Manifesting Pedagogical values in Digital learning materials

Transforming abstract concepts into foundational strategies through an iterative design process

Silja Eskelinen
Siljaeskelinen5@gmail.com

Interaction Design
Bachelor
22.5HP
Spring 2023
Supervisor: David Cuartielles
Abstract

The contradictory setting between the principles and practice in the contemporary school system affects everyday classrooms by compromising the learning environment based on core educational values. The challenges arising from the contradictions are also reflected in the digitalization of education. While physical materials have established an intuitive learning experience and are familiarized with the standard organization of learning, the development of digital materials has been driven by innovation instead of fundamental educational values.

This thesis builds a theoretical foundation for promoting contemporary educational values based on pedagogical approaches and learning theories. By using interaction design methods, the values are transformed into concrete manifestations and evaluated through an iterative design process. The four strategies that emerged from the design process aim to transform the learning experience of digital materials from content-focused to learning-focused. The strategies’ purpose is to support students’ metacognitive development by adapting the principles of constructivist learning theory and student-driven education practices to the design of digital learning materials.

In addition to the proposed strategies, this thesis aims to inspire future designers developing digital learning materials to consider the core values of education and the mentality towards learning they aspire to manifest through their design work.

Keywords: Interaction Design, Digital Learning Materials, Constructivism, Metacognitive Development, Pedagogical values
Acknowledgements

First and foremost, I want to express my deep gratitude towards all the participating teachers and students for their contributions and investment for this thesis. I also want to thank the children’s caregivers for allowing the design activities to be conducted during lessons, which made organising the workshops possible. For my supervisor David I am eternally thankful for going above and beyond with providing support, guidance, and feedback during the thesis project. Lastly, I want to thank my mum and sisters for always supporting and pushing me through thick and thin.
# Table of Contents

Abstract ......................................................................................................................... 2  
Acknowledgements ........................................................................................................ 3  
Table of Contents .......................................................................................................... 4  
Introduction .................................................................................................................. 6  
  1.1 Context .................................................................................................................. 6  
  1.2 Aim & Contribution ............................................................................................. 7  
  1.3 Limitations ............................................................................................................ 8  
  1.4 Ethical considerations .......................................................................................... 10  
2 Theoretical Background ............................................................................................ 11  
  2.1 Core values of Education ...................................................................................... 11  
  2.2 Constructivism & Social Constructivism ............................................................. 12  
  2.3 Bloom’s Taxonomy ............................................................................................... 12  
  2.4 Teacher’s Role in Contemporary Education ....................................................... 13  
  2.5 Focus on Metacognitive development ................................................................. 14  
  2.6 Learning to Learn ................................................................................................. 16  
  2.7 Principles vs. Practice .......................................................................................... 17  
3 Challenges in the Digital Transition ......................................................................... 18  
  3.1 Challenges of Digital Education ........................................................................ 18  
  3.2 Teacher’s ICT-Competency ................................................................................ 19  
4 Related Work ............................................................................................................. 20  
  4.1 GraphoGame ........................................................................................................ 20  
  4.2 Mathletics ............................................................................................................. 21  
5 Insights into Design Exploration ............................................................................... 22  
  5.1 Supporting metacognitive development ............................................................ 23  
6 Methodology .............................................................................................................. 24  
  6.1 The Double Diamond ........................................................................................... 25  
  6.2 Semi-structured Interviews ............................................................................... 26  
  6.3 Prototyping .......................................................................................................... 26  
  6.4 Wizard of Oz ........................................................................................................ 27  
  6.5 User testing ......................................................................................................... 28  
7 Design Process ........................................................................................................... 28
7.1 Teacher interviews ................................................................. 29
  7.1.1 Lisa .................................................................................. 29
  7.1.2 Jessica ............................................................................. 30
  7.1.3 Lena ................................................................................ 30
7.2 Ideation .................................................................................. 31
7.3 Prototyping.............................................................................33
7.4 Workshops............................................................................ 33
  7.4.1 Workshop 1 ...................................................................... 34
  7.4.2 Workshop 2 ...................................................................... 36
  7.4.3 Workshop 3 ...................................................................... 38
8 Discussion ................................................................................ 41
  8.1 Challenges of supporting learning through Digital materials...... 41
  8.2 Strategies for supporting metacognitive development ............ 43
  8.3 Future Work ......................................................................... 45
9 Conclusion ............................................................................... 46
10 References ............................................................................. 48
Introduction

1.1 Context

Digital learning materials are becoming more prominent in educational environments in the Nordic countries, all of which are ranking in top positions when it comes to technological infrastructures in the context of Europe. In Norway, Sweden, Denmark, and Finland, more than 90% of students are in highly digitally equipped school environments compared to an average of 37% in the rest of Europe (Wastiau et al., 2013). Although moving gradually towards more technology-driven education is an important part of the curriculum development, the implementation is still in process, and transformation has yet to result in positive outcomes (Olofsson et al., 2021). A Finnish population-based study conducted by Saarinen et al. (2021) found that frequent use of digital technologies in education was related to weaker cognitive performance based on a comparison with PISA's 2015 results. The same study also found a similar correlation between students' high ICT skills with weaker cognitive functioning. With the support of previous research findings and the evaluation of the PISA\textsuperscript{1} test performance, they concluded that although children are familiar with the use of technology, the currently available activities do not support their cognitive development (Saarinen et al., 2021). In early 2023 the Swedish Ministry of Education announced a 685 million Krones investment in physical school materials such as books for the year 2023 and half milliard for the following years (Regeringskansliet, March 2023). The investment was found necessary due to schools' unequal access to learning materials. Interestingly, the investment was explicitly directed towards physical materials, even though considerable investments have been made nationwide in recent years towards increasing digitalization of education. The National Agency of Education advised the digitalization strategy, commonly referred to as "one student, one computer" policy, which is promoted to explicitly decrease inequality in the education system (Skolverket, 2022).

The pressure of implementing technology in education comes from a global change towards information society values and the future state of the labour market (Kaisla et al., 2015). As the job market is developing towards more automation and technology is taking over human-driven labour, in the future, industries will have a more significant need for workers with skills in developing and monitoring technology (Kaarakainen et al., 2017). The recent push towards implementing digital learning materials began during the global Covid-19 pandemic, which led to schools transferring to distance

lessons. The pandemic showed both good and bad sides of technology-mediated education. The transformation was affected by political pressure, and changes had to quickly be put in action. On the other hand, the situation required teachers to adapt their practice to the digital learning environment more concretely than before (Lavonen & Salmela-Aro, 2022). For all students, this meant the added responsibility of having to perform their studies with an increased degree of independence. For younger students, this responsibility of more independent studying was significant considering the short adaptation time. The abrupt transformation to digitally mediated education negatively affected students’ motivation, engagement in class activities, and effort towards schoolwork. Although in Nordic countries, distance learning lasted a relatively short time; it brought to surface how the use of digital materials might promote the traditional education model by favouring students with naturally high self-regulative skills towards learning (Saarinen et al., 2021). The purpose of this thesis is to explore how contemporary educational values and pedagogical approaches can be promoted in digital learning materials through interaction design. So far, much focus has been put into online instructional materials and remote learning outcomes (Rice & Ortiz, 2021). However, this thesis explores digital learning materials implementation in an on-site educational context; not forgetting the accessibility to the material in the home environment during homework.

1.2 Aim & Contribution

In today’s education, more focus has been put into developing students’ preparedness to adapt into constantly changing and developing society (Nieto-Márquez et al., 2020). Since the state of society is changing faster and faster, education must prepare students to adapt knowledge instead of learning static facts. In the field of education an interest towards teaching students’ metacognitive skills has increased since it is shown to improve their academic success across board and adaptability to new information (Kuhn & Dean, 2004). There are many pedagogical approaches that aim to promote a more student-driven approach to learning such as Freire’s problem-posing education, inquiry-based learning, and constructivism (Freire, 1970; Pedaste et al, 2016; Piaget, 1964:). The core ideology is to promote education that aims to develop students’ ability to learn through discovery and problem-solving with the guidance of teachers. These approaches also highlight the importance of social learning through collaboration and dialogue which has also been shown to be crucial for children’s development of critical thinking (Fischer & Bullock, 1984). Although ICT preparedness is highest in Nordic countries, so far digital materials have increased the demand for students’ individual self-regulating skills over their learning, instead of teaching such skills (Saarinen et al., 2021).
This thesis explores how contemporary pedagogical values can be promoted through the design of digital learning materials by supporting the development of students’ metacognitive skills. The study aims to contribute to the field of interaction design through exploring how pedagogical theories and values can be transformed into concrete manifestations in digital environments in the form of interactive teaching materials. It also aims to contribute with an example of how, in the educational context, designers can intentionally serve the interest of students and practicing teachers, within the limitations set by the system. This thesis does not focus on teaching a specific learning objective, nor aims to optimize students’ performance according to generalized testing methods. Rather the aim is to explore the characteristics in digital learning materials that support the development of universal learning skills that foster students’ capability to construct knowledge.

