions and packaging</td>
<td>€20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>€173</strong></td>
</tr>
</tbody>
</table>

The production of one Diorama Kit would roughly cost about 173 euro. For a class of 16 pupils, the production cost of four Diorama Kit would be 692 euro. As schools would buy more kits, the cost per kit decreases, since more materials and electronics can be ordered together. In that case, however, labour cost should be added as well.

The kit would include the following mCookie modules and components:
- 1 CoreUSB
- 1 Hub
- 2 Audio modules
- 1 Amplifier
- 2 Speakers
- 4 Neopixel RGB LED
- 3 Crash buttons
- 2 Battery management module
- 1 USB cable
- 7 Sensor Cables

Teachers can use these modules for a lot of other projects after they completed the 3 hours programming workshop of The Diorama Project. Children who show interest in electronics and programming can experiment and build other things with it. Microduino also provides numerous tutorials on their website.

Besides the Diorama kit, schools should only provide one laptop or computer for every four pupils.
5.1.3. Programming platform

The mini-theatre is controlled by Microduino mCookie modules. Children can program these modules with Blockly4Arduino. This is a web-based, visual programming application for Arduino developed by Ingegno. To code the mCookie modules, Neopixel LEDs and 360° servo motor, special blocks were developed for The Diorama Project. The application is available at

ingegno.be/01-blockly-4-arduino/

5.1.4. Teacher’s guide

A complete instruction guide will be available for teachers at

github.com/thedioramaproxject

GitHub seems to be the best platform to host The Diorama Project. It is a website allowing developers to collaborate on open source software projects. All files of the project are downloadable for free. Teachers can even collaborate by sending suggestions or reporting mistakes in the project. On the wiki page, they can find all information about the project, as well as a list of education goals, assessment tools, links to example codes et cetera. Since GitHub hosts thousands of interesting projects, teachers can easily get in touch with other projects and software applications beside The Diorama Project.

The instruction booklets and teacher’s guide are available on GitHub from 28 August 2016.

5.2. FINAL CONCLUSIONS

The rapid development of information and communication technologies, is changing our workspace and lifestyle enormously. New jobs have similar key tasks that require a common set of competencies, called 21st century skills. Our education system should equip young people with these valuable skills and competencies, allowing them to become active citizens in our globalized society. Therefore, innovative learning and teaching methods should be implemented in our education systems.

Project-based learning is an educational approach that promotes links among is subjects and addresses transversal themes. Knowledge generation happens through the process of constructing artefacts. Tangible and familiar objects as learning tools also benefit the learning
process of children, just as creativity does. An upcoming 21st century approach to learning is STEAM education, standing for Science, Technology, Engineering, Arts and Mathematics. STEAM projects encourage pupils to apply mathematical, scientific and technological insights and concepts to create smart and innovative solutions to complex questions and real-world problems. Primary school is a good starting point to introduce STEAM education.

Most 21st century competencies can either be supported or enhanced by technologies. The use of technology and the implementation of new education strategies, however, are major challenges for teachers. They need to feel competent and value what they are teaching to make real change. Schools indicate that they feel the need for ready-to-use educational tools to tackle this problem.

To introduced children (age 9-12) to electronics and programming, a revolving, table top theatre was developed during this Master’s thesis. It is the heart of a project in which pupils go through several STEAM-orientated activities in a fun and tangible way. In four user tests, nearly 40 children tested multiple prototypes and project plans. After every user test, changes were made to the design of the mini-theatre.

The knowledge gained from user test, led to The Diorama Project, a series of seven transdisciplinary workshops that not only supports STEAM disciplines, but many 21st century skills. Children learn the basics of coding electronics, practice teamwork skills and spatial thinking. Besides, it triggers their imagination while they use writing and speaking competencies in a fun and meaningful way. Gender equality is one of the project’s strengths, since it starts from storytelling and crafting – activities that both boys and girls are familiar with. The Diorama Project is open source available for every educator or maker worldwide. All information for teachers is easily accessible on the Diorama Github page.

