Measuring the Local Viability of Science and Technology Lesson Series

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Final project

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Foreword

In October 2023, I started exploring topics for my master thesis. A colleague of Pre-University informed me there was a chance that I could conduct my master thesis for this organisation. After consultation with my supervisor and Silke Heesen, this was the case! It was decided that I would adjust their science and technology lesson series in such a way that it could foster teachers' self-efficacy and TPACK in science and technology teaching. I enjoyed studying this topic because it allowed me to investigate how I could support teachers in science and technology teaching. Besides, what made the process enjoyable was the help of my first supervisor, Dr. S. Van Der Linden, who made me understand science more and more as the master thesis took shape. She provided me with the right feedback, and I look back positively on this experience! I would also like to thank my second supervisor, Dr. Ilona Friso-Van Den Bos, who provided feedback just before the data collection took place and on my final thesis. I also would like to thank Silke Heesen and my colleagues at Pre-University who helped me during my master thesis. Lastly, I would like to thank the teachers who participated in the study and, not to forget, my friends and family, who offered me great support throughout the entire process of writing my master thesis. I hope you enjoy reading my thesis.

Kind regards,

Anouk

Summary

Since 2020, Dutch elementary schools are obligated to offer science and technology lessons at their schools. However, science and technology teaching is still not embedded at the Dutch primary school. Teachers, namely, still encounter difficulties when it comes to teaching science and technology. First, teaching with technology is what makes science and technology teaching difficult for teachers. Second, Dutch primary school teachers have low self-efficacy when it comes to science and technology teaching. In order to foster the self-efficacy and TPACK of teachers in science and technology teaching, the science and technology lesson series that were made by Pre-University were adjusted in such a way that they could foster a teacher's self-efficacy and TPACK in science and technology teaching. Gradually releasing task difficulty, making and implementing a science and technology lesson, reflecting on science and technology teaching, learning about science and technology teaching, and TPACK were added to the original design of the lesson series. The adjusted lesson series were evaluated on their local viability by examining the added value (existing effectiveness, efficiency, and enjoyability), compatibility, clarity, and tolerance of the lesson series. Results show that the adjusted lesson series could, to a certain extent, withstand itself in the context of Dutch elementary schools' classrooms. Even though both schools responded somewhat differently to the lesson series, the TPACK and self-efficacy of teachers at both schools increased to a certain extent. Nonetheless, some changes should be made to the current design in order to improve the chance that it could be implemented at a Dutch primary school.

Key words: local viability, science and technology teaching, self-efficacy, TPACK

Problem Statement

Although not all Dutch primary schools have done so, they need to incorporate science and technology teaching into their curricula. Since 2020 Dutch primary schools are obligated to offer science and technology lessons at their schools (Techniekpact, 2020). Nonetheless, some Dutch primary schools still only occasionally offer science and technology education (Djoyoadhiningrat-Hol & Klein Tank, 2022). At this point, it is important to clarify that the Dutch term of science and technology is often described as science, which exists out of life science (characteristics of organisms and human health), physical science (which examines objects that show no life; e.g., why does a boat float, how does a light circuit work, what is the freezing point of water) and earth science (which is about the solar system and the characteristics of the earth) (Martin et al., 2008). That science and technology teaching is not yet embedded at the Dutch primary school is represented in the results of TIMMS 2019, since only 45% of Dutch primary school students in 4th grade encountered science teaching during their school years, whereas the international average is higher, namely 61% (Meelissen et al., 2020). Learning about science by conducting experiments also just happened sporadically.

The reason that science and technology teaching needs to be embedded in the curriculum of Dutch primary schools is due to the desire to increase the amount of people who want to choose a technological route in their career and to prepare pupils for living in today's society (Verkenningscommissie wetenschap en technologie primair onderwijs, 2013). Therefore, STEM (science, technology, engineering, and mathematics) courses and related future careers in these sectors need to be better taught in Dutch primary schools. To support the elementary schools in teaching science and technology, science nodes (wetenschapsknooppunten) were founded in 2009 (Wetenschapsknooppunten in Nederland, 2020). The University of Twente is part of these national science nodes with an organisation called Pre-University. To guide teachers in teaching science and technology, Pre-University created science and technology lesson series about sustainability, earth and planet and robotics (Pre-University, z.d.). In the beginning of the current study informal conversations were held with Pre-University. During these conversations information was given about the lesson series. The lesson series are intended to give teachers at Dutch primary schools the tools and knowledge to independently teach and gain experience in teaching the subject of science and technology. However, especially when it came to including technologies such as robots or other difficult technologies, teachers mentioned they would have experienced difficulties teaching these types of lessons on their own. In addition, the teachers did not yet have experience in making a science and technology lessons themselves.

Based on the informal conversations with Pre-University and their desire to give teachers the competence to independently teach a science and technology lesson there is decided that the following design requirements need to be included in the design:

- Create a follow-up for the lesson series of Pre-Universities.

- The intervention should be feasible which means, it should take up more time or employees than are needed in the current situation.
- For the current research it is fine that there will be more interaction, for example by doing an interview.
- Lesson-Up is available to use.
- Use the technological products that Pre-University has.
- Teachers should know how to use technology in their lessons.
- Teachers should have confidence in making and teaching a science and technology themselves.
- Create products that Pre-University can use when the research is done.

The goal of the current study is to provide the participating teachers with the confidence to conduct a science and technology lesson on their own after engaging in the lesson series of Pre-University. In addition, teachers should also be able to use technology during their science and technology lessons once they have participated in the lesson series. The lesson series of Pre-University will be adjusted in such a way that this goal can be achieved. Since, the lesson series in the current study is a newly made intervention which is going to be used at a Dutch primary school, there will be examined how the lesson series function in practice which is part of beta testing (McKenney & Reeves, 2019). There will be examined if the lesson series function in ways that were intended or unexpected. This is done by examining the local viability of the learning environment focussing on the added value, compatibility, clarity, and tolerance of the lesson series.

Theoretical Framework

Science and Technology Teaching

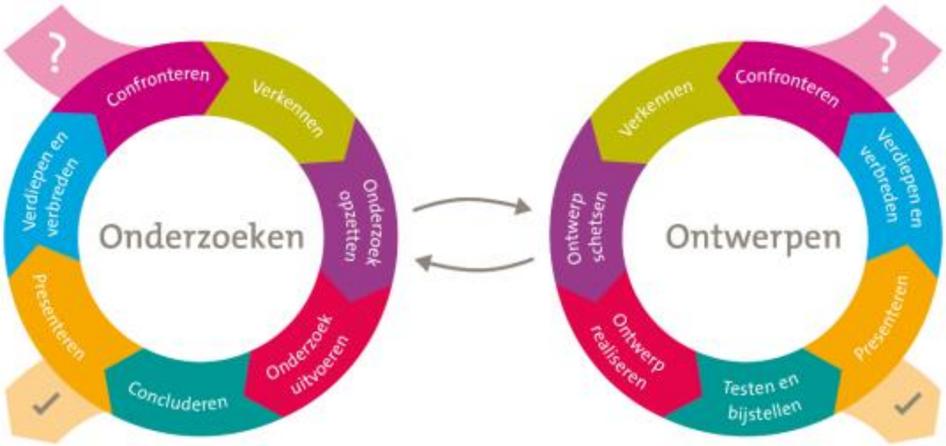
In the first chapter of the theoretical framework, it is described what science and technology teaching entails. In the following paragraphs, the theory behind science and technology teaching is explained. Followed by an in-depth description of the research cycle, design cycle, and the important characteristics of a science and technology lesson. After the difficulties teachers face while teaching a science and technology lesson will be highlighted. The first difficulty that is touched upon includes teaching with technology. Here, the technological pedagogical content knowledge (TPACK) framework is introduced. Secondly, the lack in confidence when it comes to science and technology teaching is explained and the concept of teacher self-efficacy gets introduced.

The Theory Behind Science and Technology Teaching

Science and technology lessons are founded on several ideas. First, Van Graft and Klein Tank (2018) view science and technology teaching as a way of looking at and approaching the world. Wonder and curiosity are the starting point for this type of education: Why is the world the way it is? From this curious attitude questions arise or problems are signalled. The search for answers to these questions or problems lead to solutions in the form of knowledge and/or products. In addition, science and technology teaching offers opportunities for deepening and enriching the content knowledge that is being taught. An effective science and technology lesson includes inquiry teaching (Rougoor-Fiering & Benes, 2020; Van Der Zee et al., 2021). This type of teaching aims to involve students in an authentic scientific research process (Pedaste et al., 2015). From a pedagogical perspective, the complex scientific research process is divided into small, logical connected steps that give students direction and draw attention to the important features of scientific thinking. These steps are called research units, and they together with the connection between the steps, form a research cycle which helps students by discovering new knowledge. In the Netherlands, this involves the research- and design cycle (see Figure 1) (Djoyoadhiningrat-Hol & Klein Tank, 2022; Rougoor-Fiering & Benes, 2020; Van Der Zee et al., 2021; Verkenningscommissie wetenschap en technologie primair onderwijs, 2013). The research- and design cycle consists of seven stages (See Figure 1). It is important to note that the phases of the research and design cycle do not necessarily have to be followed in the exact order (Scanlon et al., 2011). For example, a discussion can follow during any phase, or certain phases can be skipped if students, for example, examine already existing data.

Figure 1

Research- and Design Cycle (Djoyoadhiningrat-Hol & Klein Tank, 2022)



Note. At the left the research cycle is displayed and at the right the design cycle. An in-depth explanation of the different cycles is displayed in the paragraphs below.

The Phases of the Research Cycle

The research cycle consists of the following phases: confronting, exploring, setting-up the research, conducting the research, drawing a conclusion, presenting the results, deepening, and deepening, and broadening the just acquired knowledge (Djoyoadhiningrat-Hol & Klein Tank, 2022). According to Pedaste et al. (2015) the aim of the confrontation phase is to arouse the interest and curiosity of the students in relation to the problem that will be investigated in the lesson. During the exploration phase the subject that is going to be investigated is defined. This can be inspired by a student, teacher, or the surroundings (Pedaste et al., 2015; Scanlon et al., 2011; Van Graft & Klein Tank, 2018). Main concepts of the topic are discussed, and the outcome is a research question that needs to be answered or a hypotheses that needs to be tested. When the research is set up, students choose the equipment, methods, and actions they need to take in order to answer their research questions or hypotheses (Scanlon et al., 2011). This choice will be supported by the teacher, depending on the skill and subject knowledge of the students, and will be mediated by the equipment, and data collection methods available to the students. When conducting the research, students are carrying out their research by collecting evidence, using the methods and equipment previously decided upon. Afterwards the students draw a conclusion, meaning they are answering their research question or hypotheses based on the data they have found. When the students are presenting the results, they are presenting their research to others in the form of a report, poster, or video. Finally, during the deepening and broadening phase the learned content knowledge is applied to other contexts, broader concepts are explained or a reflection on the recent lesson takes place (Van Graft & Klein Tank, 2018).

The Phases of the Design Cycle

The design cycle includes the following phases, namely confronting, exploring, sketching the design, realising the design, testing the design, and adjusting it accordingly, presenting the design, and finally the deepening, and broadening of the just acquired knowledge (Djoyoadhiningrat-Hol & Klein Tank, 2022). The first step of this cycle is the same as the research cycle. During the confrontation phase, the curiosity of the students is being sparked regarding the content of the lesson (Padeste et al., 2015). According to Van Graft and Klein Tank (2018), during the exploration phase, the problem that needs to be solved and what needs to be designed is explored. During this phase, the requirements for the design are specified. It is explored which materials, tools and techniques can be used to design the product. When this is done the students make a sketch of the design. Then the students realize the design. Which means they make a prototype with the material that is available. After which, the students test the design and adjust it where needed. Think about building a construction (e.g., is there a point where the construction is too flimsy? How do we solve that? Do you need extra reinforcement?). When the design is finished, the students present their design. They can present their design to the class and explain why their design functions the way it does. During the deepening and broadening phase, a transfer can be offered, new concepts can be introduced or there can be reflected on the past lesson.

Characteristics of a Science and Technology Lesson

Science and technology lessons contain some important characteristics, namely transferring content knowledge, offering hands-on and minds-on activities, collaboration, interaction/dialogue, a meaningful context, and differentiation, certain skills and attitude are developed, students' knowledge is tested, and technology is involved. Content knowledge that is being transferred involves topics such as natural disasters, the solar system, energy sources, and technologies (Van Graft & Klein Tank, 2018). Hands-on and minds-on activities include letting students partake in research and design activities while also letting them think about the content of the lesson (Van Der Zee et al., 2021). Collaboration is guided by giving students instructions before and guiding them during collaboration (Schroeder et al., 2007; Van Der Zee et al., 2021). Dialogue/interactions stimulates thinking about the content of the lesson. Students need to share the knowledge they obtained during the lesson or ask each other questions e.g., 'How did you find the answer?'. A meaningful context can be offered by including the lives of the students and organisations/places outside the school during the lessons. Differentiation entails that differences in level and work pace are taken into account (Van Der Zee et al., 2021). In addition, students develop certain skills and attitude, e.g., students learn how to think critically or innovative, they develop different ways of thinking or learn how to observe, signal and measure (Van Graft & Klein Tank, 2018). Student knowledge is tested and gives a teacher insight in what students already know and are able to do, what they are struggling with and where remediation and/or extra practice is needed. It gives students insight into the learning goals of the lesson and their own development. Lastly, technology should be included, to let students gain experience in using technologies that are used in today's society (Rougoor-Fiering & Benes, 2020).

Difficulties with Teaching with Technology

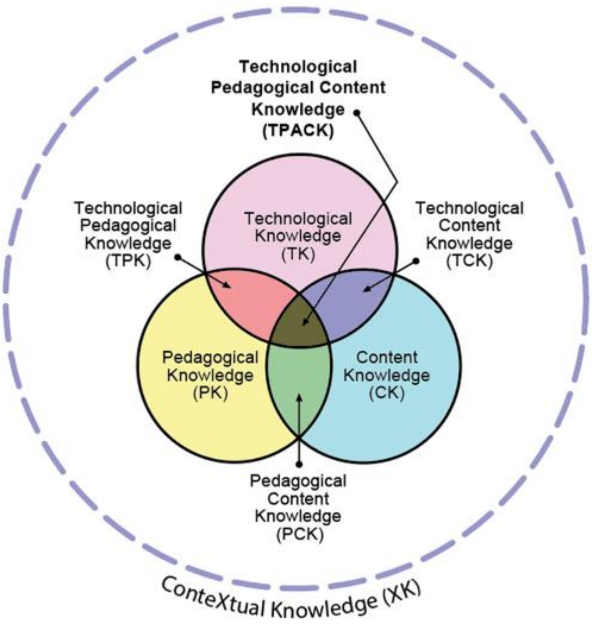
There are several reasons why science and technology education is not yet embedded in the curricula of Dutch primary schools. One reason is given in the rapport of Djoyoadhiningrat-Hol and Klein Tank (2022) stating that Dutch primary school teachers have difficulties with teaching science and technology (Djoyoadhiningrat-Hol and Klein Tank, 2022). These include having difficulties with using technology during these types of lessons. According to De Jong et al. (2021) teachers have difficulties when it comes to creating and utilising digital or online instructional materials. This is especially true when the content is utilised for more interactive learning methods like inquiry-based learning. This was already noticed by Koehler and Mishra (2009) who noted that education can become more complex as a result of emerging technologies. Technology is taken into account in their study as both digital and analogue. Examples of the newer digital technologies include computers, interactive whiteboards and software programmes (Schmidt et al., 2009). In most literature only the newer, digital technologies are taken into consideration because they are more difficult to use due to their intrinsic properties. Digital technologies, namely, can be used in various ways, are unstable, and how they function is hidden from users (Koehler & Mishra, 2009; Papert, 1980; Turkle, 1997). Therefore, teachers find using these newer digital technologies less clear and stable in comparison to using more traditional technologies.

Technological Pedagogical Content Knowledge

The TPACK framework can offer a solution for teaching a science and technology lesson that incorporates technology since it can offer guidance for the demanding task of teaching with technology (Koehler et al., 2013). The framework is based upon Shulman's theory, where he explains the concepts that together form the knowledge base of a teacher, which he refers to as the pedagogical content knowledge of a teacher (Shulman, 1986). Based on this concept, Mishra and Koehler (2006) later developed the TPACK framework. Koehler et al. (2013) explain that the TPACK framework represents three main concepts, namely the content that is being taught and the pedagogy and technology that is being used; therefore, it can be used to teach a science and technology lesson (see Figure 2). The first main concept includes content knowledge, which includes knowledge about the subject that has been taught (facts, theories, concepts, etc.) (Mishra & Koehler 2006). Think about offering the topics that are described above, such as natural disasters, the solar system, energy sources, and technologies (Van Graft & Klein Tank, 2018). The second concept involves pedagogical knowledge and refers to teacher knowledge about teaching strategies and methods. This can include taking into account difficulties with student learning, student assessment, and classroom management (Koehler & Mishra, 2005). The third concept is named technological knowledge and is about the skills that are needed to use various technologies (Mishra & Koehler, 2006).

Figure 2

The TPACK framework (Mishra, 2019)



The Interplay Between the Concepts of the TPACK Framework

During the lesson, there is an interplay between the concepts of the TPACK framework, and the concepts can work out differently in varying contexts (Koehler et al., 2013). For example, it is important to adjust the lesson to the characteristics of the classroom. The ways in which the concepts interact are named pedagogical content knowledge, technological pedagogical knowledge, and technological content knowledge. First, pedagogical content knowledge is about which teaching strategies can be used to teach the content that needs to be taught (Mishra & Koehler, 2006). This can differ for each content area that needs to be taught. The research-and-design cycle is, for example, used for science and technology teaching (Djoyoadhiningrat-Hol & Klein Tank, 2022). Second, technological pedagogical knowledge is about knowing how technologies can be used while teaching. It is questioned how technology can enhance teaching (e.g., drawing a water cycle on the schoolboard or letting students watch an interactive video) (Mishra & Koehler, 2006). Third, technological content knowledge is about the interplay of technology and the content that is being taught. Here, it is questioned how technology can enhance learning (e.g., do students read about robots in the textbook or do they use them in real life?). Finally, all these concepts come together as technological pedagogical content knowledge and include the knowledge teachers need to integrate technology into their lessons to transfer certain content to their students.

Teachers' TPACK Knowledge

According to Schmidt et al. (2009), the TPACK framework demonstrates the knowledge that teachers need to possess and how it is constructed in order to effectively incorporate technology into their lessons. A teacher demonstrates understanding the TPACK framework when they teach a science and technology lesson, which includes the three main concepts (content, pedagogical, and technological knowledge) and the connection between them (Schmidt et al., 2009). This is done by choosing the right pedagogical strategies and technologies that can enhance their science and technology teaching. The research of Tanak (2018) shows that teachers, for example, know how to combine their content, pedagogical, and technological knowledge during science lessons in order to design a learning activity where students use technology to learn about the content that is being taught or support their scientific inquiry. In addition, Angeli and Valanides (2009) mention that technology can be used to more effectively teach content that is otherwise difficult to understand by learners or difficult to represent by teachers. E.g., using visualisation to explain ecosystems or making a virtual tour of, for example, the moon. Lastly, the reason to implement technology in the classroom should be learner-centred. Technology should enable the learner to form an opinion, conduct an observation, or discover knowledge.

Difficulties with the Lack of Confidence in Science and Technology Teaching

Another difficulty when it comes to science and technology teaching is about the lack in confidence of Dutch primary teachers in their ability to teach a science and technology lesson. This is shown in the rapport of Djoyoadhiningrat-Hol and Klein Tank (2022) where they describe that Dutch elementary school teachers are often shy to take action when it comes to science and technology teaching. This is due to the fact that there is a lack of knowledge about science and technology teaching and how to engage students during these types of lessons. In the study of Rouweler (2016) it is specifically mentioned that Dutch primary school teachers have a low self-efficacy regarding teaching science. Seneviratne et al. (2019, p. 1595) describes self-efficacy as 'The feeling of confidence about one's ability to add this teaching method to one's repertory of teaching skills is an important predictor of it happening in the classroom.'. In this case, the feelings of confidence to teach a science and technology lesson. Velthuis et al. (2015) argue that having a low self-efficacy can lead to the avoidance of certain tasks. Improving the self-efficacy of teachers can help with the implementation of a new curriculum and make this into a success (Blonder et al., 2014).