Research questions:

How might we design digital materials that promote contemporary educational values and approaches?

How might we design digital learning materials that support children's metacognitive development?

1.3 Limitations

Based on existing literature, when designing educational tools, it is preferable to follow a participatory design approach involving teachers (Kaisla et al., 2015). However, due to the difficulty in finding teachers, who were able to commit to a series of participatory design activities, teachers’ perspective has instead been taken into consideration through literature findings and interviews. Direct teachers' contribution could have provided a better view on how the design can be adapted to fit in their teaching activities as well as support their professional practice. However, my position as the language teacher of the participating children and user-testing conducted during classes, the conclusions are relevant to educational context.

The design space was kept within the current technological readiness of the contemporary Nordic education system, which affected the scope of the process. This decision was made because research findings indicated that the digitalization of education is still facing challenges with securing access to equal learning opportunities. Therefore, this thesis aims to answer the fundamental challenges of contemporary education arising from research with realistic circumstances in mind.

In this thesis, digital learning material is defined through a 4A framework (Figure 1) developed to help define the core principles to follow when choosing instructional materials online (Rice & Ortiz, 2021). However, the material under exploration is not considered having an open access to any
online information or enable teacher-built learning modules or tasks. Instead, the material is defined by including access to predetermined knowledge modules based on the default learning objectives defined in the national curriculum. Therefore, some characteristics of problem-centered education and potential advantages of digital material are excluded from this thesis.

In addition, we use Merrill’s (2002) five principles of instructional materials for problem-centred educational environments to determine the characteristics of what should be considered a good quality learning material, see Figure 2. The principles are based on the features of a productive problem-centred educational environment and are used as guidelines for defining how students should be involved in the learning activities:

Figure 1: 4A Framework by Rize & Ortiz (2021)

Figure 2: Merrill's principles of instructional material for problem-centered education (2002)
1.4 Ethical considerations

Education is one of the foundational human rights, defined in United Nations general comment nr. 13 established in 1999. As described in the covenant, education as a human right is the foundation for an individual's acknowledgement of the human rights of others. The covenant defines the main features of an educational system as: Availability, Accessibility, Acceptability, and Adaptability (1999). In the Nordic countries, the right to education has been reinforced in the country's constitutional law. Meaning, that every child's access to education is protected by the law with the above stated features. In the comment nr. 13 it is stated that education empowers individuals to become independently functioning members of society, becoming one of the most important investments a state can make. Through education we learn the values of democracy, freedom, and living with nature. Values that guide us and that we should follow throughout our lives. Knowledge is recognized as the preventative act to radicalism, oppression, and poverty (OHCR, 1999).

Education serves the essential purpose of enabling citizens to become self-sufficient and independent individuals free to fulfill their personal goals in life. However, the interests of society also influence the political decisions made into the organization of education. As society is moving towards more technology-driven organizations, changes are made in curriculums around the world for education to better accommodate future society's needs. Children are exposed to technology at increasingly younger ages, and schools are using more and more digitized materials. However, as it comes to light in the theory and interviews of this thesis, the implementation of technology should not bypass the fundamental educational values. The importance of education as a foundational human right and how it affects children has been deeply considered before starting and during this thesis work. The thesis does not claim to solve current issues in educational systems. The pedagogical values and approaches mentioned here are being used as guidelines for the design process. Nevertheless, the author acknowledges that promoting values in education is a complex matter. The aim of this project is to search for ways to protect the foundational children's rights in digitized environments through design.

The thesis work involves children in an educational setting which increases the demands for ethical practices during the process. Because minors are participating in the workshops the thesis follows Powell et. al. Ethical research Involving Children guidelines (2013). As described in ERIC, it is essential for involving children in the design processes to understand their views and perspectives. The participation of children in this thesis has been considered mandatory by the author due to the nature of the thesis concerning the children's right to be in an educational environment that facilitates learning for all. The students’ caregivers have been provided with information on the study topic and activities involving children, prior to
requesting their consent for participating in this study. All data is collected following the Swedish research councils Vetenskapsrådet’s ethical guidelines during interviews and workshops to ensure each participant’s security and anonymity (2017).

2 Theoretical Background

Equality and inclusivity are the core values presented in each Nordic country’s education system. However, in recent years segregation between students with different socio-economical, ethnic, and geographical backgrounds has increased (Bernelius & Huilla, 2021). Although this phenomenon includes many contributing factors, it is examined through the perspective of this thesis topic. The chapter starts with exploring the contemporary educational values and pedagogical approaches. The universal learning skills focused on contemporary education are introduced later.

2.1 Core values of Education

In 1970 Paulo Freire introduced the Pedagogy of the oppressed where pedagogy is considered an equal and social phenomenon. Instead of an education setting where holders of all knowledge – teachers’, gift the zero knowledge – students with necessary wisdom, pedagogy should be a dialogue of both parties teaching each other (Freire, 1970). In this setting neither is the holder of ultimate knowledge but rather a source of constructing knowledge and understanding through dialogue that is yet still open to further discussion and critique. In this practice knowledge is also understood as a changing variable to be further discussed and re-understood. The banking concept, as Freire defines the traditional education, puts students in an unequal position where the students with naturally high self-regulation skills and adaptability to depositing knowledge succeed. In today’s education Freire’s ideology can be seen in education as the mentality of believing in each student’s capability to construct knowledge when provided with the right environment.

It is understood that everyone has different ways of processing and constructing knowledge. Therefore, to reinforce the development of individual learning patterns, the starting point of teaching is the problem to be solved, not facts to be memorized. In the field of education much focus has been put into supporting the development of children’s metacognitive skills and critical thinking, through more collaborative working and problem-posing teaching. The purpose is to teach children to acquire and adapt knowledge instead of memorizing it, and learn social skills related to working collaboratively. However, Saarinen et. al. criticized in their study the current
implementation of ICT in education for setting high responsibility onto the students’ themselves to self-regulate their learning and therefore failing to follow the above-mentioned core values of contemporary education (Saarinen et al., 2021).

2.2 Constructivism & Social Constructivism

Today's pedagogy considers the child as an active participant in the learning experience. Learning is not merely transmitting knowledge from teacher to children but happens through children experiencing and interacting with the world. In 1964 Piaget introduced constructivism as a child's cognitive developmental theory, where the child learns through interaction with the physical world. According to Piaget, learning happens through adaptation, where new information is understood in the light of already existing knowledge. Piaget describes the learning process through schemas that are constantly being evaluated and reconstructed with adaptation of new knowledge (Piaget, 1964). Constructivist theory highlights the importance of exploration, experimentation, and interaction with the physical world to a child's cognitive development. Constructivist theory is often also complemented with social constructivism, which highlights the importance of social interactions, especially with more intellectual individuals, for the cognitive development of children. In Vygotsky's developmental theory knowledge is constructed in social and cultural contexts, which highlights the importance of learning activities happening in groups or pairs (Vygotsky, 1962). In Social constructivism theory knowledge is constructed when individuals’ own perception is challenged with others.

2.3 Bloom’s Taxonomy

While problem-posing education and variations of constructivism aim to facilitate optimal learning experiences for children, the learning objectives set in curriculums cannot be overlooked. Constructivist theory provides educators with a description of the practices that facilitate a productive learning environment. However, the theory is not concrete in giving definition of the methods or knowledge that facilitate the constructivist practice (Draper, 2002). Before children can be expected to apply accumulated skills and knowledge in different contexts, they must be exposed to them. Bloom’s Taxonomy (Figure 3) was developed to categorize educational goals into a hierarchy of six cognitive domains of learning (Bloom et al., 1965). Taxonomy is used in curriculum design by practicing teachers at all levels of education, to evaluate the organization of learning activities. The domains are intended to follow each other in a step-by-step process, where activities are planned according to the degree of students’ capability to adapt the knowledge in more complex tasks.
The classification helps educators to evaluate curriculum learning objectives through the consideration of what is the value from students' perspective in learning specific knowledge (Anderson et al., 2001). For example, is the value of learning to read in understanding words or their meaning in that specific context. The framework offers educators a tool that can be applied to formulate learning expectations and needed skills to achieve the intended level of knowledge which then can be communicated to the students. If the teaching-learning process is considered only in remembering-applying dimensions, the learning happens superficially also described as lower-order thinking skills (Chandio et al., 2016). To ensure higher-order thinking skills critical, analytical, and problem-solving approaches should be implemented to the learning experience and assessment (Chandio et al., 2016). Implementing Bloom's taxonomy to organization of teaching may lead to better metacognitive development of students (Sudirtha et al., 2022).