5.3. REMARKS ABOUT MICRODUINO MCOKIE

Before I started a cooperation with Microduino for this Master’s thesis, I had some experience with traditional DIY electronics (Arduino, breadboard, jumper wires...) While working with the mCookies for a long time, I experienced some advantages and disadvantages of Microduino’s modules.

+ It is much easier for children to build an electronic circuit with mCookies, without the hassle of jumper wires
+ The magnetic connection takes the stress of making mistakes away
+ It is open source
- Microduino is a relatively new company and its electronic modules don’t work flawless yet. There are some issues with the battery modules and the audio modules.

- In the current version of the mCookies it is not possible to power the servo motor separately.

- Programming the modules in Arduino is too complicated for beginners. It is extremely hard to make a project from scratch, since you need to have knowledge of a lot of different libraries and elements (audio, Neopixels...)

- Instructions are only in English and Chinese.

Despite some minor issues, I would still recommend to use Microduino mCookies for this project.

5.4. FUTURE WORK

This master’s thesis is nearly finished, but a great adventure is just about to start! It is my mission to let children all over Belgium – and further – experience the joy and excitement of The Diorama Project. Before this can happen, there is still some work to do. In the next months, the introduction video and all instruction booklets will be finalised and tested with children. I will sit together with teachers to improve the Github wiki page and make everything work flawless. New tutorials, videos and tips for teachers and pupils will continuously be added to the platform. A business plan will be made, including a detailed production plan, cost analysis and retail possibilities. Since the Diorama Kits are reusable, they can be rentable to schools as well.

The project can also be adapted to other age groups and contexts. Several libraries have shown great interest for organising workshop with The Diorama Project. Besides, after-school activities in maker spaces and fab labs, STEM academies and museums are an option as well.

The Diorama Project is open-source available for teachers, workshop organisers, children and anyone who likes to tell stories. A basic project plan with the diorama kit was created, but I’m looking forward to see how people can hack it. The possibilities are endless. What if teachers would link it to their classes, create extra workshops, visit a fab lab and let their pupils use a laser cutter or 3D printer? What if they would use other electronics, or no electronics at all? What if pupils would connect all kits together or build a life-size “mini-theatre”? What if, a decade from now, it could become the inspiration for a master’s thesis of another young engineer?

I’m looking forward to see how people can hack it.


APPENDICES

APPENDIX 1: USER TEST REPORTS

This appendix includes reports of the user tests. Comments and findings of the observer during the workshop are shown in italics.

Report 1: Concept testing

Date: 12 February 2016
Participants: 4 girls

Course of the workshop:

The children brainstorm about the story they want to tell. They write all their ideas on a sheet of paper. The girls are immediately into telling a fairy tale. Next, they vote to make a mini-theatre about the Three Little Pigs.

Now, they are asked to decide what the four stages will look like. They make drawings of each stage. There is an argument about who can draw each stage. When the drawings are finished, the decide to make each one stage.

Three girls are very engaged during the tinkering time. One girl is unhappy about the stage she has to make. She makes a poster for the theatre play, instead of working on her stage. She also likes to make the little pigs. All four girls clearly enjoy this hands-on activity. When one girl is finished, she helps her friends. Together they finish all stages in 2 hours.

The children were looking forward to the sound recording. However, they first have to write the script of their story. When they are sound recording, the girls argue again about who can operate the computer. After they solve the dispute, the activity goes very well.

The children don’t have to program the mini-theatre. They can operate it with buttons.
Findings:

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstorm about story ideas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children decide together which story they are going</td>
<td>Not all participants agree with the stage they have to make</td>
<td></td>
</tr>
<tr>
<td>to make</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children decide together which story they are going</td>
<td>Argument about who can draw and operate the computer</td>
<td>Give everybody a clear task, so they know what is expected of them</td>
</tr>
<tr>
<td>to make</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants love sound recording</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The prototype works fine</td>
<td>It is unstable</td>
<td></td>
</tr>
</tbody>
</table>
Report 2: Awesome Presentation Maker (Wednesday workshops)

Date: 17 & 24 February 2016, 2 & 16 March 2016

Place: Saint Amands South Primary school

Participants: 1 boy and 3 girls (all from the same school)

Age: 10-11

Course of the project:

Workshop 1

During the introduction of the project the children talk about one show and tell two presentations that they have done before. Microsoft PowerPoint was used as a presentation tool. In media classes the learnt how to do research on the Internet. Next, the children explored the possibilities of mini-theatre. They like that it can rotate. The mCookie modules attract their attention. They try to stack it in different ways. The facilitator presents the opportunity to try the sound recording website. The boy enthusiastically recorded jokes and short messages, while the girls considered their test words twice before talking to the computer.