Teachers' Self-Efficacy

When a teacher shows they have self-efficacy, they belief they have the competence to take the necessary steps to organise and implement a specific lesson in their classroom (Tschannen-Moran et al, 1998). In the case of the current study this includes the ability of a teacher to organize and implement science and technology education. Gibson and Dembo (1984) mention that a sense of self-efficacy is shown in the belief that their teaching can positively impact student learning, which is called outcome expectancy. Teachers who show a sense of self-efficacy are confident in their own teaching abilities, which is referred to as the self-efficacy beliefs of a teacher (Blonder et al., 2014). Teachers who believe they can positively impact student learning and are confident in their own teaching abilities keep trying in situations where students are struggling, stay focused and execute different forms of feedback e.g., use less criticism when students make mistakes (Gibson & Dembo, 1984). These teachers believe they are capable of positively influencing student learning even when students are struggling or unmotivated (Blonder et al., 2014). To add, Stein and Wang (1998) mention that teachers with a high sense of self-efficacy tend to be more open to try out new teaching methods. Teachers with a high sense of self-efficacy are also more likely to use challenging teaching methods, like for example inquiry (Blonder et al., 2014). To conclude, teachers with a high sense of self-efficacy are more likely to spend more time on inquiry and get students engaged for a longer time in inquiry during a lesson (Marshall et al., 2008).

Support for Science and Technology teaching

In the following chapter, it is examined how Dutch primary school teachers can be supported by developing their TPACK knowledge and sense of self-efficacy in science and technology teaching. It is examined how gradually releasing task difficulty, observing, making, and implementing a science and technology lesson, teacher reflection, and fostering teacher knowledge can foster a teacher's TPACK and self-efficacy. These elements will later be added to the original lesson series of Pre-University.

Gradually Releasing Task Difficulty

First, gradually releasing task difficulty is discussed as a way to increase the self-efficacy and TPACK of the participating teachers. Gradually realising task difficulty involves offering teacher support while teachers learn to carry out a task independently (Labone, 2004). This can be connected to the theory of Bandura (1997), who mentioned that mastery experiences influence a teacher's self-efficacy. Mastery experiences include the experience a teacher has when carrying out a certain task. If a teacher succeeds in carrying out a task, then the teacher feels more confident that they will be able to do it again in the future (Blonder et al., 2014). In the professional development of Shah and Bhattari (2023), it was argued that self-efficacy in teaching skills can be increased through such positive mastery experiences. Meaning, the more a teacher is able to successfully master a certain task, the more confident they get. To make sure a teacher is successful in mastering a certain task, it is important to keep in mind the task difficulty and the effort it costs a teacher to successfully carry out the task (Labone, 2004). Therefore, the task difficulty should be gradually released, meaning support should be offered throughout. This was also supported by the study of Zhang and Tang (2021), who argued that gradually releasing task difficulty helps when developing TPACK. A model that includes this element is the synthesis of qualitative evidence (SQD) model of Tondeur et al. (2012), which notes a teacher should be guided when it comes to using technology in their lessons. To conclude, in the current study, the task difficulty is gradually released by offering support throughout.

Observing a Science and Technology Lesson

Second, observing a science and technology lesson is discussed as a way to foster a teacher's TPACK and self-efficacy. According to Blonder et al. (2014), prior experiences influence a teacher's sense of self-efficacy. When it comes to observing others, these are called vicarious experiences, which are one of the four sources that can influence a teacher's self-efficacy, as mentioned by Bandura (1997). Specifically, since vicarious experiences build upon seeing others succeed. For example, it helps to see another teacher succeed in carrying out a science and technology lesson (Labone, 2004). This can be done by observing another teacher successfully teaching a science and technology lesson. In addition, the SQD model of Tondeur et al. (2012) shows that using another teacher as a role model, for example, by observing a science and technology lesson of another teacher, can help with the development of a teacher's TPACK. In addition, the study of Jang (2010) also takes into account an observation of a peer instruction as a way to foster a teacher's TPACK. While observing their peers instruction, the teachers in their study took notes on the TPACK skills they saw during their observation. To conclude, in the current study, teachers will observe a science and technology lesson in order to foster their self-efficacy and TPACK in science and technology teaching.

Making and Implementing a Science and Technology Lesson

Third, making and implementing a science and technology lesson is discussed as a way to enhance a teacher's self-efficacy and TPACK. As mentioned before, Shah and Bhattari (2023) argue that self-efficacy in teaching skills can be increased through positive mastery experiences. Meaning, when a teacher is successful in carrying out a teaching task, the more confident they become. To achieve a positive mastery experience, Ross and Bruce (2007) argue that the instructional skills of a teacher should be strengthened. This strengthening was offered in the professional development programme of Lotter et al. (2018), which focused on fostering the self-efficacy of teachers in inquiry science teaching. They strengthened the instructional skills of the teachers by, among other things, letting them practice inquiry teaching. To successfully practice inquiry teaching in the classroom, Shah and Bhattari (2023) argue that teachers should make their own science and technology lesson. The idea is that the more teachers prepare themselves, the more confident they will be in teaching the lesson. In addition, to develop TPACK, Koehler and Mishra (2005) argue that it is also important to implement and make a science and technology lesson that includes the TPACK framework. The latter is called the learning-by-design approach. When teachers design a lesson, they need to consider the content that needs to be taught, the possibilities of the technology, and which pedagogical strategies they will use. To add to this, in the study of Jang (2010), the lesson is designed and carried out in the classroom in order to increase a teacher's TPACK. To conclude, in the current study, teachers will make and implement their own science and technology lesson in order to increase their self-efficacy and TPACK in science and technology teaching.

Teacher Reflection on their Science and Technology Lesson

The fourth element that will be discussed as a way to increase a teacher's TPACK and self-efficacy is teacher reflection on their own science and technology lessons. According to Blonder et al. (2014), prior successes and feedback from others can influence a teacher's self-efficacy. This belongs to verbal persuasion and emotional arousal, which are two of the four sources mentioned by Bandura

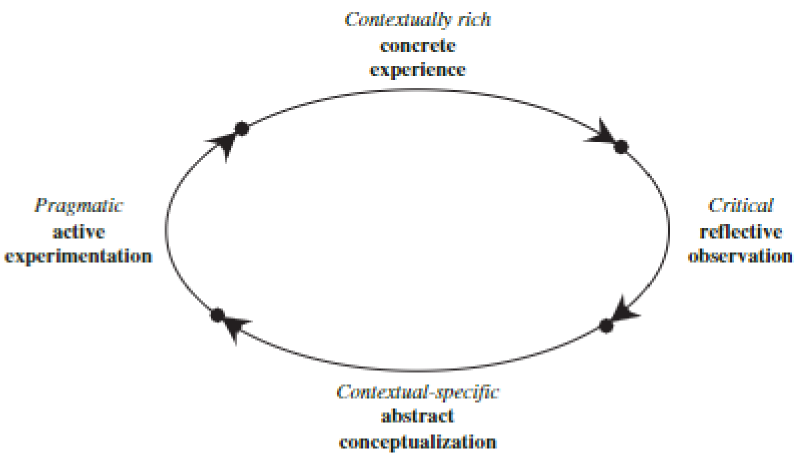
(1997) that can influence a teacher's self-efficacy. First, verbal persuasion is about others helping you succeed in carrying out a task. For example, by providing feedback (Palmer, 2011). Second, emotional arousal is about the emotions a teacher feels while carrying out a task (Bandura, 1997). Teacher reflection is a way to ventilate the emotions of a teacher, since Anderson (2002) mentions that during reflection, teachers should reflect on their own beliefs about teaching inquiry. In the study of Lotter et al. (2018), they strengthened the self-efficacy of the participating teachers in inquiry science teaching by letting them reflect on their content instruction and teaching experience. This was also found by Posnanski (2002), whose study let elementary science teachers reflect on their own teaching practice to increase their self-efficacy. Reflection is also mentioned as one of the factors that increase a teacher's TPACK in the study of Tondeur et al. (2012). This was also mentioned in the study of Jang (2010), where teachers first carried out a science and technology lesson in practice, after which they reflected on the lesson in their journals. In the current study, teachers will reflect on their own science and technology lessons by filling out a reflection form, followed by a reflection meeting, and being instructed through an e-learning on teacher reflection. The latter ensures the feasibility of the adjusted lesson series.

Supporting Teacher Reflection

In these paragraphs, information will be provided on the content of the e-learning on teacher reflection and the reflection form. The e-learning informs teachers about the relevance of reflection, how to reflect, and gives an explanation of the reflection form. In order to do so, the e-learning will inform teachers that, according to Korthagen and Wubbles (1995), reflective teachers have a higher self-efficacy than teachers who do not reflect on their teaching practices and that they are more likely to let their students partake in inquiry and create things for themselves. Afterwards, the teachers learn that the reflective teacher actively tries to improve their teaching practice (Killen, 1995) and that they can reflect on what works in the classroom, what goals should be achieved, and what issues beyond the classroom should be taken into account. Afterwards, the teachers will be informed about the experimental learning cycle that was developed by Kolb (1984) and later revised by Morris (2019) (see Figure 3). The cycle includes that the teachers need to teach a science and technology lesson in their classroom and later reflect upon this experience. During the reflection, solutions are found for problems that occurred while teaching the lesson. This will result in a learning goal that will be practiced once more in their classrooms. Lastly, teachers will be informed that questions such as 'What occurred in the classroom, and why?', and 'What could be done differently to better suit the characteristics of my classroom?' can guide their reflection process (Eggen & Kauchak, 2009; Gupta et al., 2019; Mirzaei & Phang, 2013).

Figure 3

Experimental Learning Cycle (Morris, 2019)



The reflection process will be guided by a reflection form that will include elements of the blueprint for video coaching through reflective practices of the study of Van Der Linden (2022). This blueprint includes reflection on action, for action, and in action. During reflection on action teachers look back on their teaching experiences which is suited for this research. During reflection on action Teachers try to understand their ZPP (Zone of Proximal Performance) and ZPI (Zone of Proximal Implementation). ZPP is about the general teacher knowledge a teacher possesses and can develop with external guidance (Vygotsky, 1978). ZPI is the understanding of the context in which the teacher teaches (e.g., their classroom characteristics) (McKenney, 2013). To guide the reflection on action phase, the reflection form will include elements of the reflection process of Reymen et al. (2006), which exist out of preparation, image forming and conclusion drawing. During preparation, the teacher looks back on their teaching experience. This can be guided by deliberate framing in which frameworks for effective teaching can be used and aware framing, which will pay attention to the teaching context (Van Der Linden, 2022). After preparation, there is image forming, which exist out of deliberate image forming and aware image forming. Deliberate image forming consist of examining the link between the effective teaching frameworks and what is happening in the classroom and aware image forming is about the context (e.g., classroom characteristics), and the contextual needs and constraints this brings along. Lastly, during conclusion drawing the teacher makes plans to improve their teaching practice which could result in new lesson materials or a plan of action (Van Der Linden, 2022). This can result in a learning goal that in the current study will be written down in a SMART manner, meaning being specific, measurable, acceptable, realistic, and timely (Janssens, z.d.).

Improving Teacher Knowledge

The fifth and final element as a way to stimulate a teacher's self-efficacy and TPACK is through developing their teacher knowledge. Self-efficacy can, for example, be stimulated by increasing a teacher’s content knowledge (Morris et al., 2017; Posnanski, 2002; Velthuis, 2014). In addition, Swackhamer et al. (2009) found that pre-service teachers gained self-efficacy in teaching science after learning about its content and pedagogy. This is also mentioned by Tschannen-Moran and McMaster (2009) and Lotter et al. (2018). Palmer (2011) refers to this knowledge as cognitive mastery and includes a teacher’s perceived understanding of the subject that needs to be taught. Improving a teacher’s knowledge can also help with developing a teacher’s TPACK. This is offered in the study of Jang (2010), which involved the comprehension of TPACK in order to improve a teacher’s TPACK (Jang, 2010). In order to learn about TPACK, teachers studied topics in textbooks and articles in teams, and they learned about interactive whiteboard technology. This was a specific technology that was offered in the study of Jang (2010). Learning about TPACK was also mentioned in the study of Jang and Chen (2010) in order to improve the TPACK of their participants, who were pre-service science teachers. Lastly, in the study of Lee and Kim (2014), the participating pre-service teachers needed to build their TPACK knowledge in order to improve their TPACK. Building teachers’ knowledge about science and technology teaching and TPACK will be part of the adjusted lesson series that is developed in the current study. This will be done by offering the teachers e-learnings on these topics, again to ensure the feasibility of the adjusted lesson series.

The Construction of the E-Learnings

In these paragraphs, the construction of the e-learnings will be discussed. The design requirements of Pre-University that were decided upon during the informal conversations at the earlier stages of the current research inform us to use Lesson-Up to construct the e-learnings. This online platform is used to develop e-learnings where teachers learn about teaching a science and technology lesson, TPACK, and reflection. In order to transform the information and sources that were used to describe these topics in the ‘Theoretical Framework’ into e-learnings, the Cambridge Handbook of Multimedia Learning, edited by Mayer (2021), is included in the current study. In this handbook, several design principles for designing multimedia are described. Multimedia presents media that includes words as well as pictures. Words can be printed or spoken, and pictures can include photos, graphics, diagrams, or even videos. The Lesson-Ups that will be made in the current study can be seen as multimedia since they will include words and pictures. The question is how to design the multimedia in such a way that it will enhance learning. A well-designed multimedia can result in the construction and transfer of knowledge. In order to construct and transfer knowledge, the following design principles are taken into account in the design of the Lesson-Ups that are made in the current study (for concrete examples, see Appendix A):

- Multimedia principle: it is better to include words and pictures than merely focus on words. In the current study, this is done by including pictures of theories such as the research-and-design cycle and videos about, for example, science.
- Signalling principle: the most important information should be highlighted; this can indicate a connection between graphics and words, display the organisation of the multimedia, and bring

attention to the most important information. This can be done, for example, by enlargements, using arrows, or colouring. In the current study, the most important words are coloured blue, prompts are made bold, the titles of the several subjects in the Lesson-Up are enlarged, and words that correspond to graphics are coloured in the same way as the corresponding parts of the graphics.

- Spatial and temporal contiguity principle: display written words right next to their corresponding graphic at the same time. In the current study, this is done by placing graphics, such as the research and design cycle, next to the corresponding text at the same time.
- Worked example principle: it works best when people see worked-out examples. This is done by giving several solutions to a certain question or problem after explaining the general rules. This is done by giving examples to the teachers about a science and technology lesson, several technologies, and questions to ask during reflection.
- Personalisation principle: the information in the multimedia should be presented in a personal manner. In the current multimedia, the learner is referred to as 'you'.
- Self-explanation principle: it helps when learners are asked to explain the content to themselves. This can be done by asking learners to explain the theory to themselves or by letting them answer questions or solve problems based on what they have previously learned. In the current study, the learners are invited to test their knowledge, generate answers, and think about the implementation of the learned content in their classroom.
- Feedback principle: it is best when learners receive explanatory feedback on their performance. In the current study, the answers to the questions are incorporated into the slides. The answers do not only state whether an answer is right or wrong but also include an explanation of the right answer.
- Coherence principle: it is best when only necessary information is included. This is done by only mentioning information that is necessary for the learning goals.
- Segmenting principle: the multimedia should consist of several components. This is done by creating three separate lessons. Which include the research-and-design cycle, the TPACK framework, and reflection. Also, the teachers can go through the Lesson-Ups at their own pace.

Evaluation of the Local Viability of the Adjusted Lesson Series

In the current study, based on the design requirements of Pre-University and the Theoretical Framework, the lesson series of Pre-University is going to be adjusted in such a way that it can foster a teacher's TPACK and self-efficacy in regard to science and technology teaching. Since it is a newly made intervention, it will be examined how and why the newly adjusted lesson series sustains itself in the context in which it is used, which is called beta testing (McKenney & Reeves, 2019). This concept, namely, examines the implementation of an intervention in its own context. In the case of the current study, it is the context of a classroom at a Dutch elementary school. During beta testing, the intervention can be evaluated for local viability in order to determine directions for improvement by evaluating how and why the intervention withstands in the context of the classroom (McKenney & Reeves, 2019). It will be evaluated if the adjusted lesson series functions as intended or if situations occur that were unplanned. Which can be done by gaining insight into the added value, compatibility, clarity, and tolerance of the lesson materials.

First, after implementing the lesson series, the intervention should add value to the existing teaching practices of the participating teachers. Since it is important that the learning material adds value to existing practices in order to get it implemented (Hübner et al., 2021). According to Kirschner (2019), the added value of a design exists in three categories: effectiveness, efficiency, and enjoyability. First, effectiveness entails the learning that occurs when using the intervention. In the case of the current study, it will be examined if the lesson series fostered the TPACK of the participants in science and technology teaching and what elements of the lesson series contributed to fostering their TPACK. Second, efficiency is about the time and effort that teachers need to spend on the intervention. Therefore, it will be examined if it took the teachers much or a regular amount of time and effort to partake in the lesson series. Thirdly, enjoyability entails examining teachers' self-efficacy after using the intervention and whether the teachers felt accomplished while using it. Therefore, in the current study, it will be examined if the lesson series foster teachers' self-efficacy in science and technology teaching. In addition, it will be examined what elements of the lesson series contributed to fostering their self-efficacy in science and technology teaching.

In addition to evaluating the added value of the lesson series, the compatibility, clarity, and tolerance of the lesson series are also evaluated after implementing the lesson series. Just like the added value of an intervention, compatibility also enhances the implementation success of an intervention; this entails that the intervention should align with the context in which it is used (Davis et al., 2006). For the current study this includes whether the lesson series is compatible with the teachers' knowledge and the teachers' beliefs and goals about science and technology teaching. In addition, clarity about the intervention is also important for a successful implementation (McKenney & Reeves, 2019). It should be clear what the intentions and goals of the intervention are. For example, the intention of the current lesson series is that teachers design a science and technology lesson in order to reach the intended goals, which are gaining self-efficacy and TPACK knowledge in regard to science and technology teaching. According to McKenney and Reeves (2019), how clear an intervention is can influence the tolerance of a design, because the clearer the intentions and goals of an intervention are, the better others can live up to these intentions and goals while making adaptations to the original intervention. Therefore, it will also be examined if the teachers make adaptations to the lesson series that are not in line with its previously intended goals.

Research Questions

The research question is, 'What is the local viability of the adjusted lesson series that are intended to increase teachers' self-efficacy and TPACK in science and technology teaching'. The sub-questions are:

- What is the added value of the lesson series to the teachers of two Dutch primary schools?
- How compatible are the lesson series with the teachers at two Dutch primary schools?
- How clear are the lesson series to the teachers at two Dutch primary schools?
- How tolerant are the lesson series when it is used by teachers at two Dutch primary schools?
- How do each of the participating primary schools respond differently to the lesson series when it comes to several aspects of local viability?
- How should the lesson series be altered in order to increase the chance that it could be implemented at a Dutch primary school?