2.4 Teacher’s Role in Contemporary Education

In contemporary education teachers are not considered an ultimate authority but rather a provider of guidance and support that facilitates children’s own recognition of their learning capabilities. In this new role, the teacher must consider each student as an individual and offer support in their personal development. In the contemporary school environment teachers are there to encourage collaboration and participation with the aim of promoting inclusive educational practices (Väyrynen & Paksuniemi, 2020). It is important for teachers to facilitate a learning environment where every student believes in their power to learn and contributes to the collaborative experience with their own knowledge base. Such an environment is described as responsive pedagogy practice by Smith et. al. (2016). According to Smith.
et al. the knowledge students learn today will not necessarily be relevant tomorrow, and therefore it is more important to teach students’ competences in finding, acquiring, and constructing new knowledge. Instead of teachers measuring students’ success in the number of facts they can absorb, they should encourage reflection and offer relevant feedback about the methods and practices used to reach a certain level of knowledge. This practice will develop students’ self-regulation skills and support academic achievement in the long run, since students are confident in their capabilities to seek and evaluate information but also learn to choose adequate methods to construct new knowledge (Dobber et al., 2017).

The aim for today’s education is to activate the students in their learning process, instead of passively receiving knowledge. Therefore, it is inevitable that the teacher’s approach to what it means to teach must change in the process. Instead of presenting knowledge to students, teachers must adapt to enabling students to find it through learning activities and offering guidance along the way (Bonett, 1995). Inquiry-based learning is described as making students think and act like scientists when presented a problem, meaning students learn through experiencing and forming connections between units of information, not memorizing. This practice focuses on collaborative processes between students, with the help of teachers, for constructing knowledge. In inquiry-based learning, students collaboratively choose their approach to explore an inquiry. Although the optimal amount of teacher’s direction in inquiry-based learning is still argued, studies conclude that as a byproduct of inquiry-based learning students also learn self-regulation skills and develop metacognitive skills (Dobber et al., 2017). To summarize, today teachers are not providing only knowledge but facilitating an environment where children as active participants learn to collaboratively become independent and capable beings. As Freire described, it is not only students’ learning from teachers but the teacher also reflecting and learning from students (Freire, 1970).

2.5 Focus on Metacognitive development

Metacognition was first introduced by Flavell in 1976. Flavell described metacognition as ‘individuals’ own awareness and consideration of their cognitive processes and strategies’ (1976, p. 232). Already before Flavell’s definition of metacognitive learning, Vygotsky had recognized the importance of conscious reflection and deliberate mastery for the learning process in his sociocultural theory of child development (1962). Metacognitive skill development in children is also described as meta-learning, and teaching metacognitive strategies meta-teaching (Fisher, 1998). Metacognitive learning requires more than a traditional education model where knowledge is added on top of previous learnings. Rather, metacognitive learning includes awareness of what has been learned and how it connects to one’s knowledge base. Metacognitive learning also includes
consciousness towards the processes that enabled learning to occur. In children, the base for metacognitive development begins with what Piaget describes as “reflective abstraction” meaning the child becomes increasingly aware of the existence of different viewpoints and the experience of self- conflict when their own previous understanding has changed (Piaget, 1964). Like mentioned above, metacognitive development has become an increasingly important topic in education specially to prepare children for the demands of information society (Nieto-Márquez et al., 2020).

Usually, the time for students to start more independently practicing metacognitive learning starts in upper-level grades, when studying becomes more self-regulated. However, Van Velzens study (2015) of upper-level students’ metacognitive skills resulted in only 20% of participants having explicit metacognitive understanding of the learning process (p. 29). The study results indicated that upper-level students do practice different methods to study independently but a conscious evaluation in choosing appropriate methods for their individual needs is lacking. From Van Velzens study it becomes apparent why metacognitive learning should be focused already on lower-level education. In his conclusions, Van Velzen notes how development of metacognitive learning takes time and the ideal age for students to learn implement it is adolescence (p. 145). However, A curriculum containing separate subjects such as language, math and science already implies an assumption of thinking ways children should master (Bonnett, 1995, p.43). It would be contradictory to assume from children to master thinking patterns for separate subject matters but not teach them metacognitive skills already in elementary school level. At elementary schools, students usually learn multiple subjects with the same teacher and environment, which helps the teacher to support metacognitive development throughout all learning activities.

“For example, the appropriateness and accuracy of an observation will clearly be dependent upon an understanding of the sort of thing you are looking for and why. Similarly, the usefulness of a hypothesis will depend upon an understanding of the sorts of questions to ask in a particular context. That is to say there is a danger here of conjuring up the chimera of teaching a set of free-floating "skills" when what is really required is understanding - through which skills are embedded in an apprehension both of what in general counts as and motivates a scientific enquiry and the rationale of a particular investigation under way.”

(Bonnett, 1995, p.58)
2.6 Learning to Learn

Although metacognitive development is a process happening on an individual level, in the core of many of today’s pedagogical approaches we find the importance of social interaction for cognitive development (Fischer & Bullock, 1984; Freire, 1970; Smith et al., 2016; Vygotsky, 1962). Social interaction gets learners to reflect and critically examine their internalized understanding of a topic in question. In a social setting we become influenced by other perspectives, which through evaluation of the information source and critical thinking, influence whether we change our own views. Without collaboration a new understanding would not have necessarily emerged (Fischer & Bullock, 1984).

Much of the focus in education and technology is put on making learning subjects easier to access by students, especially in mathematics and sciences. Constructionism portrays children as active creators of science in classrooms and aims at teaching topics relevant to children’s lives now, not in an abstract future (Papert, 1986). Experiencing knowledge does not only mean hands-on working but the process of inquiry-based learning where students themselves are seeking ways to formulate knowledge and evaluate different approaches for their investigation (Edelson et al., 1999). In this process, by starting with the problem, the students need to first become aware of what they do and don’t know, of the subject and what is the goal of the learning process. Later, they actively select methods and tools to pursue the intended learning outcome. The teachers’ role transforms into becoming the one who guides the students through this process. The difference in problem-posing pedagogical approaches such as constructionism is that the students themselves are empowered to evaluate, reason, and argue for the knowledge they acquire through the learning process; therefore, they also accept it in the form that suits their individual needs. As Piaget puts it, children have their reasons to deny knowledge that is in conflict with their own understanding, even more in situations where they are not given a reason or argument to change their view but rather are only exposed to a new one (Piaget, 1964).

To support metacognitive development, feedback should not be given only for the knowledge that a student has mastered after a study period. Rather, feedback should be provided in the form of a continuous dialogue throughout the learning process. It should cover aspects related to the direction of inquiry and the validity of tools and methods. The traditional pedagogy provides feedback in the form of summative assessments, meaning students are assessed only through comparison to a generalized grading system after a study period (Cizek, 2009). Summative assessments imply an expectation of a knowledge level students should master at the time of evaluation and might lead to students’ temporarily memorizing facts (Khalaf & Zin, 2018). However, traditional feedback disregards self-reflection coming from the teachers regarding the efficiency of the designed activities. On the other hand, this feedback is often perceived as either rewards or punishments from the
students’ perspective (Cizek, 2009). In contrast, formative assessment refers to feedback that is focused on improving students’ own understanding of their learning and supporting their self-regulation skills (Smith et al., 2016).

2.7 Principles vs. Practice

The difficulty of implementing developmental theories in practice while promoting pedagogical values in education has been a big issue for the field until today. Firstly, the concrete action towards promoting values and theories stems from individuals’ interpretation of their meaning (Väyrynen & Paksunieni, 2020). Secondly, although the importance of expanding metacognitive- and problem-solving skills for cognitive development has been acknowledged in the education field, concrete advice on how to implement them in teaching is lacking (Larsson, 2017). Also, compared to traditional education, a teacher’s role has become manifold, demanding more effort for planning, consideration of individual students, and managing resources of different nature. Such an environment doesn’t leave teachers much time to follow contemporary educational values and principles, having to sacrifice some aspects of creating an optimal learning environment.

The educational system looks at delivering a certain level of knowledge in what is considered necessary information for individuals living in society. In this context, the traditional way of evaluating that knowledge level is the grading system. Promoting contemporary pedagogical values becomes problematic when the traditional paradigm of education remains while being in contradiction with current pedagogical approaches, see Figure 4. The aim for contemporary pedagogical approaches is not, however, to diminish the idea of necessary knowledge, but rather transform the methods that allow for egalitarian learning opportunities for everyone. Therefore, these contemporary pedagogical values - such as learning to learn - should be considered as an important component of learning materials instead of just being seen as separate skills. When applied to the context of digital educational material production, they should not be designed to solely present learning objectives determined in national curricula, but also to deliver learning experiences covering the above-mentioned values.
3 Challenges in the Digital Transition

This chapter introduces some of the many challenges faced in schools during the transformation to digital learning materials. Furthermore, it will make a deeper examination of why such issues have occurred.