The introduction of the sound recording took too long.

The participants are introduced to two leadership functions that will be given to another child every week. One person is the project leader. He/she takes care of the design booklet and reads the instructions. Another child gets the responsibility to take care of all the supplies. He/she checks whether all the computers are shut down and the workplace is cleaned up at the end.

The leaders understood what was expected of them.

The design booklet starts with a brainstorm session. The participants write down a lot of ideas. The facilitator brought some encyclopaedias to get inspired, but the children don’t use them.

Most ideas that the children had listed, were not suitable for a show and tell presentation. They used their imagination and came up with imaginary situations, like “children on the moon”. The facilitator had to remind them that the topic should be informative.

The participants make a selection of their ideas. Arguments occur, but they are able to handle the situation themselves and make a final decision. The topic of their mini-theatre
will be ‘comedy films’. According to the templates in the design booklet, the children write down what they know about their chosen topic. They need some help with splitting the topic into four scenes. Next, they use the internet to research more information about the topic. It is a real struggle, because the children apparently don’t have much experience with using keywords in a searching engine. Besides, there isn’t much information available about comedy films, how it is made and its history for children in Dutch. Some children lose their concentration.

Workshop 2

The participants are asked to make a mind map of the things that they remember from last week. After getting some hints, they remember almost everything that they researched. Next, they continue their research. When they have found enough content, they want to start tinkering instead of writing the script. Each of them tinkers one stage, but they help each other when someone needs advice. Although the stages are spacious enough to build 3D characters and props, most three participants only stick paper on the sides. The facilitator stimulates them to reflect on their creation and reorganise it.

Workshop 3

The workshop starts again with the participants writing down what they remember about comedy films. They children can use sticky notes. The first hour of the workshop, the children finish their stages. The next hour, they use the templates in the design booklet to write the script of the presentation. First they write the introduction and the ending together. Each participant works individually about the content they researched and tinkered. Since the project got behind schedule, there is no time left to start programming.

Workshop 4

The workshop starts with sound recording. All participants feel shy and first want to practice before recording their text. The recording takes longer than planned. Since the visual programming interface is still in construction, the children are introduced to the Arduino IDE. The code is already written by the facilitator; the children only have to adjust some parameters to make the mini-theatre rotate exactly 90°. Errors occur and the code doesn’t work. While the facilitator is trying to solve the problem, the children take pictures of the mini-theatre and each other. They seem to enjoy themselves, even though the workshop is not going according to plan. Finally, the facilitator decides to use a back-up code with control buttons, similar to the code used in the concept test. The children present their mini-theatre to their parents. The final result looks nice, but the presentation itself is rather boring.
Findings:

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants have basic computer skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants like sound recording</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children prefer invented stories over informative subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants understand most of the instructions in the design booklet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information is hard to find</td>
<td>Give the children the opportunity to revise their decision</td>
<td></td>
</tr>
<tr>
<td>Tinkering is too two-dimensional</td>
<td>Show examples of previous made mini-theatres to inspire the participants</td>
<td></td>
</tr>
<tr>
<td>Electronic modules don’t work smoothly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children like taking pictures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The presentation is boring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Report 3: Awesome Presentation Maker (Saturday workshops)**

Date: 27 February 2016, 5, 12 &19 March 2016

Place: Texture, Museum of Flax and river Lys

Participants: 1 girl and 5 boys (from 3 different schools)

Age: 10-12

**Course of the project:**

**Workshop 1**

The participants are familiar with show and tell presentations. They also know how to use a computer and the Internet. Some participants have been in touch with electronics and programming before. The six children are divided in 2 teams. After the introduction to the mini-theatre and the mCookies, every team member is appointed a special task. The “project manager” is responsible for the design booklet, the “material manager” takes care of all the supplies and the “computer manager” is in charge of the laptop. Every workshop they will switch functions. The facilitator tells them about the subject that they are going to present with the mini-theatre: global warming. Both groups will work on the same topic.