Scientific and Practical Relevance

Scientific Relevance

In the current study, research is conducted to build upon previous studies that fostered the self-efficacy and TPACK of teachers in science and technology. This study intends to build upon the theory that has been discovered in previous studies in this domain. In the study of, for example, Jang (2010), the TPACK of science teachers was fostered by making and implementing a science lesson that included the TPACK framework. This also occurred in the study of Tanak (2018). However, improving TPACK in science teaching does not necessarily entail that inquiry-based instruction is involved in professional development programs. Even though this is part of the pedagogical content knowledge of science and technology teaching. Therefore, the current study, as Tanak (2018) suggests, focuses on letting the participants engage in inquiry-based instruction and intends to examine if this also fosters teachers' TPACK in science and technology teaching. In addition, it is examined which sources teachers use to improve their teacher knowledge to foster their self-efficacy in science and technology teaching. Since, as previously described, improving the cognitive mastery of teachers improves their self-efficacy (Lotter et al., 2018; McMaster, 2009; Palmer, 2011; Swackhamer et al., 2009). However, Morris et al. (2017) mention that more research should be conducted on which sources of teacher knowledge foster teacher self-efficacy in order to build upon the theory of Bandura (1997), which included four sources that foster the self-efficacy of teachers: mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal.

Practical Relevance

In the current study, the lesson series of Pre-University will be adjusted in such a way that it can foster Dutch primary school teachers' self-efficacy and TPACK in teaching science and technology. The lesson series are meant to be used by Pre-University in its intention to support Dutch primary school teachers to teach a science and technology lesson independently and therefore foster their self-efficacy and TPACK in teaching science and technology. The lesson series will follow up on the original science and technology lesson series from Pre-University and use technology that is already familiar to Pre-University. The lesson series needs to be feasible, which means they do not take up more time from Pre-Universities employees than they do currently. Lastly, the intent is that the current study develops products that Pre-University can use after the study is done, e.g., a module in Lesson-Up that they can send to future participating teachers. After examining the local viability of the adjusted lesson series that are going to be tested in the classrooms of primary schools in the Netherlands, this study will inform Pre-University and other practitioners about the aspects of the lesson series that did foster teachers' self-efficacy and TPACK in science and technology teaching and which aspects still need to be altered so that they can be better used in practice for their intended goal.

Method

In the following section, the chosen research approach and design are elaborated on. In the case of the current study, it was chosen to apply the generic model for conducting design research in education (the EDR model) in combination with a multiple-case study design. These paragraphs are followed by a description of the respondents, the procedure, and the adjusted lesson series. Afterwards, the instruments that were used for data collection were discussed, a description of the data analysis occurred, and the section was closed with a description of the reliability and validity of the research.

Research Approach and Design

To design the lesson series the generic model for conducting design research in education (EDR model) of McKenney and Reeves (2019) (see Figure 4) was used. The EDR model exists of the following phases: analysis and exploration, design and construction, and evaluation and reflection. First, during the analysis and exploration phase, the problem has been defined, by gathering information, partly through informal conversations held with Pre-University, and through a literature search (see 'Problem Statement'). A clear description of the problem, context, design requirements that should be taken in account while designing the lesson series, and goal of the study has been described in these paragraphs. Second, during the design and construction phase there was examined which theoretical underpinnings would result in the desired situation (McKenney & Reeves, 2019). In the case of the current study there was examined which design principles can result in a lesson series that can increase teachers' TPACK and self-efficacy in science and technology teaching. This was done by conducting a literature search on effective design propositions for increasing a teacher's self-efficacy and TPACK (as described in 'Support for Science and Technology Teaching'). Afterwards a design was constructed while keeping the design requirements and design propositions in mind (see Appendix B). This resulted in the lesson series that were used in the current study (see 'The Adjusted Lesson Series').

Figure 4

Generic Model for Conducting Design Research in Education (McKenney & Reeves, 2019)

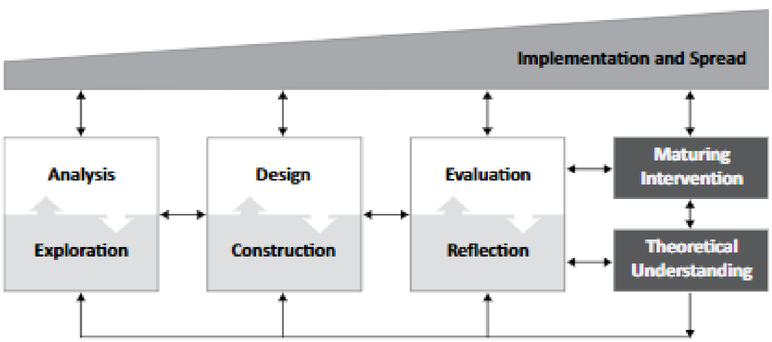


Figure 3.3 Generic model for conducting design research in education

In the third, evaluation and reflection phase, a pilot was conducted which meant the design was implemented by Dutch primary school teachers who tested the lesson series (see ‘Local Viability’, ‘Method’, ‘Results’, and ‘Conclusions’). A pilot provides insight into how an intervention performs in its context (e.g., classrooms and schools) and what changes should be made in order to let the intervention survive in the context in which it will be used (McKenney & Reeves, 2019). Pilots usually occur in the early stages of an intervention and happen on a small scale. This fits best to the exploratory case study design which can explore how new practices can be implemented in organisations (e.g., the school) (Yin, 2017). An exploratory case study can provide insight in which design features should be routinized or perhaps altered in order to get an intervention implemented. In the current study an exploratory multiple case study design was chosen to contribute to the already chosen EDR model. During a multiple case study, cases can be compared to each other, in this case there was examined how two Dutch elementary schools responded differently or similarly to the adjusted lesson series. In order to evaluate the lesson series at both schools, the pilot was evaluated on local viability to examine how and why the lesson series withstand in the context of the Dutch elementary school classroom (McKenney & Reeves, 2019). There was evaluated if the lesson series functioned as intended or if situations occurred that were unplanned. This was done by gaining insight into the added value (which exist out of effectiveness, efficiency and enjoyability), compatibility, clarity, and tolerance of the lesson series.

Respondents

In the current study two Dutch elementary schools formed the cases. The schools were compared to one another based on how the lesson series that were intended to increase teachers’ self-efficacy and TPACK in science and technology teaching sustained themselves in their classrooms, and why (McKenney & Reeves, 2019). In the current study there was examined if there was a difference in how the two Dutch primary schools responded to the lesson series. Each school offered four teachers who participated in the pilot. The teachers at both schools were between 24 and 59 years old (M=43.88, SD=12.02). The teachers at the first school were between 31 and 59 years old (M=48.00, SD=11.47). The teachers at the second school were between 24 and 48 years old (M=39.75, SD=9.34). In the current study an image was drafted on the participating schools to provide an insight in their prior experience in science and technology teaching (see ‘Baseline’). Hence, in the report of SLO written by Djoyoadhiningrat-Hol and Klein Tank (2022) there was mentioned that teachers who have little too no affinity with the domain often have difficulty with teaching science and technology. In contrast, some teachers went to a higher education that offered science and technology in their courses or followed a post higher education specified on science and technology teaching. These teachers perform relatively well in practice. This was also mentioned by Chichekian and Shore (2016). Providing an overview of the experience of the current teachers in science and technology teaching might provide an insight on why both schools for example respond differently to the current intervention.

Procedure

During this study, data was collected through a pre- and post-test and an interview. In addition, the reflection forms and lesson plan were gathered. Prior to partaking in the study, the teachers received an email in which the goal of the pre- and post-test, interviews, and sending the reflection forms and lesson plan to the researcher were shared, and consent was asked through a consent form. The teachers were informed that they could ask questions by e-mail at the start of the pre- and post-test, the interviews, and before sending the reflection forms and lesson plan to the researcher. They were also informed that the data will be pseudonymized and cannot be traced back to the individuals. Since there was a risk that the teacher could feel that the quality of their teaching was going to be critiqued, the researcher clarified that the goal of the pre- and post-test, interviews, and sending the reflection forms and lesson plan to the researcher was to evaluate the lesson series through evaluating its viability in order to determine points for improvement and not to critique the quality of their teaching. During the pilot, it was more often than not decided that the researcher would type along with the answers that the participating teachers gave to the questions that were written down on the reflection form. This was done in order to save time. In order to keep the individual voice of the participating teachers, a member check was conducted by sending an email with the question of whether the teachers agreed upon the content of the reflection forms before further analysis.

The data collection occurred prior, during, and after the lesson series took place. Firstly, prior to partaking in the lesson series, a pre-test and interview were conducted to measure the current state of affairs regarding science and technology education at the Dutch primary school and the teachers' self-efficacy and TPACK. This took approximately 1 hrs. Secondly, during the lesson series, the teacher filled in two reflection forms. This took approximately 30 min. These reflection forms were gathered by the researcher to gain further insight on the starting point in regard of science and technology teaching and on all aspects of local viability. Thirdly, during the lesson series, the lesson plan of the teachers was gathered by the researcher in order to provide additional insight on the added value of the lesson series. Filling in the lesson plan took approximately 1.5 hrs. Finally, after partaking in the lesson series, a post-test and interview were conducted, which took approximately 1.5 hrs. The post-test measured the self-efficacy and TPACK of the participating teachers and therefore provided additional information about the added value of the lesson series. In addition, during the second interview after partaking in the lesson series, the teachers were interviewed about the added value, compatibility, clarity, and tolerance of the adjusted lesson series.

The Adjusted Lesson Series

In the current study, the science and technology lesson series of Pre-University were adjusted based on the theoretical underpinnings that can foster a teacher's TPACK and self-efficacy (see 'Support for Science and Technology Teaching') and the design requirements of Pre-University (see 'Problem Statement'). From the theoretical underpinnings, design propositions were distracted, which needed to be included in the adjusted lesson series in order to foster a teacher's TPACK and self-efficacy in science and technology teaching. These entailed that task difficulty should be gradually released, teachers should observe a science and technology lesson, make and implement a science and technology lesson, reflect on their science and technology lessons, and teachers knowledge needed to be improved on science and technology teaching, TPACK, and reflection. First, the design requirements and design propositions were transformed into specific manifestations; these design options were put in a weighted matrix, and the best options were further developed through a skeleton design. The expected outcome was an adjusted lesson series that would foster a teacher's TPACK and self-efficacy, was feasible for Pre-University, and was a follow-up for their current science and technology lesson series. This entailed the lesson series needed to use technology Pre-University already used, should use Lesson-Up for transferring knowledge to teachers, and should develop products Pre-University could use after the current research was done.

The original lesson series from Pre-University that was used in the current research involved sustainability and robotics (Pre-University, z.d.). In the original lesson series, three lessons were taught by students of Pre-University and only one of the four lessons was taught by the primary school teachers. During this lesson, the teachers were offered guidance through pre-made lesson materials (e.g., a PowerPoint, worksheets, instructions on certain experiments, and a lesson plan), which should allow them to teach this lesson effortlessly without taking up too much time. Each lesson in the lesson series takes up ninety minutes (Pre-University, z.d.). The goals of each lesson are based on the learning objectives of the SLO, a Dutch organisation that describes the core goals of Dutch primary education. The lesson series are based upon the research-and-design cycle and the Gradual Release of Responsibility Instruction Model (GRRIM) (Djoyoadhiningrat-Hol & Klein Tank, 2022; Rougoor-Fiering & Benes, 2020; SLO, 2023; Van Der Zee et al., 2021). The GRRIM model exists in four stages, which indicate the gradual release of responsibility. These are I (the introduction, explanation, or modelling of the teacher), we (guided practice), you (collaborative learning), and you (independent work) (SLO, 2023). In the lesson series, students and teachers use different technologies (see Appendix C). Depending on the lesson series, students, for example, use the game Lights On, the Solar Walk Lite app or an online planetarium, Ozobots, Mbots with Mblock software, Lego Mindstorm robots with the corresponding software, and Kahoots. Depending on the lesson series, teachers transfer content knowledge through the use of a PowerPoint, Google Maps, Google Earth, a visualisation tool, the website of WNF (Wereld Natuur Fonds), videos, and demonstration tools.

In order to foster the teachers' TPACK and self-efficacy in science and technology, adjustments were made to the original lesson series. Prior to the first lesson, in order to foster teacher knowledge in science and technology teaching (Link) and TPACK (Link), the teacher went through the e-learning courses in Lesson-Up. To observe a science and technology lesson, the teacher observed the first lesson with the use of an observation form (see Appendix D). This lesson was taught by the researcher and a student of Pre-University. After the first lesson, the teacher went through the e-learning about reflection (Link). In order to gradually release task difficulty, prior to making and implementing their own science and technology lesson, the second lesson was taught by the teacher, and support was still offered through pre-made lesson materials. To reflect on their science and technology teaching, the teacher reflected on this lesson and filled in the reflection form with the help of the previously watched e-learning (see Appendix E). A reflection meeting followed in the afternoon and was guided by the filled-in reflection form of the teacher. The third lesson was taught by the researcher and a student of Pre-University. The teacher made and taught the fourth lesson on their own. The teacher filled in the empty lesson plan (see Appendix F) and made a PowerPoint for the fourth lesson. To gradually release task difficulty, the original lesson goals for the fourth lesson were already written down in the lesson plan. In addition, in the afternoon of the third lesson, the teacher could ask final questions about the fourth lesson. Finally, the fourth lesson was taught by the teacher. In the afternoon, the teacher filled in the reflection form one last time, but there was no reflection meeting.

Instrumentation

Semi-Structured Interview for the Evaluation

A semi-structured interview was held to examine how the lesson series that were intended to increase teachers' self-efficacy and TPACK in science and technology teaching sustained themselves in the classroom and why (McKenney & Reeves, 2019). The interview consisted of two elements (see Appendix G). The first part included questions about the state of science and technology teaching at the school and the teachers' TPACK and self-efficacy. The second interview was based on the study of Van Der Linden et al. (2023) and examined the added value, compatibility, clarity, and tolerance of the lesson series. Examining the added value of the lesson series occurred through asking questions about effectiveness (Compared to the beginning, how would you describe your knowledge of giving a science and technology lesson now?), efficiency (Did it take much or little time to complete the lesson series with the supporting materials?), and enjoyability (Compared to the beginning, how would you describe your confidence in giving a science and technology lesson now? To what extent did you enjoy giving a science and technology lesson?). In addition, questions were included to measure the compatibility (To what extent did the lesson series with the supporting materials match your knowledge of science and technology lessons? To what extent did the lesson series with the supporting materials match your beliefs and goals about science and technology lessons?), clarity (What was very clear and very unclear about the lesson series with the supporting materials for you as a teacher?), and tolerance of the lesson series (To what extent have you deviated from the use of the lesson series with the supporting materials?).

Pre- and Post-Test TPACK and Self-Efficacy Questionnaire

Pre-Post-Test Self-Efficacy Questionnaire

To further examine the added value of the lesson series, a pre- and post-test questionnaire was held to measure if the self-efficacy of the participants regarding teaching science and technology on average increased after using the lesson series. For the current study, the Dutch version of the questionnaire that was developed by Enochs and Riggs (1990) was used. The Dutch version is called the STEBI-NL questionnaire (Fisser et al., 2010; Moeke, 2015; Velthuis, 2014). Enochs and Riggs (1990) developed the questionnaire to measure teacher self-efficacy in science teaching. According to Enochs and Riggs (1990), the questionnaire is a valid and reliable instrument and exists of two scales, namely personal science teaching efficacy beliefs (PSTE) and science teaching outcome expectancy (STOE). Later on, Velthuis (2014) developed the STEBI-NL questionnaire, and she discovered that the reliability of the PSTE scale with a Cronbach's alpha of .86 was very good. However, she noted that the STOE scale needs further examination due to its complex nature. Therefore, in the current study, only the PSTE scale was used to measure teacher efficacy beliefs regarding science teaching. The questionnaire had a 5-point Likert- scale ranging from *strongly agree* (1) to *strongly disagree* (5) and included items such as 'I know the steps necessary to teach science concepts' and 'I understand science concepts well enough to be effective in teaching primary science'. In addition, the words 'natuur- en techniekonderwijs' were changed into 'wetenschap- en techniekonderwijs' to fully match the content of the current study (see Appendix H).

Pre-Post-Test TPACK Questionnaire

To further examine the added value of the lesson series, a pre- and post-test was held to measure if the TPACK of the participants regarding teaching science and technology on average increased after using the lesson series. In order to do so, the survey of Schmidt et al. (2009) was used (see Appendix H). This survey is a valid and reliable instrument to measure a teacher's TPACK development on each subscale with a Cronbach's alpha on the several scales ranging from .80 until .92. The subscales are 'technology knowledge', 'science content knowledge', 'pedagogical knowledge', 'pedagogical content knowledge', 'technological pedagogical knowledge', 'technological content knowledge', and 'technological pedagogical content knowledge' and were all used in the current study. The survey has a 5-point Likert-scale ranging from *strongly disagree* (1) to *strongly agree* (5) and includes items such as 'I can learn technology easily' and 'I know about technologies that I can use for understanding and doing science.'. The current study solely focused on science and technology teaching in the context of a Dutch primary school; therefore, the survey was adapted to the current study by translating it to Dutch. In addition, to match the content of the current study, on each scale only the category 'science' was used, which in this study is named 'science and technology', and the categories 'literacy', 'social studies', and 'mathematics' were removed. To inform, after removing the categories 'literacy', 'social studies' and 'mathematics' the subscales 'pedagogical content knowledge' and 'technological content knowledge' only included one item. In addition, accidentally, the item 'I can adapt my teaching style to different learners', which is part of the subscale 'pedagogical knowledge', was not included in the current questionnaire. Finally, the word programming software was added to the description of technology.

The Lesson Plan

The lesson plan was filled in by the teachers in order to be able to further examine the added value of the lesson series. This enabled examination of whether the participants obtained knowledge about the content, pedagogy, and technology and, where possible, the interplay between them to make a science and technology lesson since these are components of the TPACK framework (Koehler et al., 2013). The lesson plan was made out of information that was written down in the Theoretical Framework and included prompts to guide a teacher in making a lesson that includes the content, pedagogy, pedagogical content knowledge, and the use of technology throughout the lesson (Mishra & Koehler, 2006). First, a prompt about the content that needed to be learned included, 'What content knowledge are you going to transfer to your students?'. Second, prompts about the pedagogy included 'How do the students show that they have obtained the lesson goals?', 'How do you differentiate?', 'How will you guide collaboration and conversations between students?', 'Which materials may students use?', and 'What is expected of the students in class?'. Third, prompts about the pedagogical content knowledge included prompts about offering the research and design cycle, e.g., 'Explore; the problem is explained and the solution that needs to be designed is discussed.'. Reminders that hands-on and minds-on activities and a meaningful context should be offered were also given. Lastly, prompts were included as a reminder to include technology throughout the lesson plan.

The Reflection Form

The reflection form was filled in by the teachers to provide, to a lesser or greater extent, additional data on the starting point and on aspects of local viability (see Appendix E). The reflection form is based on the study of Van Der Linden (2022), who mentions the reflection process of Reymen et al. (2006). Besides, the study of Janssens (z.d.) is used as inspiration to compose the reflection form. First, to reflect on the preparation phase, questions are included, such as 'What went very well?', and 'What did not go as expected or did you find difficult?'. To include deliberate and aware framing during this phase, a comment is placed, which makes teachers aware of the need to reflect on their knowledge about the research and design cycle, using technology, and the characteristics of their class. Second, the teacher goes through the image forming phase. Questions like 'Can you clarify? Why did it not go as expected or was it difficult for you?' guide teachers during this reflection phase. In addition, a comment will make teachers aware of the deliberate and aware image forming that happens during this phase. Can, for example, the characteristics of their class clarify what happened in the classroom? Finally, the teachers will enter the conclusion drawing phase. The questions 'What are the most important conclusions based on the previous step?' and 'What will your plan of action be?' guide this part of the reflection process. The plan of action will be written down in a SMART manner, meaning writing down a learning goal that is specific, measurable, acceptable, realistic, and timely.