3.1 Challenges of Digital Education

The change towards digital learning materials has so far presented many issues concerning securing students’ cognitive development and promoting pedagogical values. Digital materials are meant to improve student engagement and motivation by offering multilateral experiences, engaging content, and enjoyable learning activities. Although motivation and engagement are important variables of learning, there needs to be a consideration of whether the students are engaged because of a potential gamified nature of the material, instead of their intrinsic motivation towards learning (Saarinen et al., 2021). Making learning experiences more entertaining is a valid approach that aims to resolve some of the difficulties contemporary education faces with declining student motivation towards learning.

Figure 4: Pedagogical values vs. Challenges of Contemporary Education
traditional learning materials. However, although it can improve student engagement in the content, it overlooks the consideration of contemporary pedagogical values and promotes the mentality of internalizing facts as they are presented (Saarinen et al., 2021).

Without taking metacognitive development into account, digital learning materials rely simply on the assumptions that students have learned the educational materials. Therefore, students’ awareness of how the learning occurred, or even what the intended learning goals were, could be overlooked. Also, content-centric materials, which impede students’ possibility to manipulate, revisit or interact with them, eliminate the students’ chances of practicing metacognitive skills by themselves. Looking at the pedagogical principles introduced in previous chapters, digital materials should move away from being content-aware and towards becoming learning-aware. If learning outcomes are measured through programmatically calculated grades or rewards, students will very likely not exercise self-reflection as part of their learning process. Therefore, more complex feedback should be provided (Nieto-Márquez et al., 2020).

Another issue of digital materials is the implementation of learned knowledge to other contexts especially if the material is gamified taking it further away from familiar educational materials. If the digital material is taken too far from the characteristics of learning material, the learning might happen as a byproduct or unintentionally where students might not be able to transfer the knowledge in other situations (Saarinen et al., 2021).

### 3.2 Teacher’s ICT-Competency

Multiple studies have described the difficulties teachers face when implementing digital learning materials in teaching (Kaarakainen et al., 2017; Olofsson et al., 2021; Wastiau et al., 2013). The use of digital learning materials in classrooms correlates with teacher’s own ICT competence and attitude towards technology mediated learning (Blackwell et al., 2014). However, these attitudes were shown to be more positive in schools that provided adequate support for ICT implementation for teachers. Although in Finland teachers choose the learning materials themselves, the materials need to be available on the technological infrastructure of schools and students’ homes (Kaisla et al., 2015). Due to the limitations of contemporary technological infrastructure, the implementation of more versatile materials than e-books have been low so far. Transitioning to digital learning materials is not just about exchanging computers for books, but about implementing the appropriate pedagogical models in the classroom (Kaisla et al., 2015). Therefore, it is of crucial importance to ensure that the design of digital learning materials considers aspects of adaptability to teachers’ ways of organizing the learning, especially as a part of classroom activities.
4 Related Work

This Chapter explores two digital learning environments, with different learning subjects. Both platforms are used in educational environments and homes to support the development of primary literacy skills that predict future academic achievements. GraphoGame is an application where children connect phonemes to correlating letters which supports their development of learning to read. Web-based platform Mathelitcs facilitates a fun and social learning environment which also provides useful data for supervisors to follow children’s activities and progression. These applications were chosen to explore how gamification of learning materials affects children’s learning behaviors and motivation. Both materials include predetermined knowledge modules, which means the learning content can not be modified by the user.

4.1 GraphoGame

GraphoGame ([https://graphogame.com/](https://graphogame.com/)) was developed to address the results of a longitudinal study of defining the aspects indicating dyslexia (Lyytinen et al., 2009). The study found a connection between difficulties in perceptual differentiation between acoustically close phonemes and learning connections between letter correlation to sounds. The purpose of GraphoGame is to provide early intervention for children to prevent negative effects of dyslexia and support them with reading comprehension. It consists of games where the child learns to correlate single or extended phonemic units to correlating target graphemes from distractors. If the child answers wrong, the game removes all wrong answers and repeats the same phoneme again (Lyytinen et al., 2009).

In a later study, Ronimus et al. (2014) examined the effects of rewards and difficulty-level on the child’s engagement and motivation, see Figure 5. The study acknowledges that although reward-based learning has been criticized due to its undermining effect on intrinsic motivation, it remains unclear whether the correlation is the same when rewards are received virtually. Positive effects were reported in the treatment group’s concentration markers compared to the control group but not in duration of the playing time. However, after the child was not challenged by the game’s tasks anymore, their motivation decreased significantly regardless of the rewards. Although rewards are used as motivational features, the purpose is to strengthen the connection between variables. Before we judge the reward system, we should acknowledge that in GraphoGame the purpose is not to make comparisons of the child’s performance, which in an educational environment can promote the wrong approach to learning.
Shortcomings which might affect the engagement and motivation of children to continue playing GraphoGame were acknowledged (Ronimus et al., 2014). GraphoGame offers minimal chances for the child to affect or explore the game world, which over time results in the experience becoming repetitive and the child losing interest. The game also lacks presentation of the long-term learning goals to the child. Through tasks GraphoGame offers short-term goals for the child’s performance, but goals that might motivate the child to continue playing to reach longer-term goals are missing. Also, because the game doesn’t include any comparison of the child’s own progress, they might not themself be aware of their developing reading skills. The awareness of one’s progress promotes intentional learning behavior in contrast to learning happening as a by-product of playing.

4.2 Mathletics

Mathletics (https://www.mathletics.com/uk/) is a subscription-based online application for learning math through completing courses individually or competing against other players worldwide, see Figure 6. The game also rewards players’ success with certificates and virtual currency, which can be used in the game store to personalize the student’s avatar. Depending on the context of use, Mathletics offers broad features for supervisors to adapt to the progression of the game. Player activity and performance is also available for the supervisor so they can follow and support children’s mathematical learning. Compared to Ekapeli there are more activities and possibilities for the child to explore the platform’s features. The online challenges add a social
feature to the experience, although direct communication with other players is not possible.

In Nansen et al. (2012) study of Mathletics, children especially enjoyed the challenges of live games, accumulating virtual currency and spending it by shopping in the game store. However, in the study, children also hacked the system by playing Live Mathletics on the easiest level to accumulate virtual currency and enjoy more virtual shopping. In online forums, children have been found to assist each other in getting the most points with minimal effort. This indicates that children's motivation for playing was not in learning math but in gaming and game-related features. It does not mean, however, that children would not develop their math skills as a byproduct of accumulating points. It can thus be an insight into the drawbacks of gamifying learning activities and what pedagogical values digital learning experiences promote.

5 Insights into Design Exploration

The insights from the theoretical research and the teacher interviews collectively contributed to the formulation of design opportunities. Limitations of the design process were also recognized through the evaluation of the role of learning materials in the learning process. The main limitation of digital materials is the sensitivity to social and emotional reactions happening during social learning activities. In the classroom, the teacher sees students' emotional reactions to teaching and can quickly elaborate or rephrase the learning objective if necessary. Similarly, arguments, perspectives and questions prompted through spontaneous conversations cannot be easily replaced with digital equivalents. The social learning experience is valuable in teaching students' collaborative skills and communicating one's perspective while respecting others. Supporting collaboration and social interaction is a fundamental design question to be
researched in the future, but the topic was considered an exploration for an entire project. Therefore, this thesis will not explore the collaborative properties of materials or teacher-student interactions. That said, the following Chapter includes a reflection and summary of research insights turned into design opportunities that aim to explore the research questions:

How might we design digital materials that promote contemporary educational values and approaches?

How might we design digital learning materials that support children’s metacognitive development?

5.1 Supporting metacognitive development

To avoid following the traditional educational model, we should avoid content-focused mentality and instead design learning focused digital materials, see Figure 7. Like Piaget (1964) explained, a child’s nature, a layer of exploration, discovery, and conflict, should be a part of the experience. To support the development of metacognitive skills, the learning experience in digital materials should have a clear hierarchy of how the learning experience unfolds, like Bloom's Taxonomy. As one interviewee will express later, for students to practice self-regulative skills and reach the expected learning goal, it must be communicated clearly what the expectations are.

![Figure 7: Principles for moving from Content-focused to Learning-focused digital material.](image)
Traditionally, the workflow of learning materials is first learning the concept in classroom activities and then after short theory, practicing implementation in different learning tasks with the material, like illustrated in Figure 8. The path to mastery of a topic follows a simple chronological path where in the end, students receive feedback on their performance. Students are also introduced to the next learning objective regardless of whether they have mastered the necessary understanding of the last topic. Instead, the user journey should allow access to revisit the knowledge, offer guidance during the learning experience, and prompt students to practice self-evaluation over their degree of knowledge.