First, each group writes everything that they already know about global warming in the design booklet. Next, they use a laptop to watch four short videos about global warming and climate change. The design booklet includes a template to structure the information that they extract from the videos. These videos were preselected by the facilitator before the workshop started. The children watch some videos multiple times until they are able to write down all the information. Afterwards, the design booklet suggested to search more information on the internet if they thought that something was still missing. One group did search for more information. Then, the children could decide who would make which scene. Since there are four stages and every group has just three members, the children have to think of a solution. One group decides that they will make each one stage individually, and the fourth stage together. In the other group, one member will make two stages. The design booklet includes templates for the children to sketch what the stages will look like. They aren’t able to finish the drawings during this workshop.

**Workshop 2**

At the start of this workshop, the children are asked to write down everything they remember about global warming. They get little sticky notes to stick on the template. They want to review what they didn’t remember.
The children show engagement.

Next, they finish their sketches and start tinkering. One boy even brought a motor and a battery for his miniature wind turbine. Another boy builds a boat in a city that’s flooded. Some children put more details in their creations than others, but all of them tinker enthusiastically.

Workshop 3

The workshop starts again with writing down what they remember about global warming and climate change. Overall, they remember more than last week. The participants continue with tinkering their stages. It takes longer than the group on Wednesday since they only have three team members in each group and some children got ill during the workshops. They don’t stick to the plan they made during the first workshop. The children who finished their own stage first, start tinkering the fourth stage. 40 minutes before the end of the workshop, the facilitator asks the children to finish their stages and start writing the text of their presentation. Except of one boy, all the participants struggle with summarizing the information in a text. The facilitator tries to help them, but only one participant is able to finish it before the end of the workshop. Another one wants to continue at home.

*It seems better to let the children work together on writing the text. Then they can support each other.*

Workshop 4

The facilitator has finished the presentation texts for the children. Otherwise, there wouldn’t be enough time to finish the project. Since the visual programming interface is in construction, the children are introduced to the Arduino IDE. Most of the code is already written by the facilitator, they only have to add the lines to make the servo rotate. An example is printed out and the children just have to retype it. Some participants are interested in programming, but they don’t learn much about programming in this way. One by one they record the text that they wrote. At the end of the workshop, parents and siblings of the participants come to see the presentation. The electronics don’t work perfectly all the time, but the children seem not to mind. The presentation however, is rather boring for the nonparticipants. Several children are filming what they made. They really enjoy filming every detail of their mini-theatre.
Findings:

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting information from the videos worked well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants understand the templates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants worked together very well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The sticky notes enrich the brainstorm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The project doesn’t leave enough room for imagination</td>
<td></td>
<td>Writing a fictive story with facts about climate change would be a good combination</td>
</tr>
<tr>
<td>It is hard for children to summarize the information</td>
<td></td>
<td>Children need more background knowledge about writing an essay or presentation text</td>
</tr>
<tr>
<td>A child-friendly programming interface is needed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The participants are not involved in each other’s work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children film what they made.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Report 4: Classroom workshop

Date: 16 March 2016

Place: De Vuurtoren Primary school

Participants: 10 girls and 11 boys (from the same class)

Age: 10-11

Course of the project:

The class was divided in five groups of 4 to 5 pupils. The facilitator got in touch with the teacher to organise the course of the project. The teacher introduced the project to her pupils and let them think of a fictive story for their mini-theatre. Three groups chose a fairy tale, one group wrote the story of a musical they had seen and the fifth group invented a story in the world of Minecraft. The children could write their scripts during language class. The facilitator comes to the class on Wednesday before noon to lead the sound recording and tinkering activities. The teacher is also there to help.