Data Analysis

Table 1 provides an overview of each research question and the corresponding instruments. Each research question was answered with the analysis of several data sources to better interpret the results, which is called data triangulation (Thurmond, 2001). Prior to and after the lesson series were implemented at the schools, a semi-structured interview was held to provide information on all the research questions that involved aspects of local viability. To further examine the added value of the lesson series, a pre- and post-test was held to examine if the teachers gained self-efficacy and TPACK in regard to science and technology teaching. In addition, the lesson plan was analysed to examine if the participants obtained the knowledge or what knowledge was still missing about the content, pedagogy, and technology and, where possible, the interplay between them to make a science and technology lesson since these are components of the TPACK framework (Koehler et al., 2013). The data gathered from the pre- and post-interviews, pre- and post-questionnaires and lesson plan were described for each corresponding aspect of local viability. First, this was done for the entire group of teachers that participated in the lesson series. In addition, in accordance with a multiple-case study design, the data was described for each participating school (Yin, 2017). Afterwards, a comparison was made between each of the participating schools to determine if they responded differently to the lesson series for each aspect of local viability. Lastly, the reflection forms provided additional data on the starting point of the teachers in regard to science and technology teaching and, to a lesser or greater extent, on the aspects of local viability (McKenney & Reeves, 2019). Afterwards, when all the data sources were analysed, it was examined which parts of the design should be altered.

Table 1

The Instruments and the Corresponding Research Questions

	Interviews	Pre-Post-tests	Lesson plan	Reflection form
Local viability	X	X	X	X
Added value	X	X	X	X
Compatibility	X			X
Clarity	X			X
Tolerance	X			X
Difference	X	X	X	X
Alterations	X	X	X	X

Note. Primary data sources white and secondary data sources are grey.

A Deductive, Inductive, and Thematic Analysis of the Semi-Structured Interview for evaluation

The semi-structured interviews were analysed in a deductive, inductive, and thematic manner in order to evaluate the lesson series on all aspects of local viability. The interviews were transcribed with Amberscript. Afterwards, a codebook was created with the help of ATLAS.ti (see Appendix I). Codes should at least appear twice in the interviews to be included in the code book. Since this accounts for 25% of the participants. The analysis of the semi-structured interview first started in a deductive manner. The first codes were developed based on the questions that were asked in the pre- and post-interview (Bingham, 2023). Codes for the pre-interview included codes about the current state of affairs regarding science and technology teaching at the school and the teachers' starting point in regard to their TPACK and self-efficacy in science and technology teaching. Codes for the post-interview included codes on all aspects of local viability, namely added value, compatibility, clarity, and tolerance. In the second round of coding, codes were created in an inductive manner. Meaning codes were created based on the excerpts that were found during the analysis of the interviews (Thomas, 2006). This entailed creating codes to match the excerpts about the parts of the lesson series that did foster the teachers' self-efficacy and TPACK in science and technology teaching. In addition, criteria on when and how to code for TPACK, knowledge about teaching science and technology, and self-efficacy were sharpened. Excerpts were coded for TPACK when the excerpts included information about how the teachers were using technology in their lessons. All other forms of teacher knowledge were coded for knowledge about science and technology teaching. If knowing how to include technology in their science and technology lessons contributed to their feelings of confidence, it was coded as self-efficacy.

After this round of coding, several coding rounds, in a deductive and inductive manner, were followed in order to precisely match the found experts to the corresponding codes (Bingham, 2023; Thomas, 2006). In one of the following rounds of coding, tolerance was split between adjustments that were made to the pre-made lesson materials, collaboration among teachers, and involvement of the researcher as a coach when designing the lesson. Clarity was found to involve unclarities about the pre-made lesson materials or time spent on each lesson. In addition, the codes about self-efficacy and TPACK were once again specified based on their descriptions in the Theoretical Framework. Since the TPACK code now accounted for knowledge about the content, pedagogy, technology, and the interplay between them in order to teach a science and technology lesson that includes the research and design cycle, the 'knowledge' code expired and was removed. In another round of coding, the code about which parts of the lesson series did foster the self-efficacy and TPACK of the participating teachers was further specified by splitting it into parts of the lesson series that did contribute to their self-efficacy and parts of the lesson series that did contribute to their TPACK knowledge. In the final round of coding, theme coding was used to identify recurrent patterns in the data set (Naeem et al., 2023). The code process was checked upon by a second person and stopped when saturation was found; at this moment, it was agreed upon that the codes and their descriptions represented the excerpts that were found in the pre- and post-interviews (Belur, 2018).

Analysis of the Pre- and Post-test Self-Efficacy and TPACK Questionnaire

To provide insight on the added value of the learning environment, the pre- and post-tests on self-efficacy and TPACK were analysed. To measure if the created lesson series increased the self-efficacy of primary school teachers in teaching science and technology, the PSTE-scale of the STEBI-NL questionnaire was carried out (Velthuis, 2014). In addition, to measure if the technological pedagogical content knowledge of primary school teachers increased after partaking in the lesson series, the survey of Schmidt et al. (2009) was conducted. The questionnaires were analysed with the help of SPSS. The questionnaires were first put into SPSS. Afterwards, the scores on each item of the

PSTE scale were reversed. After which, the average scores and standard deviations of each scale were calculated for the entire group of teachers. Next, the average scores and standard deviations on each scale were calculated separately for each school. The average scores were calculated to see whether the average scores on the several scales of the self-efficacy and TPACK questionnaire increased for the entire group of teachers and for each school separately after partaking in the lesson series. In addition, for each scale, the standard deviations were calculated to see if there was or was not a lot of spread between the answers that were given among the entire group of teachers and at each school separately.

Analysis of the Lesson Plan

To further examine the added value of the lesson series, an analysis of the self-made lesson plan was conducted to examine if the participants obtained the knowledge about the content, pedagogy, and technology and, where possible, the interplay between them to make a science and technology lesson, which are components of the TPACK framework (Koehler et al., 2013). In order to analyse the lesson plans, the 'Kijkwijzer' of TechYourFuture is used as a codebook (Van Der Zee et al., 2021; see Appendix J). The 'Kijkwijzer' of TechYourFuture is in line with the Theoretical Framework of the current research. Since it includes information about whether the content, pedagogy, pedagogical content knowledge, and use of technology throughout the lesson are included in the lesson plan (Mishra & Koehler, 2006). The code book exists out of criteria that should be present in a science and technology lesson and matching descriptions to see whether or not the criteria are present in the lesson plans. The current study adjusted the code book by adding a + to the code that represented one of the criteria that should be present in a science and technology lesson when all matching descriptions were found in the lesson plan, a +/- when some were present and some were not present, and a - when none of the descriptions were present (see Appendix J). When this was done, the excerpts of the lesson plans were coupled to the best fitting codes of the 'Kijkwijzer' to examine if the teacher obtained enough knowledge to match the criteria and their corresponding descriptions.

Deductive Analysis of the Reflection Form

A deductive analysis of the reflection forms was held in order to provide, to a lesser or greater extent, additional data on the starting point of the teachers in regard to science and technology teaching, the current state of affairs of science and technology teaching at their school, and on aspects of local viability. Coding in a deductive manner entails that the codes were already decided upon before the actual coding of the excerpts occurred (Bingham, 2023). In the case of the current study, this entailed that the reflection forms were analysed in a deductive manner with the codebook that was already created for analysing the pre- and post-interview. This codebook had already reached the point of saturation, meaning that while analysing the reflection forms, the codebook was no longer altered. Prior to analysing the reflection forms, a member check was conducted. After one teacher made a final adjustment to the reflection form, all participating teachers approved of the content that was written down in the reflection forms, which made them ready for analysis. In order to analyse the reflection forms, they were transferred to Atlas.ti, which offered support for the coding process. When this was done, the analysed reflection forms provided to a lesser or greater extent for each teacher additional data towards the starting point of the teachers' in regard to science and technology teaching and on the several concepts of local viability.

Reliability and Validity

The current research was valid and reliable. When research is valid, it ensures that the results of the research are explained in the right way (Kirk & Miller, 1986). In the current study, two types of validity are discussed, namely construct validity and content validity. First, Strauss and Smith (2009) argued that construct validity entails that the instruments that are chosen measure the construct they intend to measure. This can be done by using several measurements in order to answer the study's research questions, which is called data triangulation and was part of the current study (Thurmond, 2001). This means that the research was valid because multiple instruments were compared to each other in order to find the answers to the research questions. For example, next to the pre-and-post interview, a pre-and-post questionnaire was used in order to combine the answers and making conclusions about the added value of the lesson series. Second, Roebianto et al. (2023) examined several sources on content validity and stated that content validity occurs when the items on a test measure the construct it intends to examine. In the current study, the questionnaires that were used to measure a teacher's TPACK and self-efficacy were validated (Schmidt et al., 2019; Velthuis, 2014). Next to research having to be valid, Kirk & Miller (1986) add that reliable research entails the extent to which the findings of the research are unaffected by unintentional research circumstances. Reliable research ensures that its measurements can be repeated (Evers & Sermeurs, 1998). In the current study, this was ensured by a second person who checked upon the code process until it was agreed that the codebook represented the found excerpts in the pre- and post-interview (Belur, 2018). In addition, a multiple-case study design was chosen in order to examine if the lesson series were received differently in varying contexts (Yin, 2017).

Results

Baseline

Here, the current state of affairs in regard of science and technology teaching is described for all teachers and each school individually. First, at the first school two teachers partook in the robotics lesson series and two in the sustainability lesson series. At the second school al four teachers partook in the sustainability lesson series. During the pre-interview, all participants mentioned that science and technology teaching is only offered occasionally at their schools. In addition, all teachers named challenges they face with finding time, the curriculum or organising teaching a science and technology by themselves prior to partaking in the lesson series. Table 2 shows that during the pre-interview most teachers mentioned they had an educational background in science and technology teaching. In addition, there were slightly more teachers that mentioned they had affinity with science and technology teaching than not. Besides, almost all teachers mentioned they had needs that needed to be met in order to have self-efficacy and TPACK. For example, teacher 2 said: '…if I can read about it then I have the confidence that it will work out, but I just need a lot more background for that, extra information.*'*. When taking a closer look, the second school showed an advantage when it came to their background in science and technology teaching. More teachers at the first school mentioned they attended a higher education that offered science and technology courses, but it did not stick in practice, or they attended a post higher education specified on science and technology but they stopped prematurely. In addition, at the first school only two teachers expressed they had affinity with science and technology teaching in comparison to three teachers at the second school. Finally, one teacher at the second school did not need anything in order to have self-efficacy and TPACK knowledge.

Table 2

Teacher Background in Science and Technology Teaching

	School 1 (N = 4)		School 2 (N = 4)	
	No	Yes	No	Yes
Educational background in science and technology teaching (EDUY)	1	3	1	3
Affinity with science and technology teaching (AY)	2	2	1	3
Needs for having self-efficacy and TPACK knowledge (TPACK – CST)	0	4	1	3

Added Value

The Development of the Participating Teachers' TPACK

Table 3 shows the results of the TPACK pre-and-post questionnaire that was conducted prior to and after the lesson series took place. The average scores and standard deviations (between parentheses) on each scale are presented for the entire group of teachers (*Mtotal*) and separately for school one (*M1*) and two (*M2*). The pre-and-post questionnaire had a 5-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5). In the table below, it is shown that the overall average on the TPACK scales was already above 3.00 for the entire group of teachers prior to partaking in the lesson series. However, there is still a noteworthy increase in the average scores on all TPACK scales between the pre- and post-test. The highest increase was found on the pedagogical content knowledge and technological pedagogical content knowledge scales. On the technological knowledge, content knowledge, technological content knowledge, and technological pedagogical knowledge scale of the post-test, the standard deviations are still between 0.50 and 1.00, which entails that the scores lay in a range from 19.1% to 38% on each side of the average. Which means there is a difference in the answers of the participating teachers that were given on the several items that belong to these scales.

Table 3

Comparing the Results of the TPACK Pre-and-Post Test among the Two Schools.

TPACK scales	Technological knowledge	Content knowledge	Pedagogical knowledge	Pedagogical content knowledge	Technological content knowledge	Technological pedagogical knowledge	Technological pedagogical content knowledge
Mtotalpre	3.13 (0.95)	3.00 (0.53)	3.92 (0.42)	3.50 (0.54)	3.25 (0.71)	3.25 (0.40)	3.25 (0.52)
Mtotalpost	3.50 (0.74)	3.42 (0.66)	4.08 (0.44)	4.13 (0.35)	3.38 (0.74)	3.55 (0.61)	3.88 (0.18)
M1pre	2.93 (0.85)	2.75 (0.17)	3.67 (0.24)	3.50 (0.58)	3.00 (0.82)	3.30 (0.42)	3.20 (0.43)
M1post	3.39 (0.87)	3.25 (0.63)	4.13 (0.50)	4.00 (0.00)	3.25 (0.96)	3.50 (0.77)	3.95 (0.10)
M2pre	3.32 (1.13)	3.25 (0.69)	4.17 (0.43)	3.50 (0.58)	3.50 (0.58)	3.20 (0.43)	3.50 (0.62)
M2post	3.61 (0.69)	3.58 (0.74)	4.04 (0.44)	4.25 (0.50)	3.50 (0.58)	3.60 (0.52)	3.80 (0.23)

Note. Standard deviations are presented in parentheses.

The average of both schools started quite high, with the lowest average for the first school on the content knowledge scale and for the second school on the technological pedagogical scale (see Table 3). Prior to partaking in the lesson series, the second school showed a higher average on almost all TPACK scales. After partaking in the lesson series, both schools showed a noteworthy increase in the average scores on almost all TPACK scales. For the first school, this was especially true for the content knowledge, pedagogical content knowledge, and technological pedagogical content knowledge scales. For the second school, this was the case for the pedagogical content knowledge scale. Except for the second school, they also showed a slight decrease in the average score of the pedagogical knowledge scale and an average score that stayed the same on the technological content knowledge scale. In correspondence with the total variance on the technological knowledge, content knowledge, technological content knowledge, and technological pedagogical knowledge scale of the entire group of teachers, the standard deviations of the first and second schools are also still between 0.50 and 1.00 on the post-test. This was the case for the first school on the pedagogical knowledge scale and for the second school on the pedagogical content knowledge scale. This shows there was a difference in the answers of the participating teachers on these scales.

In the pre-interview, all teachers mentioned they had knowledge about the three basic components of TPACK (content, pedagogy, and technology) and/or the interplay between them in order to teach a science and technology lesson, which includes the research and design cycle, which helps students discover new knowledge prior to partaking in the lesson series. In addition, all teachers also mentioned they still missed knowledge about this matter. During the post-interview, four teachers expressed that they gained TPACK knowledge regarding the three basic components of TPACK (content, pedagogy, and technology) and/or the interplay between them in order to teach a science and technology lesson, which includes the research and design cycle, which helps students discover new knowledge. Teacher 3, for example, said, ‘As a teacher, if I was teaching a lesson, I would not use PowerPoint that fast. However, now I see it is also a support.’ These teachers also mentioned some parts in which their TPACK knowledge was still missing. In addition, four expressed that this knowledge remained the same and that they still missed knowledge on certain parts of the TPACK framework or about the curriculum. However, three out of four of these teachers mentioned they still gained some TPACK knowledge by partaking in the lesson series. Teacher 7 expressed:

> If I take into account what I did improve, then I think that it is nice how we use technology now, like Chromebooks. We got them for the first time this year, so I think when I reflect on it, I've made some steps there.

One teacher at the second school did not learn anything new because he already taught the topic of sustainability last year. This shows that most teachers’ TPACK did to a certain extent increase, and that the TPACK of the teachers of the second school increased less than the first.

Overall, the TPACK pre-and-post questionnaire and the data from the pre-and-post interview showed that the lesson series did somewhat increase the TPACK of the participating teachers. This was more the case for the first school. The difference in both schools could be declared by the results that were found in the pre-interview (as described in the ‘Baseline’ chapter), which resulted in a slightly more advanced background in science and technology teaching for the second school. This could lead to a higher average score on almost all TPACK scales at the beginning of the lesson series, a slight decrease on the pedagogical knowledge scale, and the remaining average score on the technological content knowledge scale of the second school. Some issues that remained after partaking in the lesson series for both schools included having difficulties with classroom management that were touched upon in the reflection forms and lesson plan (see Table 5). In addition, in the post-interview and reflection forms, teachers from both schools mentioned issues with using technology in the classroom that remained after partaking in the lesson series. For example, teacher 1 expressed:

> Yes, I think I am more likely to panic if I think I have taken the right steps and it does not work out, as we saw with the PowerPoint. Yes, I am not someone who is super handy with that. If it does not work out, how do I solve it? That is still my threshold.

During the post-interview, questions were asked about which part of the lesson series did contribute to the development of the teachers' TPACK. Table 4 shows that parts of the intervention that did contribute to the development of TPACK were not mentioned often by teachers at both schools. However, there were still three parts of the lesson series that were mentioned during the post-interview. The first part of the lesson series that contributed to the development of TPACK included making a (part) of or teaching a science and technology lesson, which was mentioned by two teachers. The second part was mentioned by three teachers and included studying the pre-made lesson materials in order to foster a teacher's TPACK. Teacher 7, for example, expressed: 'Yes, read the lesson plan, watch the videos, and see the pictures that were attached to it, so you can inform yourself.'. Lastly, two teachers mentioned that observing others who teach a science and technology lesson did contribute to developing TPACK. The first part of the lesson series was mentioned just as often at both schools as part of the lesson series that did contribute to the development of TPACK, the second part was mentioned more at the second school, and the third more at the first. This shows that overall, there was little to no difference between the first and second school in this regard.

Table 4

How well Design Features Influenced the Development of Self-Efficacy

	School 1 (N = 4)		School 2 (N = 4)	
	No	Yes	No	Yes
Making a (part) of or teaching a science and technology lesson did contribute to developing TPACK (IYET)	3	1	3	1
Studying the pre-made lesson materials did contribute to developing TPACK (IYST)	3	1	2	2
Observing others who teach a science and technology lesson did contribute to developing TPACK (IYOT)	2	2	4	0

The table below shows that the teachers score positively on all criteria that were used to analyse the lesson plans, which means the teachers have TPACK knowledge after partaking in the lesson series (see Table 5). This is in correspondence with the positive image that was shown on the TPACK pre- and post-test and during the analysis of the pre- and post-interview. The analysis of the lesson plans showed that all teachers scored positively on offering the research and design cycle, hands-on and minds-on activities, differentiation, using technology, and offering teacher support. All teachers scored to a certain extent positively on formative testing. However, for example, they did not describe how they would analyse the answers to the quizzes to inform future lesson planning. The second school scored less on the concept of classroom management, which includes guiding students while doing research and design, collaboration, and interaction/dialogue. However, the second school had the only teachers who included an organisation outside their school that was meaningful to their students. This means there is little to no difference between both schools in this regard.

Table 5

Analysis of the Lesson Plan

	School 1		School 2	
	Teachers 1 and 2	Teachers 3 and 4	Teachers 5 and 6	Teachers 7 and 8
Parts of the science and technology lesson				
Offering the research and design cycle (O&O)	+	+	+	+
Guiding students while doing research and design (LO)	+	+	+/-	+/-
A meaningful context (BC)	+/-	+/-	+/-	+
Hands-on and minds-on activities (HML)	+	+	+	+
Collaboration (S)	+/-	+/-	-	-
Interaction/dialogue (ID)	+/-	+	+/-	+/-
Differentiation (D)	+	+	+	+
Formative testing (FT)	+/-	+/-	+/-	+/-
Technology (T)	+	+	+	+
Supports the teacher (OU)	+	+	+	+

Enjoyability Teachers' Self-Efficacy and Feelings of Accomplishment

Prior to and after partaking in the lesson series, a pre- and post-questionnaire was conducted to measure if the self-efficacy of the entire group of teachers and the two schools individually increased. In table 6, the average scores and standard deviations (between parentheses) on the PTSE-scale are presented for the entire group of teachers (*Mtotal*) and separately for school one (*M1*) and two (*M2*). The answers that could be given on the items of the pre-and-post questionnaire ranged from *strongly disagree* (1) to *strongly agree* (5). Therefore, the table below shows that the average on the PTSE scale of the entire group of teachers was already quite high prior to partaking in the lesson series. The average score of the post-test, however, shows that the average score still increased after the teachers participated in the lesson series. The standard deviations on the post-test are lower than 0.50, which entails that the scores lay in a range of 19.1% on each side of the average. This means that the scores that were given on the items of the PTSE scale were relatively close to each other. The average score on the PSTE scale increased more at the first school in comparison to the second school. The second school also started out with a higher average score to begin with. This entails that the second school had a slightly lesser increase in their self-efficacy after partaking in the lesson series.