![Figure 8: Workflow in traditional digital learning material](image)

Implementing knowledge in tasks should facilitate metacognitive development through more puzzling tasks that require more than the direct implementation of the theory. If students are rewarded only through the number of correct answers, they might not reflect on their actions but perform them and evaluate the summative assessment. The road to the expected degree of knowledge should give the student guidance to enable them to achieve their goal while learning. Feedback during tasks often suggests the correct answer to the student, which might reinforce students' "trial and error" mentality because they eventually get the correct answer. The method also bypasses the consideration that the student may struggle with understanding the prompt and not the answer.

6 Methodology

This Chapter defines the Design methods chosen to explore the research questions from chapter 5. The Double Diamond was implemented for the planning of the project and definition of the different phases over the course of the design process. Other methods described in the chapter were implemented according to the appropriate phases defined in the Double Diamond.
6.1 The Double Diamond

The thesis structure follows the Double Diamond model (Figure 9) established by the British Design Council (2021). The purpose of the model is to be used as a guideline for different phases of the Design process. The Double Diamond includes the fundamental principles and design methods facilitating a positive change through the design process. Although the graphical representation of the double diamond shows a clear picture of the process, the implementation of the design process is not linear but rather to be modified considering the specific needs of the project’s nature (Gustafsson, 2019). The four stages each serve a different purpose for the process and include a set of methods, but they also complement each other:

**Discover:** The purpose of the Discover phase is to avoid leading the process with assumptions but rather understand the circumstances and people concerning the process.

**Define:** In the Define phase, the original challenge can be evaluated and reframed considering the insights gathered in the discovery phase.

**Develop:** This phase starts formulating various possible answers to the challenge, not in the sense of final design but for ideation purposes.

**Deliver:** Final stage is to test and evaluate different solutions with the outcomes of the Develop stage and narrow the options to a final proposal.

As mentioned in Gustafsson's analyses, the Double Diamond has its value in providing a foundation of highly developed and tested design practices and methodologies (2019). However, the direct implementation of the Double Diamond is more appropriate in the design process developed in a context where the organization has already established a systematic foundation for the project (Gustafsson, 2019). Considering the scope of this thesis work, a more flexible implementation of the Double Diamond allows room for a more iterative design process.
6.2 Semi-structured Interviews

For this thesis, interviews were conducted for qualitative research purposes (Muratovski, 2016). In semi-structured interviews the questions can be both open- and close-ended, meaning that in the interview situation, there is a possibility for further dialogue about certain topics. Nonetheless, the designer has predetermined the sequence of the questions according to the topics addressed in semi-structured interviews (Muratovski, 2016). One of the purposes of semi-structured interviews is to gather expert knowledge from the people affected by the design process. However, Wood (1997) also highlights the importance of considering the nature or expertise of the interviewee that affects the insights gathered through a dialogue. Three semi-structured interviews were conducted to collect insights, the latest happening in the prototyping phase, due to the scheduling difficulties.

Teachers were chosen with different levels of expertise from elementary school education. A broad spectrum of experience provided a wide perspective of the teacher’s education and insights into the changes that might have happened over time. The focus of the interviews was not to focus solely on digital learning material but rather get an in-depth understanding of how teachers approach pedagogical values and how they are promoted in pedagogical education. Also, the interview’s purpose was to understand what variables facilitate an efficient learning environment, to separate between variables that can -and should be- included in learning materials, and which the teacher should facilitate.

6.3 Prototyping

Prototyping is a method that enables the evaluation of various variables surrounding the design scope and offers answers to design questions (Houde & Hill, 1997). Houde and Hill define a prototype as any representation of an idea regardless of the tools it was created with, but rather through the purposes it serves to the designer. They categorize prototypes in three dimensions describing the purpose of the prototype role, look & feel, and
implementation (1997). Buchenau et al. further defined experience prototyping as enabling the evaluation of the first-hand experience of possible future conditions through prototypes (2000). Experience prototyping defines prototypes more broadly to also address questions related to integrated experiences through providing informative personal experiences (Buchenau et al., 2000).

This thesis evaluated the prototypes through Houde & Hill's dimensions definitions and implemented them as experience prototypes. The role dimension is evaluating the purpose and functionality of an artifact for the user, in this thesis namely: what role does digital material play in enabling the metacognitive development in an educational environment, and where are the limitations. The look & feel dimension explores the sensory experiences of users with the artifact, correlating to students' experience of the prototypes. Implementation dimension answers the usability questions relating to the components that allow the prototypes to perform their functions, meaning how the prototypes delivered the learning experiences through their interactive elements. The prototypes were also formulated to simulate integrated experience of possible educational material and implemented in an educational environment. Through conducting workshops in an educational environment with elementary school students, participants could more easily relate to the prototypes' intended circumstances of use. Also, the designer was able to experience the implementation of the prototype in classroom activities from the perspective of a teacher.

6.4 Wizard of Oz

Wizard of Oz (WOZ) is a simulation technique that aims to create a fabricated illusion of a fully functioning design proposal that users can test (Bernsen et al., 1993). The WOZ technique allows the user to experience the complete system interaction, or a simulation of it. The process includes the wizards, whose task is to ensure users' actions are responded to in the simulation. However, WOZ is not suited to all design processes, as Bernsen et al. (1993) describe the four limitations of the method:

1. The behaviors of the simulated interactive systems should be behaviors humans are familiar with performing.

2. The system should have relatively narrow and well-defined application domains.

3. The cost-time risk of building the WOZ system should be considered, meaning that if the test fails, the whole system might have to be
rebuilt. Therefore, rapid prototyping techniques are preferable in cost-benefit terms.

4. Cognitively demanding interaction often demands users' spontaneous input behavior such as gestures, speech or writing, and the technique should only be undertaken if those inputs are not restricted in unnatural or unprincipled ways.

The benefits of WOZ prototyping are creating a realistic experience of an interactive user experience without implementing more time-consuming programming. Through simulation of realistic interaction, WOZ also allows the user to give more defined feedback on the experience, influencing the iterations more profoundly (Molin, 2004). However, the last limitation of WOZ technique caused the method to be implemented only in the first prototype, which will be explained in chapter 7.3.

6.5 User testing

According to Bastien (2010), user testing is a method allowing an individual within the target audience to interact with a prototype by conducting specific tasks or exploring it freely. The designer observes the behavior and actions of the tester during the session to identify issues in user flows or design decisions under evaluation (Bastien, 2010). However, because the participants were minors in this study, the organization and execution of the workshops had to be modified to fit the age of the audience. Usability testing with children requires simplifying the directions given before starting the session and providing enough time for exploration, considering the developmental stage of the children (Hanna et al., 1997). In this thesis project, user testing was conducted during three separate workshops with the same participants. After each workshop, the results of user testing were evaluated according to observations and children's feedback, which resulted in modifications of features for the next workshop's prototype.

7 Design Process

For this process, the selected form of digital material is a platform, meaning the material is a web or application-based learning environment like Ekapeli and Mathletics. The term platform in this context is defined by the limitations for expressing contradictory or varied knowledge provided through the material. This means the platform will only provide knowledge and learning experiences predetermined by the creators without offering an optional perspective or possibility to express different views by the user (Gillespie,
Platforms are the primary type of delivery mechanism for digital materials used currently, whether we talk about teachers’ produced materials or company provided. The reason for choosing platforms was to keep the design exploration within a contemporary education environment. Platforms are often widely accessible within technological resources of schools and homes and tend to follow standard usability guidelines, which means teachers or students do not necessarily need to learn entirely new systems to work with. Platforms are often a lower-risk option for classrooms because while a student can break a computer, they cannot break the platform, meaning the school does not need to invest finances in new equipment repeatedly.

7.1 Teacher interviews

To understand the implementation of pedagogical approaches and values in everyday classrooms, three teachers with varied educational experiences were interviewed. First interviews were held face-to-face before starting the design process. Last interview was conducted via phone during the second week of the design process due to scheduling difficulties. Teachers’ names have been changed to protect their privacy.

7.1.1 Lisa

Lisa did her studies in the 70s and described the nature of education similar to the decade's social phenomena "hippie and freedom era." The education was very much student-driven and included many group activities. Instead of strictly determined learning objectives, the students were assigned to consider and discuss together the valuable knowledge and skills needed to be a teacher for children. At the beginning of her career the curriculum was not strict but rather a guideline, and the approach to learning was more holistic.

Lisa found that children learn through every situation and interaction during the day but, more importantly, require a social or emotional connection with the source of knowledge to accept the learning experience. In Lisa's experience, teachers must reflect on their practice through children's reactions to teaching.