Sound recording

All children are very enthusiastic about the sound recording activity. They understand the instruction booklet. It explains how to use the recording webpage. They try it out in groups of two children. There are not many questions asked. Each team has its script ready so they can immediately start recording. The children empathise with their character. A boy imitates the voice of Little Red Riding Hood’s grandmother. Some girls are singing the songs of the musical that they remake. The pupils clearly have fun, but stay engaged. It is quite noisy in the classroom, so the microphones of the laptops pick up a lot of background noise. One group of girls has an argument about who can operate the laptop. By pushing the laptop back and forth, they lose their previous recordings. They see the consequences of bad teamwork and restart recording peacefully.

Not all groups are finished at the same time. The duration of the stories varies. The groups that finish first can already start tinkering.

*Starting a new activity while not some groups haven’t finished the previous activity, is not the best thing to do. The slower groups may act careless to finish faster.*
**Tinkering**

The teacher had asked the children to bring some crafting supplies with them. The pupils definitely thought about what to bring for their stories. One group had printed images of their characters, another group brought a little Playmobil bed and yarn. The teacher and the facilitator also provide a lot of crafting supplies, including recycled materials and household items.

*It is a good idea to ask the children to think about the supplies they will need for their stages, characters and props.*

Not all groups have the same approach to tinkering the four stages. Even though most groups have four team members and four stages, they don’t make each one stage. Most groups work together as a team. Some team members make the characters, some other take care of the background, yet another team member builds the props or sticks everything together. It is remarkable that there are no arguments during the tinkering activity. Again, some groups finish earlier than others.
Findings:

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time between writing the script and recording it</td>
<td></td>
<td>Time to make adjustments</td>
</tr>
<tr>
<td>Pupils are very engaged and motivated during the activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructions are clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Too much background noise during the sound recording</td>
<td>Try to use an external microphone next time</td>
</tr>
<tr>
<td>Children thought about what they were going to make</td>
<td></td>
<td>Let them draw it before making. They can also make a plan together</td>
</tr>
<tr>
<td>All kinds of crafting supplies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Some groups finish early</td>
<td>Provide additional challenges</td>
</tr>
<tr>
<td>Great teamwork</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Report 5: Storytelling at the library

Date: 22 April 2016

Place: Local Library Bellegem

Participants: 4 girls and 3 boys (from the same class)
Age: 11-13

Course of the project:

A small class of 6th graders was invited for a one-day workshop at the local library. After the facilitator introduces herself and the project, the teacher divides the seven pupils in two groups. The group with four members will later be referred to as “group 4”, the group with three members will be called “group 3”. All children are enthusiastic about the project. The workshop starts with cutting the cardboard stages. Both groups choose a different kind of cardboard, but they are all able to cut it by themselves. From the beginning it is clear that the teacher is helping group 4 a lot. This behaviour may influence the progress and final result of the project.

Scriptwriting

The children will base their story on a book that they can choose from the library. Since the time is limited they are suggested to choose a picture book. Group 4 decides faster than group 3. They already start writing the script of their story. The teacher coordinates the group by asking questions like: “How are you going to start writing? Who are the characters? Where are they? What is happening?”. The children answer the questions, but there isn’t much teamwork going on. They have the idea to let the mini-theatre turn clockwise and counter-clockwise, so the can go back to another stage during the play. The teacher writes the script down.

*The questions that the teacher asks are good to make the pupils think about their story. Integrate these questions in the instructions. Also give teachers the advice to only take action when there is an argument or children struggle with the instructions.*

At the moment that group 4 is almost finished with writing their script, group 3 is still reading their book. They have chosen a longer and more complicated story. The workshop gets unbalanced, so the facilitator asks the teacher to let group 4 slow down and work on their own. She helps group 4 with the structure of their story by asking them: “How does the story start? How does it end? What are the most important events in the story?”. They write the story by themselves.
Practice programming and sound recording

Since group 4 is getting ahead of schedule, the two girls start practice using the sound recording website. They two boys get a short introduction to the mCookie modules and the programming interface. The sound recording website works well, but problems occur during the installation of the Arduino IDE. The children can't test the code that they have written. The facilitator decides to fix the problem during lunch break. Group 4 starts tinkering. When group 3 finishes their script, they are also introduced to the electronics and test them.