Table 6

Comparing the Results of the Self-Efficacy Pre-and-Post Test among the Two Schools.

PSTE scales	Personal science and technology teaching efficacy beliefs
Mtotalpre	3.30 (0.42)
Mtotalpost	3.84 (0.44)
M1pre	3.18 (0.43)
M1post	3.92 (0.42)
M2pre	3.42 (0.43)
M2post	3.76 (0.46)

Note. Standard deviations are presented in parentheses.

In the pre-interview that was conducted at the start of the lesson series, questions were asked if the teachers had confidence in their ability to teach a science and technology lesson. In the pre-interview, four teachers mentioned they mostly had little or no confidence in their ability to teach a or an aspect of a science and technology lesson. Teacher 1 said, ‘Well, I also do not think I am very sure about myself in this case because I do not have so much experience with it and I am not trained in it, or something like that.’ Two of these teachers, who were evenly distributed among the schools, mentioned that they were confident in using technologies such as Chromebooks during their lessons. Four teachers mentioned they had confidence in their ability to teach a or an aspect of a science and technology lesson. Teacher 4, for example, replied with the statement, ‘Well, I think enough confidence, because I do not panic if a lesson does not bring what I had planned out in advance.’ Three out of four of these teachers belonged to the second school. Therefore, more teachers at the second school expressed confidence in their ability to teach a science and technology lesson before the lesson series took place.

At the post-interview that was conducted after the lesson series took place, questions were asked about whether the teachers confidence in their ability to teach a science and technology lesson increased. In the post-interview, four teachers mentioned that their confidence in their ability to teach a science and technology lesson increased. Teacher 6, for example, replied, ‘Well, that confidence... has grown.’ Two out of four of these teachers also named parts of a science and technology lesson where their confidence was still missing. In addition, four teachers mentioned their confidence in the ability to teach a science and technology lesson stayed the same and was still missing on certain parts after partaking in the lesson series. Teacher 4 for example replied, ‘I don’t think my confidence has changed’. Still, three out of four of these teachers still mentioned they were willing to teach a science and technology lesson themselves after partaking in the lesson series. The one teacher who solely mentioned at the post-interview that their confidence level in teaching a science and technology lesson did not increase by partaking in the lesson series belongs to the second school. This result shows that confidence in the ability to teach a science and technology lesson increased less among the teachers of the second school.

The data from the self-efficacy pre- and post-test and the interviews showed that the lesson series did, to a certain extent, foster the self-efficacy of the participating teachers. This was more the case for the teachers at the first school. This difference could also be explained by the difference in the starting point of both schools when it comes to science and technology teaching (see the ‘Baseline’ chapter), which showed that the second school had a slightly more advanced background in science and technology teaching than the first school. This advantage could explain the higher average score on the PTSE scale prior to participating in the lesson series and the slighter increase in their average score after partaking in the lesson series. Overall, parts of a science and technology lesson on which the confidence level of most participating teachers’ was still missing included teaching with technology. Teacher 4, for example, expressed that teaching with more difficult technologies, such as robots, was still a part of science and technology teaching, where his confidence still lacked:

> So, especially when you talk about programming or robotics, for example, there is a big difference in terms of ability. But you actually have to start at the same level for everyone, and then for many children, it goes as follows: for some, it goes too slowly, and for others, it goes much too fast, and you notice that. Well, yes, especially with lessons such as programming, I find that, I find that difficult. Like with this lesson series, it all goes fairly evenly, and then it actually runs smoothly.

During the post-interview, teachers mentioned parts of the lesson series that did contribute to a sense of self-efficacy. Table 7 shows which parts of the lesson series were mentioned and how often. The table shows that not all teachers named parts of the lesson series that did contribute to their sense of self-efficacy. Nonetheless, four parts of the lesson series were mentioned to contribute to the teachers’ sense of self-efficacy. First, five teachers mentioned that making a (part) of a science and technology lesson or teaching it did contribute to a sense of self-efficacy. One teacher mentioned it again in their reflection forms. Second, at the post-interview, two teachers mentioned that studying the pre-made lesson materials did contribute to a sense of self-efficacy. This was also true for observing others who teach a science and technology lesson and gradually releasing the task difficulty. Teacher 1 said about the latter: ‘If you asked me if I wanted to teach a science and technology lesson, then I would have hesitated, but since we have entered our school now, you are shown the way, and then it turns out to be going very well after all.’ Making a (part) of a science and technology lesson or teaching it was slightly mentioned more times at the first school than at the second school. The other parts of the lesson series that did contribute to a sense of self-efficacy were all mentioned solely at the first school. This also shows that the second school was helped less by partaking in the lesson series when it comes to increasing their self-efficacy.

Table 7

How well Design Features Influenced the Development of Self-Efficacy

	School 1 (N = 4)		School 2 (N = 4)	
	No	Yes	No	Yes
Making a (part) of a science and technology lesson or teaching it did contribute to a sense of self-efficacy (IYESE)	1	3	2	2
Studying the pre-made lesson materials did contribute to a sense of self-efficacy (IYSSE)	2	2	4	0
Observing others who teach a science and technology lesson did contribute to a sense of self-efficacy (IYOSE)	2	2	4	0
Gradually releasing the task difficulty did contribute to a sense of self-efficacy (IYSBSSE)	2	2	4	0

Efficiency

During the post-interview, questions were asked about the efficiency of the lesson series, and the results showed that the lesson series was not yet efficient enough. However, table 8 shows that in the post-interview, half of the teachers mentioned that partaking in the lesson series took a regular or less than regular amount of time. Nonetheless, two of these teachers mentioned that the amount of time the lesson series cost was solely fine for the duration of the project. In addition, half of the teachers expressed that partaking in the lesson series took up much time. The latter was also written down by one teacher in their reflection forms. In contrast, during the post-interview, most teachers expressed that partaking in the lesson series took them a regular, too little amount of effort. Most of the teachers who did mention that partaking in the lesson series took much time and effort belonged to the second school. Which drafts the image that partaking in the lesson series costs the teachers at the second school more time and effort than the teachers at the first school. Parts of the lesson series that took up much time and effort were making and preparing the lessons. Parts of the lesson series that were mentioned in the reflection forms and post-interview that saved time and effort were already having pre-made lesson materials that could be used or the collaboration with colleagues and guidance of the researcher that occurred while making the lesson. As mentioned by teacher 3, who said:

> If you make a lesson, do it with your, with your colleagues, or with two people, five/six together, seven/eight together, three/four together, because it takes you less time together. If you work together and consult like we did, we had something within an hour and a half.

Table 8

The Amount of Time and Effort it Took the Teacher to Partake in the Lesson Series

	School 1 (*N* = 4)		School 2 (*N* = 4)	
	No	Yes	No	Yes
It took the teacher overall a regular or less than regular amount of time to partake in the lesson series (ETL)	1	3	3	1
It took the teacher overall a regular or less than regular amount of effort to partake in the lesson series (EEL)	0	4	2	2

Compatibility

During the post-interview, questions were asked about the compatibility of the lesson series with the prior knowledge, beliefs, and goals of the teachers. Half of the teachers had mentioned the lesson series was compatible with their prior knowledge (see Table 9). One teacher expressed it again in the reflection forms. In contrast, the other half of the teachers thought the lesson series was mostly not compatible with their prior knowledge about teaching a science and technology lesson. The same image was drafted when it came to the beliefs and goals of the teachers. In the post-interview, half of the teachers expressed that the lesson series was compatible with their beliefs and goals when it comes to science and technology teaching. The other half of the teachers mentioned their beliefs and goals in regard to teaching a science and technology lesson changed or that the lesson series were not compatible with their beliefs and goals. The compatibility of the lesson series with the beliefs and goals of the teachers was evenly distributed among the schools. Nevertheless, the lesson series was less compatible with the prior knowledge of the teachers of the first school. Not to mention, two teachers of the first school with whom the lesson series were mostly not compatible with their prior knowledge about teaching a science and technology lesson did mention that the lesson series were compatible with their prior knowledge about technology. This was the case for one teacher at the second school, which brings the difference between the schools in this matter slightly closer to each other. Parts where the lesson series were not always compatible with the prior knowledge of the teachers were, for example, e-learnings, solar energy, and making a Kahoot. For the last two solutions were already found during the lesson series.

Table 9

The Compatibility of the Lesson Series with the Prior Knowledge and Beliefs and Goals of the Teachers

	School 1 (*N* = 4)		School 2 (*N* = 4)	
	No	Yes	No	Yes
The lesson series were compatible with the prior knowledge of the teacher (CKY)	3	1	1	3
The lesson series were compatible with the beliefs and goals of the teacher (CBGY)	2	2	2	2

Clarity

The results of the pre- and post-interview show that the lesson series was not clear enough for all teachers. Table 10, namely, shows that most teachers expressed unclarities about the pre-made lesson materials during the post-interview, and four teachers expressed unclarities about the time that was spent on each lesson. Teacher 3 mentioned the latter:

> When you teach a lesson, for example, about technology, actually every lesson, by the way, be careful with your time. The concentration of children is approximately three-quarters of an hour. Think of lessons that last three-quarters of an hour. Go there. That is also practically feasible.

During the post-interview, teachers who participated in the sustainability lesson series were the only ones who mentioned these types of unclarities about the time that was spent on each lesson. Teachers who participated in the sustainability lesson series mainly belonged to the second school, where most teachers were situated, who expressed that the time spent on each lesson was unclear. The unclarities about the pre-made lesson materials that were named in the post-interview included unclarities about the materials that were used during the lessons, information and assignments that were included in the pre-made lesson materials, and the level of difficulty of the pre-made lesson materials. In addition, unclarities about the number of learning goals in one lesson were added after analysing the reflection forms. The number of learning goals was also mentioned in the post-interview as the reason that the lesson series took up too much time on a regular school day.

Table 10

Unclarities about the Lesson Series

	School 1 (*N* = 4)		School 2 (*N* = 4)	
	No	Yes	No	Yes
The pre-made lesson materials were unclear for the teacher (CNLP)	0	4	1	3
The time spent on each lesson was unclear for the teacher (CNT)	3	1	1	3

Tolerance

The results of the pre- and post-interviews show that certain parts of the lesson series played out differently when they were implemented at the schools. In the post-interview and reflection forms, most teachers mentioned that they made adjustments to the pre-made lesson materials that were not in line with the previously intended goals of the lesson series (see Table 11). Teacher 6, for example, mentioned:

> Yes, in the lesson that I taught myself, as I have already indicated, I have examined how much I considered things to be effective in transmitting something; for example, that linear, well, I deleted it and applied it in a different way.

Furthermore, during the post-interview, all teachers mentioned they collaborated with their colleagues when they participated in the lesson series. However, this was not yet taken into account in the current design of the lesson series. To add to that, most teachers mentioned they used the involvement of the researcher as a coach when designing the lesson. Previously, it was expected that asking some final questions would be enough in order to make their own science and technology lesson. This shows that there were still some adjustments made to the current design of the lesson series when it was implemented at the schools. Making adjustments to the pre-made lesson materials and collaboration among colleagues happened just as often at the two schools. In contrast, having the researcher there to help with designing the fourth lesson occurred less at the second school than at the first. In the post-interview and reflection forms, teachers mentioned adjusting the information in the pre-made lesson materials by making them up-to-date and at the right level of difficulty, adding certain materials to make more challenging assignments or removing certain assignments, and lastly, making the instruction shorter than was previously intended.

Table 11

Adjustments that were not in Line with the Previously Intended Goals of the Lesson Series

	School 1 (N = 4)		School 2 (N = 4)	
	No	Yes	No	Yes
Adjustments that were made to the pre-made lesson materials (TLP)	1	3	1	3
Collaboration among teachers (TC)	0	4	0	4
Involvement of the researcher as coach when designing the lesson (TIR)	0	4	2	2

Conclusion and Discussion

Main Findings

In order to answer the research question 'What is the local viability of the adjusted lesson series that are intended to increase teachers' self-efficacy and TPACK in science and technology teaching' the lesson series were evaluated on all aspects of local viability. These were added value (existing effectiveness, efficiency, and enjoyability), compatibility, clarity, and tolerance. During the analysis of the data sources, it was found that the local viability was not yet where it could be. Even though it can be said that the lesson series added value since it somewhat increased the TPACK and self-efficacy of the participating teachers in science and technology teaching, teachers also enjoyed partaking in the lesson series. The lesson series was not yet efficient enough for most teachers. The lesson series were also not always compatible with the previous knowledge and the beliefs and goals of the teachers. Nonetheless, for most issues, solutions were already found during the lesson series, and often the lesson series led to changes in the beliefs and goals of the participating teachers. Most teachers mentioned unclarities about the pre-made lesson materials and half about the time spent on each lesson. This entails that the lesson series was not yet clear enough for the participating teachers. Finally, the teachers made adjustments to the lesson series that were not in line with the previously attended goals of the lesson series, which makes the lesson series not yet tolerant enough. Teachers made adjustments to the pre-made lesson materials, collaborated, and got help with designing the fourth lesson.

Differences Between the First and Second School

In addition, it was examined if the participating schools responded differently on several aspects of local viability. First, the lesson series added more value to the first school than to the second school. Namely, the TPACK and self-efficacy of teachers at the first school increased more than those at the second school. This could be explained by the difference between the schools that was found in their prior experience in science and technology teaching. Since teachers who are more experienced in science and technology teaching perform better in practice (Chichekian & Shore, 2016; Djoyoadhiningrat-Hol & Klein Tank, 2022). This could explain why the second school of teachers received less benefit from the lesson series. Since they had more expertise in teaching science and technology, the series was unable to make the same kind of impact as it had on the first school. In addition, it took the second school more time and effort to participate in the lesson series. However, there was not much difference when it came to their compatibility, clarity, and tolerance. Nonetheless, the teachers who found that the time spent on each lesson was not clear were mostly situated at the second school. Not to mention, more teachers at the second school designed the fourth lesson without help from the researcher. Even though this was named as a part of the lesson series, that saved time and effort. Which could explain the differences between the schools when it came to the time and effort that was spent on the lesson series due to the importance of gradually releasing the task difficulty while developing teacher self-efficacy and TPACK in order to keep a balance between the effort that needs to be put into a task and successfully accomplishing it in check (Labone, 2004; Tondeur et al., 2012).

Recommended Alterations to the design

Finally, it is discussed how the lesson series needs to be altered to increase the chance that it could be implemented at a Dutch primary school. When it comes to added value, teachers' TPACK was still missing on classroom management and using technology in the classroom. The latter was also mentioned as a part of science and technology teaching where teachers' self-efficacy is still lacking. Therefore, more emphasis should be put on guiding teachers in their technology use and classroom management. First, this can be done by improving the design of how teachers learn about science and technology teaching and TPACK, since these were not named as parts of the lesson series that did contribute to the development of the teachers' TPACK and self-efficacy. This came as a surprise because improving teachers' knowledge about science and technology teaching was mentioned by Swackhamer et al. (2009) as a way to foster teachers' self-efficacy. In addition, Jang (2010) mentioned that improving teachers' TPACK knowledge was a way to foster TPACK. In the study of Jang (2010), teachers needed to learn about TPACK in groups by studying textbooks and articles in teams. Besides, during these group sessions they learned about IWB technology. Since teaching with technology and classroom management remains difficult for teachers in regard to their self-efficacy and TPACK in science teaching, it might be important to include learning about teaching science and technology and TPACK in a collaborative team session were these topics can be discussed.

Second, in order to provide more guidance on how teachers can organise their classroom management during science and technology teaching and corporate technology in these lessons, an adjustment of the design for teacher reflection is discussed. Teacher reflection was not named as a part of the lesson series that did contribute to the development of the teachers' TPACK and self-efficacy. The reason that reflection was not named as a part of the lesson series that did contribute to developing teachers' self-efficacy and TPACK could be because the answers on the reflection form were quite short. This form of teacher reflection, however, did not contribute enough to the development of the participating teachers' TPACK and self-efficacy. Nonetheless, Lotter et al. (2018) and Tondeur et al. (2012) named teacher reflection as a way to foster teachers' self-efficacy and TPACK. Therefore, it is advised to find a better way to support teacher reflection, for example, by videotaping the science and technology lesson, which allows the teacher to share their teaching experience with colleagues and therefore receive feedback from peers who help identify the teacher's strong and weak points (Jang, 2010; Lotter et al., 2018). Here, classroom management and technological issues can be discussed, which were the two topics on which the current intervention could offer more support.

When it comes to the tolerance of the design, teachers used the lesson series with the supporting materials differently than previously intended. To start, teachers still needed to make changes to the pre-made lesson materials because they were not clear enough. Even though teachers should have been able to use the pre-made lesson materials right away as they were intended to offer the teachers support during the second lesson, which they needed to teach on their own before making and implementing their own science and technology lesson. This was done in order to gradually release task difficulty to improve the teacher's self-efficacy and TPACK (Labone, 2004; Tondeur et al., 2012). In addition, during the lesson series, the teachers needed more guidance from the researcher when designing the science and technology lesson than previously expected. Therefore, it is advised to make the pre-made lesson materials more clear and include support while designing the science and technology lesson in order to better contain the gradual release of task difficulty as a way to foster a teacher's TPACK since this was not yet named as a part of the lesson series that did contribute to the development of a teacher's TPACK (Tondeur et al., 2012). This is also advised since preparing and making the lessons now still costs the teachers too much time and effort. Finally, every teacher collaborated during the current lesson series. This finding, however, did not come as a surprise since Anderson (2002) and Tondeur et al. (2012) already argued that teachers should collaborate to increase their self-efficacy and TPACK. Including collaboration among colleagues could also benefit the suggested alterations concerning learning about science and technology teaching, TPACK, and supporting teacher reflection.

Implications for Research

This study intends to build upon the previously explored theory on how to foster a teacher's self-efficacy and TPACK in science and technology teaching. First, in the study of, for example, Lotter et al. (2018), it is discussed that improving teachers knowledge of science and technology teaching can improve their self-efficacy. Palmer (2011) calls this type of knowledge cognitive mastery, and it concerns a teacher's understanding of the subject that is being taught. Morris et al. (2017), however, suggested further research should be done on which sources of teacher knowledge can exactly foster teachers self-efficacy. This is done to build upon the theory of Bandura (1997), who already mentioned that mastery experience, vicarious experience, verbal persuasion, and emotional arousal are incentives to foster a teacher's self-efficacy. In the current study, it was examined which parts of the lesson series did contribute to the development of the teacher's self-efficacy in science and technology teaching. It was found that two teachers mentioned that studying the pre-made lesson materials fostered their self-efficacy in science and technology teaching. Even though this is not extensive, it still accounts for 25% of the participants in the current study and might indicate that it could be a potential source for increasing a teacher’s self-efficacy.

In addition, in the current study, it is examined how a teacher's TPACK in science and technology teaching can be fostered. In previous studies, for example, Jang (2010) and Tanak (2018), the teachers needed to make and implement a science lesson that included the TPACK framework in order to foster their TPACK. However, in this process, inquiry-based instruction was not yet included in the professional development programs. Even though this is part of the pedagogical content knowledge of science and technology teaching (Mishra & Koehler, 2006; Rougoor-Fiering & Benes, 2020; Van Der Zee et al., 2021). Therefore, Tanak (2018) suggested that the participating teachers also engage in inquiry-based instruction in order to foster their TPACK in science and technology teaching. This was done in the current study by letting teachers design and teach a science and technology lesson that involved inquiry-based instruction (e.g., the research-and-design cycle) (Djoyoadhiningrat-Hol & Klein Tank, 2022). This part of the lesson series was mentioned by two teachers as a part of the lesson series that did contribute to their TPACK development in science and technology teaching. Even though it was not named often, the results indicate that designing and making a lesson that includes inquiry-based teaching could foster a teacher's TPACK in science and technology teaching.