According to Lisa's experience with older students, the teacher does not have to argue for the importance of knowledge as much as with younger children. This does not mean that older students are easier to teach but that younger children are not mature enough to understand the value of knowledge, and teachers must be more innovative with their approach.

Lisa pointed out the contradiction between teachers having to meet every student at their level and then grading them according to generalized measures. Contradiction is also in the evaluation methods: each student’s optimal learning style and understanding of the subject might not be the same as in the standardized test, according to Lisa. She explained further that
even if the child has not succeeded in the test, they might have an excellent understanding of the learning objective but not how it is addressed in the test.

According to Lisa, learning materials are a secondary learning tool, but still, the teacher carries the primary responsibility of enabling learning for each student. Therefore, she believes digitizing education should not be done with the belief that it will produce higher learning outcomes. Lisa elaborated further that technology should not be created with the contradictory mentality of education, meaning the purpose of learning is to meet generalized criteria through generalized learning techniques.

7.1.2 Jessica

Jessica studied pedagogy in the past decade and describes her education as content focused. Her interest in studying pedagogy was to learn how to become a good teacher. However, she found that education focused more on testing whether the pedagogy students knew the topics they were supposed to teach according to the curriculum. She found the system inefficient because, in her view, she had already been tested on her knowledge during her comprehensive school education. Therefore, university education should have included more valuable skills for becoming a good teacher instead of focusing on the content of teaching. Jessica experienced the Swedish pedagogy slogan "lifelong learning” in contradiction with the lack of education for future teachers on the practices that facilitate equal learning opportunities for everyone.

During her internships, she saw that teachers did not have the resources to meet every child at their level because they also had to follow all the learning objectives determined in the curriculum. Surprisingly, Jessica’s answers about what facilitates learning aligned with Lisa’s, although they graduated from teacher education over 30 years apart. She believed teachers should be able to argue for children why they should be learning specific topics and have sensitivity to students' personal views. Learning must be made meaningful to children, and it cannot happen if the teacher themselves does not reflect on why and how knowledge would be meaningful to children. In Jessica’s view, digital materials and technology should not be implemented in education before the education field finds a common understanding of how to facilitate the learning process for everyone instead.

7.1.3 Lena

Lena has been a practicing teacher for decades and is involved in a mentoring program where she helped newly graduated teachers to organize their teaching. From her observation of newly graduated teachers, she agreed with Jessica’s experience that teacher education focuses too much on the content of the curriculum. She noted that the recent change in the curriculum also increased the demand for content-focused education and learning criteria
instead of trusting the teachers' consideration of meaningful learning experiences. She found the new curriculum more limiting for teachers to practice consideration of individual students' needs because the grading criteria and learning objectives are strictly defined.

From Lena's perspective, there is no use in introducing a new learning objective if the student has not learned the ground knowledge of the topic. However, due to resource limitations and following the curriculum's learning objectives, teachers must compromise to consider each student's needs. Lena's view on facilitating learning implies good organization of classroom activities. The learning objective, the goal of the session and expectations of learning outcomes must be clear for students to meet the intended criteria. Before students can reflect and adapt their knowledge, they need to understand the factual base. Young children cannot formulate knowledge unless first introduced to the basic terminology and idea of the concept. The implementation and adaptation of knowledge comes later. Lena believed that applying the framework from Bloom's taxonomy for organizing teaching was the best practice to facilitate optimal learning experiences.

Lena uses digital materials to support some classroom activities, but she does not see digital materials offering all the necessary functions for students to learn efficiently. She used digital materials to motivate students because students preferred computers over writing. However, she also saw many students struggling with handwriting tasks because they mainly used computers and phones to write with, thus she decided to use computers only occasionally. From Lena's perspective, digital materials cannot replace some essential features of the learning process: dialogue, collaborative working, and the teacher's role. She found the user-friendliness of digital materials problematic because they can reinforce the mentality of clicking until it is right instead of evaluating the answer. Lena also stated that if teachers do not enforce intentional learning practices and reflective thinking, students are unlikely to practice them in any material.

### 7.2 Ideation

During the ideation phase, the descriptions from chapter 5.1 were drawn as guidelines to formulate concrete characteristics and features for building prototypes. In the table, the different columns represent the [Educational] Components, which are the different variables facilitating the learning process. Characteristics are the intentions of components, which will be enabled by the design of the concrete Features, see Table 1.
<table>
<thead>
<tr>
<th><strong>Component</strong></th>
<th><strong>Characteristic</strong></th>
<th><strong>Features</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization of learning</td>
<td>Presentation of expectations for the activity, self-awareness of individuals degree of knowledge and representation of learning objective.</td>
<td>Chronological order of the information with flexible access.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learning objectives should be broken into units of information that formulate the knowledge base that are later adapted in the creation of a concept.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Help students to recognize their own knowledge base and connection to new knowledge. (Constructivism)</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Access to revisit the learning objective. Clear communication of the units of information included in the objective. Allowing discovery, exploration, and manipulation of information.</td>
<td>Easy navigation that allows revisiting material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presenting information in different forms and through user actions.</td>
</tr>
<tr>
<td>Assessment</td>
<td>Guidance during the learning experience for students to meet the intended level of knowledge. Continuous evaluation before proceeding to the next activity.</td>
<td>“Help” button that recognizes if a student is struggling with the problem or answer and guidance accordingly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opportunity for self-assessment that enables students to recognize if they have reached the intended degree of knowledge before proceeding.</td>
</tr>
<tr>
<td>Implementation</td>
<td>Tasks should follow Bloom’s taxonomy hierarchy.</td>
<td>Support remembering and understanding of the learning objective before more puzzling tasks.</td>
</tr>
</tbody>
</table>

Table 1: Prototyping guidelines expressed in terms of components, characteristics, and features.
7.3 Prototyping

The process continued in an iterative form including prototyping, workshop, and evaluation stages. Each prototype was iterated after a previous workshop's experiences and observations, adding new or revised features that would be under examination in the following one. All prototypes were built taking advantage of the interactive properties of Google Slides. The prototyping tool was evaluated as efficient in serving the intended purpose and functionality within the timeline of the three workshops. The tool's constraint forced students to have to perform some tasks outside of the slide show, or even editing one of the slides as an input modality during the first workshop. However, this limitation in terms of affordances of the tool became irrelevant during testing.

The reasoning for the chosen prototyping tool was also practical. For all children to test the prototype simultaneously, some students were using computers provided by the school. The computers had restricted operating systems that prevented using open web browsers and receiving files or emails from unfamiliar addresses. The prototypes could be opened with the student's computer systems using Google Classroom and Google apps from within education systems operators. The drawback of the prototypes was their demand for high-capacity internet connection because the school's internet was occasionally slowing down the flow of the material's animations and progression.

The tool also limited the formulation of tasks requiring text input from students, which could be beneficial in tasks where students formulate their own arguments or conclusions. However, this limitation brought me to a re-evaluation of an earlier opinion; I had believed that clickable tasks were ineffective in supporting cognitive development. During the iterative design process, a new perspective emerged on how clickable tasks can be designed to promote the development of cognitive processes. The realization might not have happened without the limitation and considering the complexity of text inputs, excluding it as an option kept the design space within the current technological resources available in lower education. Through excluding tasks with text input, the prototypes didn’t require implementation of WOZ method, which allowed more time for observations during workshops.

7.4 Workshops

Three workshops were held with five elementary school children to explore the form and functionality of the features described in chapter 7.2. The workshops could be performed during language class because the author is the group's teacher in normal circumstances. In normal circumstances the writer is a mother tongue language teacher in Finnish for the participating children. The familiarity of students and researcher with each other was taken into consideration from both positive and negative sides:
• Children might be shy with new people and hold back their reactions and communication. Because children knew each other and the facilitator, they might express themselves more freely.

• Children tend to give positive feedback, especially to the adults they are familiar with, to please them. Because children knew each other and the facilitator, they might mirror peers' opinions or aim to please the facilitator.

Both sides were considered when formulating the assessment criteria and feedback questions for the participants during workshops. They were also considered when evaluating the results of workshops.

The learning objective was chosen from the Swedish curriculum for 4th graders' nature studies, a subject that could be listed under science. Some of the features under evaluation required the topic to spread throughout two lessons, following the hierarchy of learning adapted from Bloom's Taxonomy. The topic was also considered suitable for all ages represented in the group, with some adaptations made to suit the youngest students' testing circumstances, which will be addressed in the workshop descriptions later. The learning objective was "The water cycle," and in the first two workshops, students were introduced to water’s different forms and reactions between the states (solid, liquid, gas). In the second material, the forms and reactions were adapted and implemented in the different stages of the cycle.