Tinkering

After lunchbreak, both groups are tinkering. In group 4 each team member makes one stage. The teacher helps with the props and the characters. They use the printer to print out images of the characters in the book. Group 3 divides the work differently. The boy is making the background of the stages, because he doesn't like using the glue gun. The two girls make the characters and the props. There are no arguments during the tinkering activity, but the boy of group 3 doesn’t seem to enjoy it as much as the girls do.

Sound recording

The girls of group 4 lead the sound recording, since they practiced the application before. The teacher helps again and also plays a character in the play. Sound recording in group 3 doesn’t go so well. They are more shy about recording their voices and making lots of fun instead of taking the activity serious. The facilitator advised them to do it faster, because they were running out of time.

Programming

The boys of group 4 start programming while the girls are still finishing the stages. The facilitator printed out what they have to program. They can do it quite well on their own. Unfortunately, the electronics give some mistakes (sound doesn't play in the right order) and there is too much friction in the prototype. Group 3 is still finishing their stage and doesn't have the time to program their mini-theatre. Both teams present what they made. Some children look disappointed.
### Findings:

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher helps too much</td>
<td>Put a line about this in the teacher instructions</td>
<td></td>
</tr>
<tr>
<td>One team is faster than the other team</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scriptwriting goes well</td>
<td></td>
<td>Include some instructions for guidance</td>
</tr>
<tr>
<td>Children are inventive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructions for sound recording are clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some children make fun of the sound recording</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troubles with the electronics and programming platform</td>
<td></td>
<td>This should work flawless</td>
</tr>
<tr>
<td>Prototype doesn’t work well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not enough time for all teams to finish</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Report 6: Programming and reflection

Date: 27 April 2016

Place: De Vuurtoren Primary school

Participants: 10 girls and 11 boys (from the same class)

Age: 10-11

Course of the project:

This workshop was the final part of the project described in user test 2 and report 4. The workshop planned to start with the programming activity and afterwards give the children the chance to finish their stages and make adjustments.

Each group gets one instruction booklet and one laptop. Even though each group has four to five members, almost everybody stays involved in the activity. One boy of a team with five members, doesn't stay with his team and goes to other teams to help them when questions or problems occur. The teacher and facilitator also help when necessary. Now and then, arguments arise, but there are no major disputes. The instruction booklet is used actively (appendix 2).

When the groups are uploading the code to their mCookie core module, an error occurs on every computer. Since the facilitator can't solve it immediately, the children have permission to start tinkering again. Even the teams that finished their stages during the first workshop, are making adjustments. The children are very happy and excited. Some groups finish earlier than the others.

Prepare an extra activity for groups that finish early, such as making a presentation poster.

After the break, the errors in the Arduino IDE are solved. The children continue programming. When they get the assignment to make the big gear rotate exactly 90° by adjusting the variable of time and speed, every team is extremely focused. They work precisely. The first group that finds the right value, reveals it to the other teams. Fortunately, most teams accidently filled in different speed values, so the time value was different as well. Therefore, the programming activity stayed challenging for every team.

Because of the computer issues, the children didn't have the time to finish the programming activity. The audio was not integrated yet. During the presentation for their classmates, the computer was used to play the audio files.
APPENDIX 2: USER TEST INSTRUCTION BOOKLETS

User test 1: Design Booklet 1
User test 1: Design Booklet 2
User test 1: Design Booklet 3

SUPER COOLE SPEEKSPELT MAKER

[Diagram and text content]

[Additional diagrams and text]

[More diagrams and text]

78
User test 2: Instruction Booklet Sound Recording
User test 4: Instructions Connecting mCookies

1.

2.

3.

4.

Klaar!
User test 4: Instruction Booklet Blockly4Arduino

Project 1:
Laat de verhalenmaker draaien!

Open de programmeeromgevingen

Wat gaan we maken?