Implications for Practice

Furthermore, there are also implications for practice. The data gathered in this research showed that the lesson series, to a certain extent, led to an increase in the participants' self-efficacy and TPACK in science and technology teaching. What was in line with theory was that making a (part of) or teaching a science and technology lesson, studying the pre-made lesson materials, and observing others were mentioned as parts of the lesson series that did foster teachers' self-efficacy and TPACK (Jang, 2010; Koehler & Mishra, 2005; Labone, 2004; Lotter et al., 2018; Palmer, 2011; Shah & Bhattari, 2023; Tanak, 2018; Tondeur et al., 2012). In addition, gradually releasing task difficulty was mentioned as a part of the lesson series that did foster teachers' self-efficacy (Labone, 2004). In the paragraphs above, adjustments were made to the current design of the lesson series. Since teacher reflection, learning about TPACK, and science and technology teaching were not named as parts of the lesson series that did contribute to the development of a teacher's TPACK and self-efficacy, even though this was in line with theory (Jang, 2010; Lotter et al., 2018; Swackhamer et al., 2009; Tondeur et al., 2012), To add to this, gradually releasing task difficulty was not named as a way to develop TPACK, even though this was expected (Tondeur et al., 2012). As previously described, changes that could be made include putting more emphasis on learning about science and technology teaching, TPACK, teacher reflection, making the pre-made lesson materials more clear, letting colleagues collaborate, and offering more guidance when designing the science and technology lesson. Changing these aspects of the lesson series could increase the local viability of the lesson series and, therefore, increase the chance that Pre-University can implement the lesson series in the context of a Dutch primary school (McKenney & Reeves, 2019; Yin, 2017).

Limitations

In the current study, there were some limitations. First, no observations were conducted that could be used as a data source. These were used as a data source in the study of Ozel and Luft (2013) to be able to examine what happened in the classroom. This would have been a valuable perspective on the results since it could provide information on the technological and classroom management issues that were touched upon in the post-interviews and reflection forms. First, classroom observations could provide further insight into the classroom management that is needed during science and technology lessons since they can depict how several classes respond differently to the lesson series (Cohen & Goldhaber, 2016; Steinberg & Garret, 2016). Is it a class that demands more structure when it comes to classroom management? This can provide more insight into the pedagogical knowledge of the TPACK framework since it includes the concept of classroom management. Using the TPACK framework to teach a science and technology lesson also entails adjusting the concepts of the TPACK framework to the characteristics of the classroom in which the observation can provide further insight (Koehler et al., 2013). Second, the observation can be used to provide further insight into how teachers include technology in their classrooms, since this was still a learning point for the teachers that participated in the current study. It can be examined if the teachers have enough technological knowledge and, therefore, skills to use various technologies in their classrooms (Mishra & Koehler, 2006).

The second limitation involves the generalisability of the current study. The generalisability is about the extent to which the results of a study can also be applied to other schools; this is called external validity (Smaling, 2009). This can help measure whether the developed lesson series can also be useful in other contexts. In the current study, two schools were chosen to form the cases for this study. For both schools, the teachers background in science and technology teaching was examined. This was done to examine how the lesson series performed in different contexts (Yin, 2017). In the current study, it was found that the teachers of the second school were somewhat more experienced in science and technology teaching than the teachers of the first school, which could explain why their self-efficacy and TPACK increased less in comparison to the teachers at the first school (Chichekian & Shore, 2016; Djoyoadhiningrat-Hol & Klein Tank, 2022). However, both schools started quite high on the pre- and post-tests and interviews when it came to their TPACK and self-efficacy when it comes to science and technology teaching. Therefore, it might be useful to examine how a school that starts lower in these areas responds to the lesson series to see if the found results are also applicable to these types of contexts.

The third limitation, which involves the interrater reliability of the codebook that was created in the current study, should be discussed. In the current study, the coding was performed by one coder and checked and agreed upon by a second person. However, interrater reliability, where several coders were involved and agreed upon the code process, ensures that the collected data fully represents the concepts that were measured (Belur, 2018; McHugh, 2012). When interrater reliability is applied, it is examined how often the several coders assign the same codes to the same excerpts as the other coders. This ensures that the results of the research are unaffected by the conditions of the research at hand. Meaning, the found results do rely on more coders instead, who needed to agree with each other on the several codes and corresponding excerpts instead of one coder. Making this adjustment would have ensured that the findings were even more valid and reliable than they already were, since it ensures that the results of the research are explained in the right way, and they would have been less affected by the prescribed conditions of the current research (Kirk & Miller, 1986).

Future Directions

In the current study, information was gathered on the local viability of the adjusted lesson series, meaning it was examined how the adjusted lesson series performed in the context of a Dutch primary school classroom (McKenney & Reeves, 2019). It was found that the lesson series, to a certain extent, could withstand themselves in the context of a Dutch elementary school classroom. However, both schools that participated already started off with quite a high self-efficacy and TPACK when it came to science and technology teaching prior to partaking in the lesson series. To examine if the results of the current study are also generalizable to a larger context, it is advised to conduct research at schools that score lower or maybe even higher in both areas prior to using the lesson series (Smaling, 2009; Yin, 2017). In addition, it was examined what alterations need to be made to the design of the lesson series in order to improve the chance that the lesson series could get implemented in the context where it was meant for (McKenney & Reeves, 2019; Yin, 2017). To improve this chance, it was recommended that some changes be made to the current design. Once these changes are made to the current design, this leads to a more stable design, which could be implemented once more in a broader context. This is part of gamma testing, where the effectiveness of a more stable intervention can be tested (McKenney and Reeves, 2019). Measuring effectiveness during gamma testing entails examining whether or not the intervention is capable of meeting its intended goals when it gets implemented without having to make any adjustments while doing so. This can be done to examine if taking the advised chances is indeed effective.

In conclusion, the lesson series improved teachers' TPACK and self-efficacy in teaching science and technology at the second school more than at the first. In addition, the evaluation of the lesson series also showed improvements in its local viability could still be made. Nonetheless, the lesson series did foster the self-efficacy and TPACK of the participating teachers at both schools to a certain extent, which indicates promising results for future versions of the current design.

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Appendix

Appendix A: E-Learnings

Example of the Multimedia and Signalling Principle

Note. This slide of the e-learning shows a picture of the research- and design- cycle and a corresponding text were the most important words are highlighted, prompts are made bold, and the title is enlarged.

Example of the Spatial and Temporal Contiguity Principle

Note. In this slide the graphic is placed next to the corresponding text at the same time.

Example of the Worked Example and Personalization Principle

Note. In this slide a worked-out example is given of a science and technology lesson that is put in the context of the students. In the slide, the teacher is addressed by using the word ‘je’ this is a Dutch translation for the word ‘you’.

Example of the Self-Explanation and Feedback Principle

Note. In this slide teachers get questioned about what they have previously learned about the research-and-design cycle. Feedback is directly provided by clicking on the magnifying glass.

Appendix B: The Design

Design requirements and design propositions

Design requirements	**Design propositions self-efficacy**	**Design propositions TPACK**	**Specific manifestations**
Create a follow-up for Pre-Universities lesson series.	Gradually releasing the task difficulty.	Gradually releasing the task difficulty.	Let them create and teach the fourth lesson (while keeping the lesson goals of the fourth lesson in mind) with some guidance of the researcher
The intervention should be feasible which means, it should take up more time or employees than is needed in the current situation.	Observing a science and technology lesson.	Observing a science and technology lesson.	Use an observation form to observe the lesson and make notes.
	Implementing a science and technology lesson in the classroom.	Implementing a science and technology lesson in the classroom.	Implement the lesson during the fourth lesson.
	Reflecting on their science and technology lesson.	Reflecting on their science and technology lesson.	Create a reflection form they can fill in themselves.
For the current research it is fine that there will be more interaction, for example by doing an interview etc.	Reflecting on their science and technology lesson.	Reflecting on their science and technology lesson.	Fill in a reflection form and have a reflection meeting in the afternoon
Lesson-Up is available to use.	Supporting teacher knowledge.	Supporting teacher knowledge.	Interactive Lesson-Up Manual
	Reflecting on their science and technology lesson.	Reflecting on their science and technology lesson.	Interactive Lesson-Up on reflection
Teachers should have confidence in making and teaching science and technology themselves.	Gradually releasing task difficulty.		Let them create and teach the fourth lesson (while keeping the lesson goals of the fourth lesson in mind)

			with some guidance of the researcher
	Supporting teacher knowledge.		Interactive lesson-Up Manual Video
	Observing a science and technology lesson.		Use an observation form to observe the lesson and make notes.
	Making a science and technology lesson and implementing it in their classroom.		Let them create and teach the fourth lesson by filling in a workbook or lesson plan (while keeping the lesson goals of the fourth lesson in mind) with some guidance of the researcher.
	Reflecting on their science and technology lesson.		Reflect on the second and fourth lesson while using a reflection form and having a reflection meeting
Teachers should know how to use technology in their lessons.		Gradually releasing task difficulty	Let them create and teach the fourth lesson (while keeping the lesson goals of the fourth lesson in mind) with some guidance of the researcher
		Supporting teacher knowledge	Manual Interactive Lesson-Up Video
		Observing a science and technology lesson	Use an observation form to observe the lesson and make notes.
		Making a science and technology lesson and implementing it in their classroom.	Let them create by filling in a workbook or lesson plan (while keeping the lesson goals of the fourth lesson in mind) with some guidance of the researcher. Carry out the

			lesson during the fourth lesson
		Reflecting on their science and technology lesson.	Reflect on the second and fourth lesson while using a reflection form and having a reflection meeting
Use the technological products that Pre-University has.	Making a science and technology lesson and implementing it in their classroom.	Making a science and technology lesson and implementing it in their classroom.	Use the technologies Pre-University already uses to inform their employees or during the lesson series
Create products that Pre-University can use when the research is done.	Supporting teacher knowledge.	Supporting teacher knowledge.	Manual Interactive Lesson-Up Video
	Make a science and technology lesson.	Make a science and technology lesson.	Workbook Using a lesson plan form.
	Reflecting on their science and technology lesson.	Reflecting on their science and technology lesson.	Make a reflection form they can fill in themselves. Interactive Lesson-Up

Weighted matrix

	Design requirements							
Design options	Follow up	Product for Pre-U	Feasible	For research	Lesson-Up	Self-efficacy	TPACK	Technology from Pre-U
Create and teach the fourth lesson while keeping the original lesson goals	+	+	+	+	-	+	+	+
Explanation through a manual	+	+	+	+	-	+	+	-
Explanation through an interactive lesson-up	+	+	+	+	+	+	+	+
Explanation through a video	+	+	+	+	-	+	+	-
Workbook for guiding lesson planning	+	+	+	+	-	+	+	-
Guided lesson planning in real life	+	-	-	+	-	+	+	-
Form for lesson planning	+	+	+	+	-	+	+	-
Filling in a reflection form	+	+	+	+	-	+	+	-
Having a reflection meeting	+	-	-	+	-	+	+	-
Observe students	+	+	+	+	-	+	+	-

with observation form.								

Skeleton design

Design task	Materials	Activities	Participation
Scaffolding is used, which means task difficulty is gradually released.	Lesson series of Pre-University	The teacher teaches the second lesson with the help of the lesson plans of Pre-University. The fourth lesson they will create and teach themselves according to the original lesson goals.	The researcher offers the teacher guidance while making the fourth lesson by offering supporting materials and allowing the teacher to ask final questions about designing the lesson. The teacher teaches the fourth lesson based on their created lesson plan.
Support teacher knowledge	Lesson-Up module	Going through the Lesson-Up.	The teacher goes through the Lesson-Up.
Learn about technology	When needed a manual on how to use the technology	Going through the manual if needed. Perhaps for the Lego Mindstorm robots and Mbot. There are manuals, but perhaps a more easy to use manual is needed.	The teacher goes through the manual.
Observe a science and technology lesson	Lesson observation form.	Observe a student who teaches a science and technology lesson.	The teacher observes a student.
Make a science and technology lesson.	Pre-made lesson materials of Pre-University Lesson-Up modules When needed a manual on how to use technology Lesson form	Going through the previous made lesson materials, Lesson-Ups and perhaps a manual about the Lego Mindstorm robots or the Mbot. Creating a lesson-plan with guidance of a lesson form and a little guidance of the researcher.	The teacher uses the lesson plan to design a science and technology lesson.
Implement the lesson plan	The created lesson form and PowerPoint	Carry out the lesson.	The teacher teaches the fourth lesson of the lesson series.
Reflect on the science and technology lesson	Reflection form Lesson-Up module	Reflect on the lesson by using a reflection form and learning about reflection by going through the Lesson-Up on reflection. Having a reflection meeting.	The teacher reflects on the lessons they teach, so the second and fourth lesson of the lesson series. The researcher is present during the reflection meeting.

Enactment
Teachers learn about science and technology teaching, TPACK and reflection
Teachers considerably learn about the technology that is used
Teachers observe a science and technology lesson
Teachers make a science and technology lesson
Teachers implement the lesson plan in the classroom
Teachers reflect on their science and technology lesson

Outcome
Increased self-efficacy in science and technology teaching
Increased knowledge of TPACK.
Having an intervention that is feasible for Pre-University
Have a follow-up for Pre-Universities lesson series
Use technology that Pre-University uses
Lesson-Up is used
Have materials that Pre-University can use when the research is done. Such as the Lesson-Up module about science and technology teaching, TPACK, and reflection.

Appendix C: Technologies that are used in the Lesson Series

Lessons for 5/6	Earth and planets	Sustainability	Robotics
1	Solar walk lite app/ an online planetarium/ a demonstration tool/videos/PowerPoint	Website lights on/videos/PowerPoint	Ozobot/videos/PowerPoint
2	Google maps/videos/PowerPoint	Tool esa/videos/PowerPoint	Videos/PowerPoint
3	Google earth/ videos/PowerPoint	Website of WNF/videos/PowerPoint	Mbot/videos/PowerPoint
4	-	-	Mbot

Lessons for 7/8	Earth and planets	Sustainability	Robotics
1	Google Earth/videos/PowerPoint	Nasa tool/videos/PowerPoint	Videos/PowerPoint
2	Google/vidoes/PowerPoint	Kahoot	Videos/PowerPoint
3	Videos/PowerPoint	Videos/PowerPoint	Lego Mindstorm robots/videos/PowerPoint
4	-	-	Lego Mindstorm robots

Appendix D: Observation Form

Informatie vooraf

- Links staat de stap van de onderzoekscyclus. Let op! Soms worden stappen overgeslagen of vaker bezocht.
- Kijk naar de kijkvragen. Zet een ✗ als het niet gebeurd en een ✓ als het wel gebeurd.
- Beschrijf daarachter per vraag de leraar activiteiten en gebruikte materialen.

Stap onderzoekcyclus	Kijkvraag	✗ / ✓	Activiteit	Materialen
Confronteren De leerling maakt kennis met het onderwerp.	Hoe is de belevingswereld van de kinderen bij deze stap betrokken?			
	Wordt er technologie gebruikt?			
Verkennen Het onderwerp wordt uitgelegd.	Hoe worden de begrippen uitgelegd?			
	Wordt het GRRIM- model toegepast?			
	Worden leerlingen uitgenodigd tot interactie met elkaar of de leerkracht?			
	Wordt er technologie gebruikt?			
Opzetten van het onderzoek De kinderen maken een onderzoeksopzet.	Welke vraag gaan ze beantwoorden?			
	Hoe gaan ze te werk?			
	Waar moet het aan voldoen?			
Onderzoek uitvoeren De kinderen voeren het onderzoek uit.	Hoe werken ze samen?			
	Hoe wordt het gesprek tussen leerlingen begeleid?			
	Hoe wordt het bewijsmateriaal vastgelegd?			
	Wordt er gedifferentieerd?			
	Wordt technologie gebruikt?			

Concluderen Op basis van de resultaten wordt antwoord gegeven op de onderzoeksvraag.	Hoe leggen de leerlingen het resultaat vast?			
Presenteren de leerlingen tonen wat zij hebben onderzocht, hoe zij dit hebben gedaan en wat de conclusie is.	Hoe presenteren de leerlingen hun eindproduct?			
	Waar moet de presentatie aan voldoen?			
Afsluiting hier kan een verdieping en verbreding worden aangeboden en gereflecteerd worden op de les.	Hoe wordt er verdieping en verbreding aangeboden?			
	Hoe wordt het reflecteren vormgeven?			
	Wordt er technologie gebruikt?			

Informatie vooraf

- Links staat de stap van de ontwerpcyclus. Let op! Soms worden stappen overgeslagen of vaker bezocht.
- Kijk naar de kijkvragen. Zet een ✖ als het niet gebeurd en een ✓ als het wel gebeurd.
- Beschrijf daarachter per vraag de leraar activiteiten en gebruikte materialen.

Stap ontwerpcyclus	Kijkvraag	✖ / ✓	Activiteit	Materialen
Confronteren De leerling maakt kennis met het probleem waar een oplossing voor ontworpen gaat worden.	Hoe is de belevingswereld van de kinderen bij deze stap betrokken?			
	Wordt er technologie gebruikt?			
Verkennen Het probleem wordt uitgelegd en de oplossing die ontworpen moet worden wordt besproken.	Hoe worden de begrippen uitgelegd?			
	Wordt het GRRIM- model toegepast?			
	Worden leerlingen uitgenodigd tot interactie met elkaar of de leerkracht?			
	Welke materialen, gereedschappen en technieken zijn beschikbaar?			
	Aan welke eisen moet de oplossing voldoen?			
	Wat wordt er van de leerlingen verwacht?			
	Wordt er technologie gebruikt?			
Ontwerp schetsen De kinderen maken een ontwerpschets	Hoe wordt er gedifferentieerd?			
	Hoe werken de leerlingen samen?			
	Hoe wordt het gesprek tussen leerlingen begeleid?			
	Hoe weten de leerlingen waar het ontwerp aan moet voldoen?			
Ontwerp realiseren De leerlingen maken het prototype met het materiaal dat beschikbaar is.	Hoe werken de leerlingen samen?			
	Hoe wordt het gesprek tussen leerlingen begeleid?			
	Wordt er gedifferentieerd?			
	Wordt technologie gebruikt?			
Ontwerp testen en bijstellen Het ontwerp wordt getest en waar nodig bijgesteld.	Hoe weten de leerlingen waar het ontwerp aan moet voldoen?			
Presenteren De leerlingen presenteren hun ontwerp aan de klas.	Hoe wordt de presentatie vormgegeven?			
	Wat moeten ze vertellen?			
Afsluiting hier kan een verdieping en verbreding worden aangeboden en gereflecteerd worden op de les.	Hoe wordt er verdieping en verbreding aangeboden?			
	Hoe wordt het reflecteren vormgegeven?			
	Wordt er technologie gebruikt?			

Appendix E: Reflection Form

Informatie vooraf

- Vul het reflectie formulier zo uitgebreid mogelijk in. Ben je klaar? Stuur het formulier ingevuld op naar a.a.hilderink@student.utwente.nl.

Reflecteren op het lesgeven
Voorbereiding
• Wat ging al heel goed?   • Wat liep niet zoals verwacht of vond je nog lastig?
Beeldvorming
• Kun je het verklaren? Waarom ging iets heel goed?   • Kun je het verklaren? Waarom liep iets niet zoals verwacht of vond je het nog lastig?
Conclusies trekken
• Wat zijn de belangrijkste conclusies van de vorige stap?   • Hoe ga je hieraan werken? Maak een SMART- doel bij jouw leerpunt.

Met opmerkingen [ah1]: Hier omschrijf je wat er gebeurd is tijdens de les. Denk hierbij aan jouw kennis over de onderzoeks-en-ontwerpcyclus, over het inzetten van technologie en aan de kenmerken van jouw klas.

Met opmerkingen [ah2]: Hier ga je dieper in op de situaties die je hierboven hebt beschreven. Denk hierbij aan jouw kennis over de onderzoeks-en-ontwerpcyclus en over het inzetten van technologie of aan de kenmerken van jouw klas om het te verklaren.