7.4.1 Workshop 1

The first workshop was planned to familiarize the children with the overall form of workshops and the possible user experience of the digital material. I prototyped the learning experience for the session following a traditional education model with the added intention to explore its effect on facilitating learning. The session used WOZ to give direct feedback on the tasks, see Figure 10.

![Figure 10: WOZ method to simulate asynchronous feedback.](image)
The prototype unveils units of information with complimentary animations and illustrations step-by-step to direct participant's attention (Figure 11, image A/B). Theory was also revealed through students' actions to add a layer of interactivity to the content representation although students were not able to manipulate it (Figure 11, image A/B). After an initial theoretical phase, students proceeded to the task section, where they were to apply the learning objective to different tasks (Figure 11, image C). The last task was explicitly created to see how the students perceived the learning objective and reflected about the experience in the form of a self-evaluation. Last page questions were formulated to describe in their own words the learning objective and then evaluate their knowledge of the topic before and after going through the material (Figure 11, image D). However, learning goals or introductions of the topic were not presented.

**Reflection**

The first workshop had two main lessons learned. Firstly, the planned workshop duration was too optimistic and as a result, not everyone had the time to test the learning material. Secondly, the students needed help with the language of the material since it was made in their second language. All students are fluent in the language used in the material but not in the context of the learning objective. The language barrier resulted in students needing help translating the material and answering questions in their native language, extending the time.

From the design exploration dimension, feedback was collected through observations, notes, and user comments. Technically the prototype functioned as planned. Students were also advised to revisit the material when needed during tasks. During the tasks, students mainly answered directly referencing the material but struggled with tasks that required knowledge adaptation to other phenomena not presented in the material's
graphic presentations. In multiple-choice tasks students were implementing metacognitive strategy by choosing options they knew the answer to at first, reducing the options for the ones they were unsure about. However, when students had to describe the learning objective by themselves in the last page, it became clear that students did not understand the topic but had memorized the phrases from the material and gambled on their answers. WOZ was used in tasks requiring students to categorize or connect information units, this is the case when they had to open the slide show in editing mode and change one of the slides. Interestingly, students eventually repeated the task until they got it correct because they did not know the answer. During the task, it was also observed that students answered wrong in two cases; when they did not understand the question or failed to formulate connections between units of knowledge from the theory.

7.4.2 Workshop 2

For the second workshop the prototype was built with the design questions in mind and the evaluation of the first workshop, see Figure 12. The workshop structure changed to ensure all students had sufficient time to review the material and intended exercises. The workshop started with a brief for the students listing some of the tasks to help them explore the material. The material was built in the student's native language to ensure they understood the learning objective and tasks. All students were testing the prototype simultaneously, with two younger students working together with one computer.

The prototype aimed to explore how different learning organization and task formulation influence the learning experience, including the self-evaluation process (Figure 12, image A). Instead of starting with the theory, students were first introduced to the purpose and expected learning outcomes of the learning experience (Figure 12, image B). The theory was presented throughout the learning activities that translated into triggering interactive actions and manipulation of elements in the interface, which was intended to help formulate correlations between the cause/effect within the topic (Figure 12, image C). The tasks were formulated to require knowledge adaptation and problem-solving instead of only direct implementation. To avoid students guessing their answers, they were given a help button to reformulate the task if the student struggled with the question. If students answered wrong, they would also be directed to help. After the tasks, students were again presented with the expected learning outcomes and self-evaluated whether they met the intended goal (Figure 12, image D).
Reflection

The workshop structure was more streamlined, allowing for better observation and discussion of the experience with students. A significant difference from the first workshop was the time students spent exploring the material. Although the first workshop only had nine slides for students to go through, it took much longer than the second prototype, which included 56 slides. Students also did not raise any questions while navigating through the material during the second test, indicating that the usability matched their ICT competence. After the test, students were asked to reflect on different aspects of the material through dialogue.

Students agreed that being introduced to the expectations before the theory helped them understand the purpose of the material and directed their focus during the exploration. However, they also reported that the tasks were easy, and only one student used the help button. Unfortunately, the reformulation did not help them because they did not understand one of the words in it. During testing, I observed that students did not guess their answers because they were not answering wrong either. One student commented upon the tasks "They were easy because I did not have to write," which confirms the difficulty in balancing the right amount of effort and difficulty when formulating tasks.

Students who tested the previous prototype reflected upon comparing the two experiences. They preferred the second prototype's experience and tasks but thought the first one had a more compressed representation of the learning objective. In the second prototype, the learning objective was broken into three different sections and had less writing and more illustrations and animations appeared through user actions. The purpose of breaking the theory was to help students to separate the cause-and-effect parts of the
learning objective, but it might have led to information overload. However, students were also keen to finish the material because they had access to other platforms afterwards, making them restless when the theory chapter took longer. Even with added interactions and animations, students' motivation for learning remained the same.

The next workshop learning objective will continue the last topic to evaluate how recalling the knowledge base works. The tasks will have to be more challenging, and the help button will include an option for students to choose whether to get help with the task itself or with the question's wording. As per the student's request, the learning objective will be communicated more clearly. The purpose is to determine how students can recognize their knowledge base to adapt it to the new topic. Also, an iteration will be made on the tasks to explore how they can practice metacognitive strategies during the tasks since the second prototype's tasks were too easy.

7.4.3 Workshop 3

The third workshop aimed to conduct a user test using a prototype built according to observations and students' feedback from the previous workshops. The topic of the prototype was chosen as a logical continuation of the previous topic. It was a conscious decision to examine the effect of features aiming to support metacognitive development. Each student tested the materials from a separate device, but the two youngest students were allowed to sit together and collaborate during the test. The decision was made according to the authors' evaluation of general literacy level of same aged children compared to the assumed difficulty of the material (Figure 13).

Figure 13: Youngest students collaborating during workshop.
The third prototype was built considering the constructivist theory of learning by activating the student already during the theory section of the test, and through developing the learning experience to address the higher stages of Bloom's taxonomy. To implement the strategy around metacognitive skills, the prototype started with students recalling the central pieces of knowledge from the previous workshop through a short categorizing task (Figure 14, image A). This time students were asked to go through the learning goals before starting with the rest of the material to ensure they would complete the step. The theory section presented general terms and knowledge related to "The waters cycle" directly with figurative illustrations. However, the cycle itself was formulated as a task where students themselves had to explore different stages of the cycle (Figure 14, Image B). This approach is intended first to provide students with the necessary components of knowledge, and then activate them to formulate connections among separate pieces of information and into a more significant concept. In the second prototype, the tasks were too easy for the students, and only one reported using the help button unsuccessfully. This time the tasks were made more puzzling, intentionally aiming for students using the help button more and increasing the demand for complex problem-solving processes (Figure 14, Image C). In the final step, students revisited the intended learning goals with complementary questions related to each goal's content to support their reflection on the learning process (Figure 14, Image D).

Figure 14: Third prototype following constructivist theory and adapting cognitive domains from Bloom's Taxonomy.

Reflection

The older students skipped through the theory section during the workshop and proceeded directly to the tasks. However, because the tasks required new knowledge and adaptations of previous knowledge, they needed help with the answers. Due to the frustration generated, they requested help from the
workshop leader, but were advised to visit the theory sections first. After going through the theory section, students understood the learning objective and performed the tasks with a higher degree of success. This time, students were more engaged with the theory because they had the power to affect the progress of the workshop. Interestingly, the two younger students went consciously through the entire material, reading through each prompt and paying attention to every detail. Moreover, although the topic is typically taught in higher classes, the younger students performed the tasks without confusion or getting overwhelmed.

Through observations and later discussions, students reported having no issues figuring out the water cycle by themselves in the theory section. That supports the approach of combining constructivist theory and Bloom's Taxonomy hierarchy in the learning experience by first providing students with necessary knowledge but letting them formulate the connections that construct the learning. Teaching and learning through realization and problem-solving served its purpose, considering students had not been introduced to the water cycle before. The theory task also involved information that had not been addressed before in the prototypes, but students could use the knowledge base and metacognitive strategies to construct knowledge. The method was also unanimously voted as the students' favorite form of content representation, which somehow indicates how much kids want to act instead of being passive receivers of knowledge.

This time the tasks were designed to be considerably more challenging than in the second prototype. Some tasks also challenged the student's adaptation to knowledge from another context. The intention was to observe the use of the help button during tasks and try how the formulation and setup of tasks can affect students' answering process. All students reported using the help button on occasion and that the problem's reformulation had helped them realize the answer. Interestingly, the students who skipped the theory initially could not answer the questions even with the provided help button until they visited the theory section. Here, students had gained a false level of confidence due to the previous workshop tasks being easy. Furthermore, since the material task in the third workshop also required adaptation and connection of knowledge to new circumstances, the students were forced to understand each unit of information and draw conclusions that were not taken directly from the theory.