Elektronica bouwen en blokken samenstellen

Code schrijven:

Code naar Arduino uploaden

Handleiding

Wat hebben we nodig?
APPENDIX 3: QUESTIONNAIRE AND RESULTS

Vragenlijst minitheater-workshop
16 maart, Basisschool De Vuurtoren

Je geslacht:  M - V  (schrap wat niet past)
Je leeftijd:

Duid aan wat jouw gevoel is bij de vragen.
Je mag op de stippellijnjes meer uitleg schrijven.

Hou je van taal en verhalen schrijven?

Hou je van knutselen?

Diorama: verhaal schrijven en geluid opnemen
Vond je het fijn om een verhaal te schrijven voor jullie diorama?

Kon je goed helpen met de groep?
Wat vond je van geluid opnemen?

…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

Welk personage speelde je? Wie had dat beslist?
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

Vond je dat goed?

Diorama maken
Vond je het leuk om het diorama te maken?

…………………………………………………………………………………………………………
…………………………………………………………………………………………………………
RESULTS

Language and storytelling

Do you like language and writing stories?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Did you enjoy writing a story for your diorama?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

- yes, it was a super unique story
- it was a lot of fun
- It was nice to choose a story with my teammates
- someone else wrote the story
- I really enjoyed it
- It wasn't very difficult

Could you support your team?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

- yes, we divided the assignments
- Not always
- Yes, the others and I had plenty of good ideas
- yes, it was very nice that everybody worked together
- We had a nice team
- yes, i could really help a lot
- we all did the same amount of work

What did you think of recording sound?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

- sometimes it was difficult, but it went ok
- nice and funny
- I enjoyed that we could do different voices
- I think it’s a good idea
**Tinkering**

*Do you like tinkering?*

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All kids like tinkering

*Did you enjoy making the diorama?*

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**

- yes, it was great!
- yes, but sometimes the things we tinkered fell down. It was nice with the workshop teacher.
- It was so much fun, everybody could help a lot

**Teamwork**

*Who decided about the character you played?*

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>our team together</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>myself</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>one team-mate</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>other team-mates</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>no answer</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

*Was it fine for you that you had to play this character?*

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Vragenlijst minitheater-workshop
27 april, Basisschool De Vuurtoren

Je geslacht: M - V (schrapt wat niet past)
Je leeftijd:

Duid aan wat jouw gevoel is bij de vragen.
Je mag op de stippellijntjes meer uitleg schrijven.

Had je al eens ooit geprogrammeerd? JA NEE
Als je ja hebt geantwoord: Wat had je toen gemaakt en welk programma heb je gebruikt?

Programmeren

Vond je het fijn om te programmeren?

Kon je goed helpen met de groep?
Het resultaat

Wat vond je moeilijk?

Wat heb je bijgeleerd?

Wat vond je het allerleukste van deze workshop?

Zou je nog eens zo'n diorama willen maken?

Wat zou je anders doen dan dit diorama?
RESULTS

Programming

Have you ever programmed before?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>NO</td>
<td>3</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

If YES, what did you make and which programming environment did you use?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drone</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Scratch</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Robot</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>I often program</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>forgot it</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>no answer</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Did you enjoy programming the diorama?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:
- yes, it went smoothly
- it was very nice
- it was quite hard
- The teacher explained it very well to me, so I could do it
- yes, I enjoy using the computer
- I liked it, but it was also difficult
- my teammate did everything

Could you support your team?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2 - 0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:
- yes, I had a super nice team
- yes, everybody did a part of it
- yes, everybody could do something
- yes, actually everybody helped
## Project as a whole

### What was difficult for you?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>managing the presentation</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>tinkering</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>using the computer</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>nothing</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>everything</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>no answer</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

### What did you learn?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>programming</td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>a lot</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>recording sound</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>others</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>no answer</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

### What was the most fun of this workshop to you?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>tinkering</td>
<td>4</td>
<td>1,5</td>
<td>5,5</td>
</tr>
<tr>
<td>recording sound</td>
<td>0</td>
<td>3,5</td>
<td>3,5</td>
</tr>
<tr>
<td>presentation</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>teamwork</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>using the computer</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>everything</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>others</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>no answer</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Would you like to make this kind of diorama again?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 8</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What would you do different than this diorama?

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>nothing</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>recording sound</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>tinkering</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>topic</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>no answer</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>