Met opmerkingen [ah3]: Hier beschrijf je de belangrijkste conclusies van de vorige stap. Ook Maak je een SMART-doel.

Appendix F: Lesson Plan

Informatie vooraf

- Je start met het opschrijven van de leerpunten afkomstig van jouw reflectie formulier.
- Links staat de stap van de ontwerpcyclus. Let op! Soms mag je stappen overslaan of vaker aanbieden.
- Beantwoord de hulpvragen voor het plannen van de les.
- Beschrijf daarachter per stap van de ontwerpcyclus de leraar- en leerlingactiviteiten en materialen. Ter ondersteuning staan er hulpvragen in de comments!
- Vergeet niet de PowerPoint te maken en materialen te verzamelen. Stuur het ingevulde lesformulier naar a.a.hilderink@student.utwente.nl

Leerdoelen leraar

Hulpvragen	**Leerpunten voor jezelf**
• Waar wil je in deze les op letten ten aanzien van je eigen vaardigheden? • Beschrijf dit zo concreet mogelijk	

Leerdoelen leerlingen

Aan het einde van deze les
• Beredeneren waarom iedereen moet participeren om een duurzame wereld te creëren. • Een duurzaamheidsplan voor een school opstellen aan de hand van de geleerde stof. • De opgedane kennis van de vorige drie lessen toepassen.

Hulpvragen voor het plannen van de les	**Doelen, beginsituatie en succescriteria**

• Welke doelen wil je behalen deze les?
• Welke kennis ga je de leerlingen aanleren?
  o Welke concepten kennen ze al?
  o Waar ga je op voortbouwen?
• Hoe bied je hands-on en minds-on activiteiten aan?
• Hoe ga je de belevingswereld van de leerlingen erbij betrekken?
• Welke vaardigheden ga je aanleren of verder ontwikkelen?
  o Wat kunnen ze al?
  o Waar ga je op voortbouwen?
• Hoe ga je differentiëren in de les?
  o Zijn er kinderen die sneller zelfstandig aan het werk kunnen omdat ze al over bepaalde vaardigheden of kennis beschikken of juist meer begeleiding nodig hebben? Hoe ziet dit eruit?
  o Zijn er kinderen die altijd heel snel klaar zijn? Wat gaan deze kinderen doen?
• Hoe ga je de leerlingen laten samenwerken?
  o Hoe ga je dit begeleiden?
  o Wat wordt er hierin van de leerlingen verwacht?
  o Hoe ga je gesprekken tussen leerlingen structuren of leerlingen daarin helpen?
• Hoe ga je technologie inzetten in de les?
  o Wat voor kennis ga je visualiseren?
  o Hoe kunnen leerlingen de techniek inzetten?
  o Welke techniek gebruik je voor het toetsen van de kennis?
• Wat zijn de succescriteria voor de leerlingen?
  o Wat moeten de leerlingen doen om aan te tonen dat de doelen zijn behaald?	

Tijd	Stap ontwerpcyclus	Activiteit – Wat doet de leraar? Wat doen de leerlingen?	Benodigde materialen
5 min	**Confronteren** De leerling maakt kennis met het probleem waar een oplossing voor ontworpen gaat worden.		
15 min	**Verkennen** Het probleem wordt uitgelegd en de oplossing die ontworpen moet worden wordt besproken.		
5 min	**Ontwerp schetsen** De leerlingen maken een ontwerpschets.		
30 min	**Ontwerp realiseren** De leerlingen maken het prototype met het materiaal dat beschikbaar is.		
10 min	**Ontwerp testen en bijstellen** Het ontwerp wordt getest en waar nodig bijgesteld.		
15 min	**Presenteren** De leerlingen presenteren hun ontwerp aan de klas.		
10 min	**Verdieping en verbreding** Hier wordt een verdieping en verbreding aangeboden. Ook wordt er gereflecteerd op de les.		

Met opmerkingen [ah1]: Hoe wordt de belevingswereld van de kinderen bij deze stap betrokken?
Hoe wordt technologie ingezet?

Met opmerkingen [ah2]: Hoe worden de leerlingen uitgenodigd tot interactie met elkaar of met de leerkracht?

Met opmerkingen [ah3]: Hoe worden de begrippen uitgelegd?
Hoe wordt het GRRIM- model toegepast?
Hoe worden de leerlingen uitgenodigd tot interactie met elkaar of met de leerkracht?
Aan welke eisen moet de oplossing voldoen?
Welke materialen, gereedschappen en technieken zijn beschikbaar?
Wat wordt er van de leerlingen verwacht?
Hoe wordt technologie ingezet?

Met opmerkingen [ah4]: Hoe wordt er gedifferentieerd?
Hoe werken de leerlingen samen?
Hoe ga je het gesprek tussen leerlingen begeleiden?
Hoe weten de leerlingen waar het ontwerp aan moet voldoen?

Met opmerkingen [ah5]: Hoe werken de leerlingen samen?
Hoe ga je het gesprek tussen leerlingen begeleiden?
Wordt technologie gebruikt?

Met opmerkingen [ah6]: Hoe weten de leerlingen waar het ontwerp aan moet voldoen?

Met opmerkingen [ah7]: Hoe wordt de presentatie vormgegeven?
Wat moeten ze vertellen?

Met opmerkingen [ah8]: Wat voor een verdieping en verbreding biedt je aan?
Waar gaat de reflectie over?
Wordt de kennis getoetst?
Wordt er technologie gebruikt?

Tijd	Stap ontwerpcyclus
5 min	**Confronteren** De leerling maakt kennis met het probleem waar een oplossing voor ontworpen gaat worden.
15 min	**Verkennen** Het probleem wordt uitgelegd en de oplossing die ontworpen moet worden wordt besproken.
5 min	**Ontwerp schetsen** De leerlingen maken een ontwerpschets.
30 min	**Ontwerp realiseren** De leerlingen maken het prototype met het materiaal dat beschikbaar is.
10 min	**Ontwerp testen en bijstellen** Het ontwerp wordt getest en waar nodig bijgesteld.
15 min	**Presenteren** De leerlingen presenteren hun ontwerp aan de klas.
10 min	**Verdieping en verbreding** Hier wordt een verdieping en verbreding aangeboden. Ook wordt er gereflecteerd op de les.

Met opmerkingen [ah1]: Hoe wordt de belevingswereld van de kinderen bij deze stap betrokken?
Hoe wordt technologie ingezet?

Met opmerkingen [ah2]: Hoe worden de leerlingen uitgenodigd tot interactie met elkaar of met de leerkracht?

Met opmerkingen [ah3]: Hoe worden de begrippen uitgelegd?
Hoe wordt het GRRIM- model toegepast?
Hoe worden de leerlingen uitgenodigd tot interactie met elkaar of met de leerkracht?
Aan welke eisen moet de oplossing voldoen?
Welke materialen, gereedschappen en technieken zijn beschikbaar?
Wat wordt er van de leerlingen verwacht?
Hoe wordt technologie ingezet?

Met opmerkingen [ah4]: Hoe wordt er gedifferentieerd?
Hoe werken de leerlingen samen?
Hoe ga je het gesprek tussen leerlingen begeleiden?
Hoe weten de leerlingen waar het ontwerp aan moet voldoen?

Met opmerkingen [ah5]: Hoe werken de leerlingen samen?
Hoe ga je het gesprek tussen leerlingen begeleiden?
Wordt technologie gebruikt?

Met opmerkingen [ah6]: Hoe weten de leerlingen waar het ontwerp aan moet voldoen?

Met opmerkingen [ah7]: Hoe wordt de presentatie vormgegeven?
Wat moeten ze vertellen?

Met opmerkingen [ah8]: Wat voor een verdieping en verbreding biedt je aan?
Waar gaat de reflectie over?
Wordt de kennis getoetst?
Wordt er technologie gebruikt?

Appendix G: Semi-Structured Interview for Evaluating the Lesson Series

Interview schema: huidige situatie wetenschap en techniek onderwijs

Voorstellen

Ik ben Anouk Hilderink. Ik volg de master Eduational Science and Technology aan de UT in Enschede. Hiervoor heb ik de pabo in Deventer gevolgd, dit was de Academische Pabo waardoor ik nu de master kan volgen. Ik heb ook een jaartje lesgegeven. Ik gaf toen les aan groep 8 en groep 1/2.

Doel van het onderzoek

Het doel van dit interview is om te verkennen wat de huidige stand van zaken van het wetenschap en techniek onderwijs bij op jullie school is (toestemmingsformulier geven plus leestijd incalculeren). Het is belangrijk om te vermelden dat de eigen leerkrachtvaardigheden of kennis niet worden geëvalueerd. Het interview gaat slechts over de evaluatie van het lesmateriaal en hoe dit verbeterd kan worden. Het interview wordt opgenomen en de data wordt gepseudonimiseerd. Zo zijn de gegevens niet te herleiden naar jou als persoon. De resultaten van het onderzoek worden gebruikt voor de ontwikkeling en het verbeteren van het door Pre-University gemaakte lesmateriaal voor het vakgebied wetenschap en techniek. Mocht je nog vragen hebben dan mag je die stellen. Zijn er nog vragen die je zou willen stellen voor we met het interview beginnen?`

TOESTEMMINGSVERKLARING ONDERTEKEND?

DAN GA IK NU DE OPNAME AANZETTEN OK?

Het interview

Bestaande situatie

Ik ga je eerst wat vragen over hoe jouw eigen ervaringen met wetenschaps- en technieklessen op school:

1. Wat is jouw leeftijd?
2. Wat is jouw geslacht?
3. Aan welke groep geef je les?
4. Welke opleiding heb je gevolgd?
    a. Ben je tijdens de opleiding in aanraking gekomen met wetenschap en techniek onderwijs? Zo ja, hoe?
5. In hoeverre besteedden jullie al aandacht aan wetenschap en techniek op school?
6. Wat vindt je van wetenschap en techniek?
    a. Waarom is wetenschap en techniek wel of niet belangrijk?
7. In hoeverre heb je zelf al kennis over en/of ervaring met het ontwerpen of geven van wetenschaps- en technieklessen?
    a. Indien ze zelf lessen ontwerpen en geven: Hoe zien jouw wetenschaps- en technieklessen eruit?
    b. Over welke kennis beschik je al?
8. In hoeverre heb je zelfvertrouwen om een wetenschaps- en techniekles te geven?
    a. Hoe uit zich dit?
9. Hoe zet je nu technologie in tijdens jouw lessen?
    a. Indien ze gebruik maken van technologie: Hoe wordt de technologie tijdens wetenschaps- en technieklessen ingezet?
    b. Hoe maak je beslissingen over het inzetten van technologie tijdens deze lessen of lessen in het algemeen?
10. Hoe kijk je naar het gebruik van technologie in jouw lessen?
11. In hoeverre heb je het zelfvertrouwen om een wetenschaps- en techniekles met gebruik van technologie te geven?
    a. Hoe uit dit zich?

Input van de leerkracht

12. Heb je nog dingen toe te voegen die we nog niet hebben behandeld? En waarvan je wel denkt dat ze relevant zijn voor ons om te weten?

Afsluiting

13. Bedankt voor je deelname. In combinatie met het afsluitende interview aan het einde van de lessenserie ga ik onderzoeken op welke aspecten het gemaakte lesmateriaal verbeterd kan worden. Bij interesse zou ik je een samenvatting van de onderzoeksresultaten kunnen toesturen. Zou je dit willen?

Interview schema: Pre-U Wetenschaps- en Technieklessenserie

Voorstellen

Ik ben Anouk Hilderink. Ik volg de master Eduational Science and Technology aan de UT in Enschede. Hiervoor heb ik de pabo in Deventer gevolgd, dit was de Academische Pabo waardoor ik nu de master kan volgen. Ik heb ook een jaartje lesgegeven. Ik gaf toen les aan groep 8 en groep 1/2.

Doel van het onderzoek

Het doel dit interview is om te weten wat je van de lessenserie en de bijbehorende hulpmiddelen vond. Het is belangrijk om te vermelden dat de eigen leerkrachtvaardigheden of kennis niet worden geëvalueerd. Het interview gaat slechts over de evaluatie van het lesmateriaal en hoe dit verbeterd kan worden. Het interview wordt opgenomen en de data wordt gepseudonimiseerd. Zo zijn de gegevens niet te herleiden naar jou als persoon. De resultaten van het onderzoek worden gebruikt voor de ontwikkeling en het verbeteren van het door Pre-University gemaakte lesmateriaal voor het vakgebied wetenschap en techniek. Mocht je nog vragen hebben dan mag je die stellen. Zijn er nog vragen die je zou willen stellen voor we met het interview beginnen?

TOESTEMMINGSVERKLARING ONDERTEKEND?

DAN GA IK NU DE OPNAME AANZETTEN OK?

Evaluatie*

Toegevoegde waarde

Effectiviteit

Zelfvertrouwen

1. In vergelijking tot het begin, hoe zou je je zelfvertrouwen ten aanzien van het geven van een wetenschaps- en technieklesnu beschrijven?
   a. Hoe komt dat?
2. Heeft een onderdeel van de lessenserie met bijbehorende hulpmiddelen in het bijzonder heel erg of juist helemaal niet bijgedragen aan jouw zelfvertrouwen om een wetenschaps- en technieklesnte geven?
   - Het gebruik van de e-learnings
   - Het gebruik van de informatie uit de bestaande lesmaterialen
   - Het observeren van een wetenschap en techniek les
   - De reflectie
   - Het zelf geven van een wetenschap en techniek les volgens het lesformulier van Pre-University
   - Het zelf maken van een wetenschap en techniek les
   - Het zelf geven van een wetenschap en techniek les
   - Eventueel de handleiding voor de Mbot
3. In welke onderdelen van een wetenschaps- en techniekles heb je nu juist wel veel zelfvertrouwen of juist nog helemaal niet?
   - Het aanbieden van het ontwerp- en onderzoeksproces
   - Leerlingen ondersteunen bij het onderzoeken en ontwerpen
   - Het aanbieden van hand-en minds-on leren
   - Betekenisvolle context bieden
   - Samenwerken
   - Interactie uitdagen/ dialoog stimuleren
   - Differentiëren
   - Toetsen
   - Kennis over de inzet van technologie o.b.v. beeldmateriaal, simulaties, uitvoeren van experimenten etc.

- Kennis over de vakinhoud en hoe dit aan te bieden

Kennis

4. In vergelijking tot het begin, hoe zou je jouw kennis ten aanzien van het geven van een wetenschaps- en techniekles nu beschrijven?
    a. Hoe komt dat?
5. Heeft een onderdeel van de lessenserie met bijbehorende hulpmiddelen in het bijzonder heel erg of juist helemaal niet bijgedragen aan jouw kennis over het geven van een wetenschaps- en techniekles?
    - Het gebruik van de e-learnings
    - Het gebruik van de informatie uit de bestaande lesmaterialen
    - Het observeren van een wetenschap en techniek les
    - Het reflectie gesprek
    - Het zelf geven van een wetenschap en techniek les volgens het lesformulier van Pre-University
    - Het zelf maken van een wetenschap en techniek les
    - Het zelf geven van een wetenschap en techniek les
    - Eventueel de handleiding voor de Mbot
6. Over welke onderdelen van een wetenschaps- en techniekles heb je nu juist wel veel kennis of juist nog helemaal niet?
    - Het aanbieden van het ontwerp- en onderzoeksproces
    - Leerlingen ondersteunen bij het onderzoeken en ontwerpen
    - Het aanbieden van hand-en minds-on leren
    - Betekenisvolle context bieden
    - Samenwerken
    - Interactie uitdagen/ dialoog stimuleren
    - Differentiëren
    - Toetsen
    - Kennis over de inzet van technologie o.b.v. beeldmateriaal, simulaties, uitvoeren van experimenten etc.
    - Kennis over de vakinhoud en hoe dit aan te bieden
7. Hoe en waarom pasten de specifieke technologieën die in uw les gebruikt werden bij de leerdoelen?*
8. Hoe en waarom pasten de specifieke technologieën die in uw les werden gebruikt bij de instructiestrategieën die u gebruikte?*
9. Hoe en waarom passen de leerdoelen, instructiestrategieën en gebruikte technologieën allemaal bij elkaar in uw les?*

Efficiëntie

10. Kostte het doorlopen van de lessenserie met bijbehorende hulpmiddelen veel of weinig tijd?
    a. Kun je ook vertellen waarom?
11. Kostte het doorlopen van de lessenserie met bijbehorende hulpmiddelen veel of weinig moeite?
    a. Kun je ook vertellen waarom?

Plezier

12. In hoeverre had je plezier in het geven van een wetenschaps- en techniekles?
    a. Hoe kwam dat?
13. In hoeverre had je plezier in het geven van een wetenschaps- en techniekles met behulp van technologie?

a. Hoe kwam dat?

Compatibiliteit

14. In hoeverre sloot de lessenserie met bijbehorende hulpmiddelen wel of niet aan bij jouw kennis van wetenschaps- en technieklessen?
    a. Kun je ook vertellen waarom?
15. In hoeverre sloot de lessenserie met bijbehorende hulpmiddelen wel of niet aan bij jouw kennis over het gebruik van technologie tijdens wetenschaps- en technieklessen?
    a. Kun je ook vertellen waarom?
16. In hoeverre sloot de lessenserie met bijbehorende hulpmiddelen wel of niet aan bij jouw overtuigingen over wetenschap- en technologie lessen?
    a. Kun je ook vertellen waarom?

Duidelijkheid

17. Wat was er heel duidelijk en heel onduidelijk aan de lessenserie met bijbehorende hulpmiddelen voor jouw als leerkracht?
    - E-learnings
    - Observatie formulier
    - Reflectie formulier
    - Activiteiten
    - Lesformulier
    - PowerPoint
    - Werkbladen
    - Evt. handleiding voor de Mbot
18. Ben je tijdens het gebruik van de lessenserie met bijbehorende hulpmiddelen bepaalde onderdelen tegengekomen die heel duidelijk of heel onduidelijk waren voor jou als leerkracht?

Tolerantie

19. Kun je de stappen beschrijven die je hebt doorlopen tijdens het gebruik van de lessenserie en bijbehorende hulpmiddelen?
20. In hoeverre ben je afgeweken van het gebruik van de lessenserie met bijbehorende hulpmiddelen?
    a. Hoe heb je dit gedaan?
    b. Waarom heb je dit gedaan?

Input van de leerkracht

21. Heb je nog dingen toe te voegen die we nog niet hebben behandeld? En waarvan je wel denkt dat ze relevant zijn voor ons om te weten?

Afsluiting

22. Bedankt voor je deelname. Op basis van het interview ga ik onderzoeken op welke aspecten het gemaakte lesmateriaal verbeterd kan worden. Bij interesse zou ik je een samenvatting van de onderzoeksresultaten kunnen toesturen. Zou je dit willen?

Note. Van Der Linden, S., Papadopoulos, P. M., Nieveen, N., & McKenney, S. (2023). ReflAct: Formative assessment for teacher reflection in video-coaching settings. *Computers And Education/Computers & Education, 203*, 104843. https://doi.org/10.1016/j.compedu.2023.104843.

Harris, J., Grandgennet, N., & Hofer, M. J. (2012). Testing an instrument using structured interviews to assess experienced teachers’ TPACK. In C. Maddux, & D. Gibson (Eds.), *Research highlights in technology and teacher education 2012*. Aace.

Appendix H: Pre-and-Post-Test Self-Efficacy and TPACK Questionnaires

Vragenlijst

Bedankt voor het invullen van deze vragenlijst. De vragenlijst bestaat uit twee delen. Het eerste deel van de vragenlijst start met een paar vragen met betrekking tot de demografie en gaat vervolgens over op stellingen met betrekking tot jouw kennis over het inzetten van technologie tijdens wetenschaps- en technieklessen. Alhoewel technologie een breed begrip is, wordt het in deze studie gezien als digitale technologie of digitale hulpmiddelen die wij gebruiken, denk aan computers, laptops, iPods, draagbare apparaten, het digibord, software programma's, programmeer software, enz. Het tweede deel van de vragenlijst gaat over het zelfvertrouwen die je hebt in het geven van een wetenschaps- en techniekles. Jouw antwoorden zullen niet herleidbaar zijn naar jouw als persoon en zullen volledig vertrouwelijk behandeld worden. Probeer alle vragen te beantwoorden en als je niet zeker of neutraal bent over jouw antwoord, mag je altijd 'Noch eens/ noch oneens' invullen. Mochten er vragen of onduidelijkheden zijn dan mag je die stellen. Nogmaals bedankt voor het nemen van de tijd om deze vragenlijst in te vullen!

Deel 1

Stelling	Volledig oneens	Oneens	Noch mee eens/noch oneens	Mee eens	Helemaal mee eens
Ik weet hoe ik mijn eigen technische problemen moet oplossen.					
Ik kan technologie gemakkelijk leren te gebruiken.					
Ik blijf op de hoogte van belangrijke nieuwe technologieën.					
Ik probeer vaak technologie op verschillende manier uit.					
Ik ken veel verschillende technologieën.					
Ik beschik over de technische vaardigheden die ik nodig heb om technologie te gebruiken.					
Ik heb voldoende kansen gehad om met verschillende technologie te werken.					

Stelling	Volledig oneens	Oneens	Noch mee eens/noch oneens	Mee eens	Helemaal mee eens
Ik heb voldoende kennis over wetenschap en techniek.					
Ik kan een wetenschappelijke manier van denken gebruiken.					
Ik heb verschillende manieren en strategieën om mijn begrip van wetenschap en techniek te ontwikkelen.					
Ik weet hoe ik de prestaties van leerlingen in een klaslokaal moet beoordelen.					
Ik kan mijn manier van lesgeven aanpassen op basis van wat leerlingen momenteel wel of niet begrijpen.					
Ik kan het leerproces van leerlingen op meerdere manieren beoordelen.					
Ik kan een breed scala aan onderwijsstrategieën gebruiken in klassikale setting.					
Ik ben bekend met het gebruikelijke begrip en misconcepten van leerlingen.					
Ik weet hoe ik het klassenmanagement moet organiseren en handhaven.					
Ik kan effectieve onderwijsstrategieën selecteren om het denken en leren van leerlingen tijdens wetenschaps- en technieklessen te begeleiden.					
Ik heb kennis over technologieën die ik kan gebruiken voor het begrijpen en beoefenen van wetenschap en techniek.					
Ik kan technologieën kiezen die de onderwijsstrategieën voor een les verbeteren.					
Ik kan technologieën kiezen die het leren van leerlingen tijdens een les verbeteren.					

Stelling	Volledig oneens	Oneens	Noch eens/noch oneens	Mee eens	Helemaal mee eens
Mijn lerarenopleiding heeft ervoor gezorgd dat ik meer ben gaan nadenken over hoe technologie de onderwijsstrategieën die ik in mijn klaslokaal gebruik kan beïnvloeden.					
Ik denk kritisch na over het gebruik van technologie in mijn klaslokaal.					
Ik kan het gebruik van de technologieën waar ik over leer aanpassen aan verschillende onderwijsactiviteiten.					
Ik kan lessen geven waarin wetenschap en techniek, technologieën en onderwijsstrategieën op de juiste manier worden gecombineerd.					
Ik kan technologieën selecteren die ik in mijn klas kan gebruiken en die verbeteren wat ik onderwijs, hoe ik lesgeef en wat leerlingen leren.					
Ik kan strategieën die de inhoud van het vakgebied van wetenschap en techniek, technologieën en onderwijsstrategieën combineren, waarover ik tijdens de lessenserie heb geleerd, gebruiken in mijn klaslokaal.					
Ik kan leiding geven bij het helpen van anderen bij het coördineren van het gebruik van de inhoud, technologieën en onderwijsstrategieën op mijn school.					
Ik kan technologieën kiezen die de inhoud van een les verbeteren.					

<u>Deel 2</u>

Geef ook hieronder aan in hoeverre je het eens of oneens bent met elke stelling door een kruis te zetten in het juiste vakje naast elke stelling. Bovenaan het antwoord blad staan de opties waaruit je kunt kiezen. **Let op!** De opties staan in tegenovergestelde richting en begint van links naar rechts met 'Helemaal mee eens' en eindigt met 'Volledig oneens'.

Stelling	Helemaal mee eens	Mee eens	Noch mee eens/ noch oneens	Oneens	Volledig oneens
Wetenschap-en techniekonderwijs geef ik net zo goed als alle andere vakken					
Ik weet hoe ik leerlingen concepten uit het wetenschap- en techniekdomein moet aanleren					
Ik kan leerlingen zodanig begeleiden bij wetenschap- en techniekonderzoek, dat zij zelf antwoorden kunnen vinden op hun eigen vragen					
Over het algemeen ben ik tevreden over de manier waarop ik wetenschap- en techniek onderwijs geef					
Ik begrijp zelf de wetenschap- en techniekinhouden goed genoeg om de kinderen deze inhouden op een effectieve manier te leren					
Ik kan leerlingen uitleggen wat het onderliggende verschijnsel is bij een proefje					
Ik ben over het algemeen in staat om wetenschap- en techniekvragen te beantwoorden					
Ik heb de benodigde vakdidactische vaardigheden om les te geven in wetenschap- en techniek					
Als mijn directeur of collega bij een les aanwezig is, dan vind ik het prima als dat een wetenschap- en techniekles is					
Als een leerling moeite heeft met een wetenschap- en techniekconcept, dan weet ik hoe ik de leerling moet helpen om het beter te begrijpen					
Als ik wetenschap- en techniek geef vind ik het fijn als leerlingen vragen stellen					

Stelling	Helemaal mee eens	Mee eens	Noch mee eens/ noch oneens	Oneens	Volledig oneens
Ik weet wat ik moet doen om leerlingen voor wetenschap- en techniek te motiveren					

Note. Schmidt, D., Baran, E., Thompson, A., Mishra, P., Koehler, M. J., & Shin, T. J. (2009). Technological pedagogical content knowledge (TPACK) [Technische pedagogische vakinhoudelijke kennis]. *Journal of research on technology in education*, *42*(2), 123–149.

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Appendix I: Codebook Semi-Structured Interview for Evaluating the Lesson Series

<u>Code book pre-post-test interview</u>

Codes	Description
Self-efficacy – SESY	Teachers have confidence in their ability to teach a or an aspect of a science and technology lesson which includes the research and design cycle which helps students discover new knowledge prior to partaking in the lesson series.
Self-efficacy - SESN	Teachers mostly have little or no confidence in their ability to teach a or an aspect of a science and technology lesson which includes the research and design cycle which helps students discover new knowledge prior to partaking in the lesson series.
Self-efficacy - TSESN	Even though teachers mostly have little to no confidence in their ability to teach a or an aspect of a science and technology lesson which includes the research and design cycle which helps students discover new knowledge prior to partaking in the lesson series this confidence is present on some part.
Support for developing self-efficacy and TPACK - CST	What does the teacher need for developing or having self-efficacy and TPACK knowledge
TPACK – TSY	A teacher has knowledge about the three basic components of TPACK (content, pedagogy and technology), and/or the interplay between them in order to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge prior to partaking in the lesson series.
TPACK – TSN	A teacher misses knowledge about the three basic components of TPACK (content, pedagogy and technology), and/or the interplay between them in order to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge prior to partaking in the lesson series.
Difficulty – DY	Challenges teachers face with finding time, the curriculum or organising teaching a science and technology by themselves prior to partaking in the lesson series.
No affinity – AN	A teacher mentions that the domain of science and technology overall does not suite them.
Affinity – AY	A teacher mentions that they are interested in the domain of science and technology or find it fun to teach these types of lessons.
Education in science and technology – EDUY	They attended a higher education that offered science and technology courses or post higher education specified on science and technology.
Education in science and technology did not stuck or they stopped prematurely - EDUYN	Even though they attended a higher education that offered science and technology courses, but it did not stick, or they attended a post higher education specified on science and technology but they stopped prematurely.

No education in science and technology - EDUN	They did not encounter science and technology courses during their higher education or afterwards.
Embedding in the curriculum is low – O	Science and technology is not embedded in the curriculum and offered just occasionally or out of own initiative.

Codes	Description
Added value	
The lesson series - IYSBSSE	Gradually releasing the task difficulty did contribute to a sense of self-efficacy
The lesson series – IYOSE	Observing others who teach a science and technology lesson did contribute to a sense of self-efficacy
The lesson series - IYOT	Observing others who teach a science and technology lesson did contribute to developing TPACK
The lesson series – IYESE	Making a (part) of a science and technology lesson or teaching it did contribute to a sense of self-efficacy
The lesson series – IYET*	Making a (part) of a science and technology lesson or teaching it did contribute to developing TPACK
The lesson series - IYSSE	Studying the pre-made lesson materials did contribute to a sense of self-efficacy
The lesson series - IYST	Studying the pre-made lesson materials did contribute to developing TPACK
Effectiveness – ETY	If the teacher, after partaking in the lesson series, gained TPACK knowledge regarding the three basic components of TPACK (content, pedagogy and technology), and/or the interplay between them in order to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge.
Effectiveness - ETN	Whether the TPACK knowledge mostly stayed the same after partaking in the lesson series about the curriculum or regarding the three basic components of TPACK (content, pedagogy and technology), and/or the interplay between them in order to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge or about the curriculum.
Effectiveness - TETY	Even though the teacher did not gain TPACK knowledge they still express parts of the TPACK framework or the curriculum in which there knowledge did improve.
Effectiveness – TETN	Even though the teacher gained TPACK knowledge they still express parts of the TPACK framework or the curriculum in which there knowledge is still missing.
Efficiency – ETL	It took the teacher overall a regular or less than regular amount of time to partake in the lesson series and perhaps the teacher mentions parts of the lesson series that made the teacher safe time.
Efficiency - ETM	It took the teacher overall much time to partake in the lesson series and perhaps the teacher mentions parts of the lesson series that took up much time.
Efficiency – TETL*	Even though it took the teacher overall a regular or less than regular amount of time to partake in the lesson series they still mention ways in which the lesson series took up much time.
Efficiency - TETM	Even though it took the teacher overall much time to partake in the lesson series they still mention parts of the lesson series that saved time or did not take up to much time.
Efficiency – EEL	It took the teacher overall a regular or less than regular amount of effort to partake in the lesson series and perhaps they also mentioned parts that took up a little amount effort.

Efficiency - EEM	It took the teacher overall much effort to partake in the lesson series and perhaps they also mentioned parts that took up much effort.
Efficiency - TEEM	Even though took the teacher overall a regular or less than regular amount of effort to partake in the lesson series the teacher mentions parts of the lesson series that cost more effort.
Enjoyability - EAY	The teacher felt accomplished while teaching a science and technology lesson which includes the research and design cycle which helps students discover new knowledge while partaking in the lesson series.
Enjoyability – ESEY	The confidence in the ability to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge increased after using the lesson series.
Enjoyability – TESEN*	Even though the confidence in the ability to teach a science and technology lesson increased it still misses on certain parts.
Enjoyability – ESEN	The confidence in the ability to teach a science and technology lesson which includes the research and design cycle which helps students discover new knowledge stayed the same and the teacher mentioned parts were it still misses.
Enjoyability – TESEY*	Even though the level of confidence to teach a science and technology lesson stayed the same they are willing to teach science and technology themselves after partaking in the lesson series.
Compatibility	
Compatibility – CKY	If the lesson series were compatible with their prior knowledge about teaching a science and technology lesson.
Compatibility - CKN	If the lesson series were mostly not compatible with their prior knowledge about teaching a science and technology lesson.
Compatibility - TCKN	Even though the lesson series were on parts not compatible with their prior knowledge, the lesson series were compatible with their prior knowledge about technology.
Compatibility – CBGY	If the lesson series were compatible with the beliefs and goals of the teacher regarding science and technology lessons.
Compatibility - CBGNY	If the lesson series were not compatible with or led to a changes in the beliefs and goals of the teacher regarding science and technology lessons.
Clarity	
Clarity - CNT	The time spent on each lesson was unclear for the teacher
Clarity - CNLP	The pre-made lesson materials were unclear for the teacher
Tolerance	
Tolerance – TLP	Adjustments that were made to the pre-made lesson materials that weren’t in line with the previously intended goals of the lesson series
Tolerance – TC	Collaboration among teachers that weren’t in line with the previously intended goals of the lesson series.
Tolerance - TIR	Involvement of the researcher as coach when designing the lesson that weren’t in line with the previously intended goals of the lesson series.

Appendix J: 'Kijkwijzer' TechYourFuture

Codes	Criteria	Specifieke kijkpunten
O&O+	1. Het ontwerp- en onderzoeksproces wordt expliciet aangeboden. Alle kijkpunten zijn terug te zien in het lesplan.	1.1 de leerlingen leren onderzoeken en ontwerpen aan de hand van een stappenplan/cyclus voor ontwerpen en onderzoeken 1.2 de leerlingen leren bij het onderzoeken om vragen te stellen, onderzoek uit te voeren, waarnemingen te interpreteren en een relatie te leggen tussen onderzoek en kennis, en bevindingen te delen 1.3 de leerlingen leren bij het ontwerpen om systematisch problemen op te lossen, ontwerpkeuzes te maken met oog voor de gebruikers en context, en bevindingen te delen
O&O+/-	1. Het ontwerp- en onderzoeksproces wordt enigszins aangeboden. Er zitten 1 van de 2 kijkpunten in het lesplan.	
O&O-	1. Het ontwerp- en onderzoeksproces wordt niet aangeboden. Geen enkel kijkpunt is aanwezig in het lesplan.	
LO+	2. De leerlingen worden ondersteund bij het onderzoeken en ontwerpen. Alle kijkpunten zijn terug te zien in het lesplan.	2.1 de leerlingen worden geïnstrueerd in de kennis en vaardigheden ten aanzien van onderzoeken en ontwerpen 2.2 het leermateriaal geeft aan hoe de leerlingen begeleid kunnen worden tijdens het ontwerpen en onderzoeken
LO+/-	2. De leerlingen worden enigszins ondersteund bij het onderzoeken en ontwerpen. Er zitten 1 van de 2 kijkpunten in het lesplan.	
LO-	2. De leerlingen worden niet ondersteund bij het onderzoeken en ontwerpen. Geen enkel kijkpunt is aanwezig in het lesplan.	
HML+	3. Er is sprake van hands- en minds-on leren. Het kijkpunt is terug te zien in het lesplan.	3.1 het leermateriaal biedt lessen/opdrachten waarin denken en handelen zijn geïntegreerd
HML-	3. Er is geen sprake van hands- en minds-on leren. Het kijkpunt is niet aanwezig in het lesplan.	
BC+	4. De kennis, vaardigheden en houdingsaspecten worden in een betekenisvolle context aangeleerd. Alle kijkpunten zijn terug te zien in het lesplan.	4.1 het leermateriaal sluit aan bij de leef- en belevingswereld van de leerlingen 4.2 het leermateriaal biedt suggesties voor het betrekken van relevante bedrijven/instanties buiten de school (bedrijfsbezoeken, excursies, museumbezoek, schoolomgeving)
BC+/-	4. De kennis, vaardigheden en houdingsaspecten worden enigszins in een betekenisvolle context aangeleerd. Er zitten 1 van de 2 kijkpunten in het lesplan.	

BC-	4. De kennis, vaardigheden en houdingsaspecten worden niet in een betekenisvolle context aangeleerd. Geen enkel kijkpunt is aanwezig in het lesplan.	
S+	5. De didactiek van samenwerkend leren wordt toegepast. Alle kijkpunten zijn terug te zien in het lesplan.	5.1 de leerlingen worden geïnstrueerd in de samenwerkvaardigheden 5.2 het leermateriaal geeft aan hoe de leerlingen begeleid kunnen worden tijdens de samenwerking 5.3 het leermateriaal laat leerlingen reflecteren op de samenwerking
S+/-	5. De didactiek van samenwerkend leren wordt enigszins toegepast. Er zitten 1 of 2 van de 3 kijkpunten in het lesplan.	
S-	5. De didactiek van samenwerkend leren wordt niet toegepast. Geen enkel kijkpunt is aanwezig in het lesplan.	
ID+	6. De leerlingen worden uitgedaagd om interactie/ dialoog te leren. Alle kijkpunten zijn terug te zien in het lesplan.	6.1 het leermateriaal biedt mondelinge taalactiviteiten 6.2 het leermateriaal biedt suggesties om de mondelinge taalproductie te bevorderen (bijvoorbeeld denkvragen, vragen doorspelen, wachttijd bieden)
ID+/-	6. De leerlingen worden enigszins uitgedaagd om interactie/ dialoog te leren. Er zitten 1 van de 2 kijkpunten in het lesplan.	
ID-	6. De leerlingen worden niet uitgedaagd om interactie/ dialoog te leren. Geen enkel kijkpunt is aanwezig in het lesplan.	
D+	7. Het leermateriaal biedt mogelijkheden om te differentiëren. Het kijkpunt is terug te zien in het lesplan.	7.1 het leermateriaal speelt in op verschillen in kennis en vaardigheden van de leerlingen (preteaching, extra ondersteuning, verdieping en verbreding)
D-	7. Het leermateriaal biedt geen mogelijkheden om te differentiëren. Het kijkpunt is niet aanwezig in het lesplan.	
FT+	8. Formatieve toetsing wordt toegepast om het leren van leerlingen te bevorderen. Alle kijkpunten zijn terug te zien in het lesplan.	8.1 het leermateriaal biedt leerlingen inzicht in de te behalen doelen 8.2 het leermateriaal biedt handreikingen voor het verzamelen en analyseren van de leeruitkomsten van leerlingen 8.3 het leermateriaal biedt handreikingen voor het benutten van de analyses van de leeruitkomsten van de leerlingen
FT+/-	8. Formatieve toetsing wordt enigszins toegepast om het leren van leerlingen te bevorderen. 1, 2 of 3 van de 4 kijkpunten zitten in het lesplan.	

FT-	8. Formatieve toetsing wordt niet toegepast om het leren van leerlingen te bevorderen. Geen enkel kijkpunt is aanwezig in het lesplan.	8.4 het leermateriaal biedt leerlingen zicht op hun eigen leerontwikkeling
T+	9. Het leren wordt ondersteund door technologie/media. Alle kijkpunten zijn terug te zien in het lesplan.	9.1 het leermateriaal ondersteunt het leren met behulp van de inzet van online beeldmateriaal 9.2 het leermateriaal ondersteunt het leren met behulp van de inzet van simulaties of programma’s of apps voor virtuele experimenten, dataverwerking (bijvoorbeeld om grafieken te maken) en digitale presentatietools
T+/-	9. Het leren wordt enigszins ondersteund door technologie/media. 1 van de 2 kijkpunten zitten in het lesplan.	
T-	9. Het leren wordt niet ondersteund door technologie/media. Geen enkel kijkpunt is aanwezig in het lesplan.	
OU+	10. Het leermateriaal ondersteunt de leerkracht in het doeltreffend uitvoeren van het onderwijs. Alle kijkpunten zijn terug te zien in het lesplan.	10.1 het leermateriaal biedt leerkrachten achtergrondkennis over de vakinhouden 10.2 het leermateriaal biedt leerkrachten achtergrondkennis over de didactiek
OU+/-	10. Het leermateriaal ondersteunt de leerkracht enigszins in het doeltreffend uitvoeren van het onderwijs. 1 van de 2 kijkpunten zitten in het lesplan.	
OU-	10. Het leermateriaal ondersteunt de leerkracht niet in het doeltreffend uitvoeren van het onderwijs. Alle kijkpunten zijn terug te zien in het lesplan.	

Appendix K: AI Statement Quillbot

To be fully transparant about the construction of the current master thesis it is important to note Quillbot was used at the very end of the writing process to conduct a final spelling check. All work was already written before this final spelling check was conducted.