In a later discussion, the oldest student stated, "I prefer to use study books because I am used to them." Familiarity with the affordances and use patterns of materials is an essential aspect for designers to consider, because the long existence of study books has formed a specific frame of how students use the material that has not yet reached digital materials. Books are intuitive for students as a way to find the needed information during tasks and, therefore, are still considered more convenient than digital materials even by students, who are digital natives.
8 Discussion

This chapter describes the main findings of the thesis through linking research insights with reflections from the design process. First, the challenges of supporting learning through digital materials and causes of slow transition to digital education are described. Later, the results of the design process are presented and a possible future design projects related to the thesis topic are proposed.

8.1 Challenges of supporting learning through Digital materials

A significant limitation of supporting the development of metacognitive skills and critical thinking through digitized environments is the crucial role of social interaction. The two educational core aspects: being mindful of one's own learning and the ability to intentionally implement metacognitive strategies, are connected to the individuals’ behavioral traits, making them complicated issues to address. As mentioned during the teacher interviews, educators must reinforce these behaviors in students to ensure the learner’s future ability to self-learn. Variables such as nuances of social interaction, individuals’ behavioral traits, and national curriculum play a significant role in the learning environment. However, they are for the time being out from the scope of designing digital materials. Therefore, contemporary educational values can only be supported to a certain degree through generalized strategies that support students' development of problem-solving skills and metacognitive strategies. This does not mean the variables should not be considered as an essential question when designing digital materials. Instead, designing digital materials should include understanding of the degree in which these behaviours can be influenced by creating supporting strategies.

Considering the students’ engagement with the material, the struggle is to find the balance between being too convenient and requiring too much effort. To facilitate a productive learning environment, the content’s representation should be exciting and fascinating to spark students' curiosity. However, digital material with excessively moving components might overload the working memory or distract students’ intention away from the learning experience (Saarinen et al., 2021). Also, if students are granted access to roam free through the material, they might skip many essential steps of the learning process for convenience. Special features intended to support complex problem-solving and metacognitive development might be considered too tricky or unnecessary by the students. Like during workshops, students tend to look for shortcuts, which might promote the behavior of trying to perform the tasks in a haste. However, allowing the students to affect the progression of the experience seemed to tackle the issue of skipping
theory parts. The opportunity to access other platforms during class is a temptation for students that might cause teachers to decline from using digital materials due to the difficulty of maintaining students' focus in the learning activities and supervising them (Ilomäki & Lakkala, 2011).

Physical learning material has a considerable history of being the primary learning material, and therefore, they are still associated with being most suitable for the organization of teaching. Thus, implementing them in education brings teachers and students a certain level of security and familiarity to the learning environment. Although digitizing education is being pushed through curriculum changes and investments in improving schools' technological infrastructures, there is a lack of judgment related to the fundamental variables affected by the change (Polly et al., 2021). Developing the same familiarity as using physical materials across all school subjects should be attempted with digital materials in the future. Refraining from considering the issue of materials functionality in classrooms would be inconsiderate and, so far, has led to some teachers still preferring physical materials (Kaisla et al., 2015). Transferring to a digital learning environment also affects the standard methods that foster the learning process, such as handwriting supporting internalizing information. Although memorizing facts is less valuable in the current information technology era, we cannot overlook the value of the essential cognitive processes being developed through education. The question of how digital materials can create the necessary learning experiences required to secure cognitive development should be answered before we proceed to explore all of the additional opportunities they provide.

Learning material is not only determined by the content it provides but also its suitability to the learning environment. Currently, teachers are provided with various physical materials to choose from according to which one supports their pedagogical approach. The considerably higher cost of developing digital materials compared to physical materials also affects publishers' reluctance to provide a broader range of digital materials (Kaarakainen et al., 2017). However, digital materials will likely become more prominent in future educational environments, although the adaptation will take time. Therefore, it is crucial that as the presence of technology in education rises, we take note of the struggles faced by teachers who are expected to adapt to the change. As described in the theoretical chapter, through interviews and my own experience as a teacher during workshops, the struggles related to implementing digital materials also have an effect in the teachers' everyday practice. Therefore, emphasis should be put on supporting teachers, which in turn will bring the ability to provide an egalitarian learning environment for all students.
8.2 Strategies for supporting metacognitive development

The four strategies described below are manifestations of the design exploration that aimed to define how contemporary pedagogical values could be turned into concrete representations in interactive digital learning materials. The strategies were influenced by the research findings and concretely emerged through the design process. The intention of these strategies is to provide a foundation of principles and guidelines to inspire designers developing digital learning materials in the future.

Organization of learning defines the foundational principles for facilitating a learning experience that promotes contemporary pedagogical values and supports metacognitive development.

Knowledge describes the characteristics of learning focused knowledge representation.

Feedback specifies how to move away from reward-based assessment, not through lowering expectations, but offering guidance.

Implementation presents the crucial aspects of consideration for the formulation of tasks.

For interaction designers the prototypes shown in this thesis are an example of how we can produce a broad range of representations of ideas by utilizing even the simple forms of interaction. The four strategies for promoting contemporary pedagogical values and supporting metacognitive development in digital materials are as follows:

Organization of learning

To support intentional learning and the development of metacognitive skills, students should be provided with clear expected learning outcomes before being introduced to the learning objective. Through expectations, students can evaluate whether their actions lead towards reaching the intended degree of knowledge. The learning objective should be broken into parts that follow the hierarchy in Bloom's taxonomy. Students must first understand the meaning of different variables related to the learning objective before being able to formulate concepts by connecting the units. It is also beneficial when students adapt the knowledge into a concept when they revisit previous lessons' learning goals. Revisitation helps students direct their intention to the connection between old and new knowledge and emphasizes the process of adapting knowledge instead of recalling facts. After completing all tasks, students should evaluate whether they have reached the expected learning outcomes by revisiting the learning goals. Organization of learning creates the workflow for the material, see Figure 15.
Figure 15: Workflow based on contemporary educational values and supports metacognitive development.

**Knowledge**

Piaget's constructivist theory and Freire's problem-posing approach share the idea of utilizing students’ previous experiences and knowledge in the learning process. Children are naturally curious and motivated to learn by taking action. If knowledge representation is considered only through providing engaging content, the learning heavily relies on the child’s interest in the subject. However, allowing the child to formulate the knowledge themselves through taking action supports the development of skills such as knowledge adaptation to a new context and problem-solving. Providing a new theory as a task also supports metacognitive development by requiring students to evaluate previously accumulated knowledge to formulate an understanding of the new. To avoid distracting students from the learning situation and overloading the working memory, the experience should not be taken too far from the educational context or filled with many stimulating properties.

**Feedback**

Considering what attitude towards the motivation for learning digital materials promotes, assessment should be provided in the form of guidance instead of results or collected rewards. I propose avoiding summative assessment to support the mentality that learning is valuable for each student's personal growth. Instead, the material is designed to secure each student's capability to complete all tasks at their own pace without comparison to others. Usually, students draw wrong conclusions for two reasons: they misunderstand the question, struggle to formulate a conclusion, or sometimes a consequence of both. Providing students with a help button to reformulate the problem is an efficient way of helping the student in case of both issues. The purpose is to help the student formulate the correct conclusion but not make the task easier by hinting at the right option. However, if the student makes a mistake, they should also be provided with reformulation to evaluate if they misunderstood the question or formulated an incomplete conclusion. Not offering a shortcut by removing part of the problem or proceeding to the next task after a wrong answer,
students are not encouraged to practice behaviors such as changing their answer or re-evaluating their approach after a mistake.

**Implementation**

To support students' cognitive development, the tasks should be formulated in a way that does not require only direct implementation of facts. Instead, the problems should challenge students to use their entire knowledge base to evaluate their approach. While sufficient text input tasks with appropriate feedback are not yet present in digital materials, most answering methods are still through simple user actions. Therefore, task formulation significantly influences how the material supports children's cognitive development. Before students decide to take action, they should evaluate the appropriate approach to the problem and choose the units of knowledge that can be adapted and implemented to formulate a conclusion. Bloom's Taxonomy can be used as a framework for developing an appropriate progression of tasks, starting from reinforcing the understanding of the separate units of knowledge to creating new knowledge through adaptation. To support the behavior of thoroughly evaluating the approach to the task before taking action, I suggest against adding time pressure or rewards to the tasks. Time pressure and rewards can promote the mentality of answering in haste and comparing results to others instead of focusing on individual development.

### 8.3 Future Work

This thesis aims to open a space for exploring how contemporary educational values and pedagogical approaches can be promoted by the design of digital learning materials. The central research question under the examination of this study was how we might support children's cognitive development through design.

Due to the scope of this thesis, teachers’ perspectives and participation were relatively small, considering their significant role teachers have as facilitators of the learning experience in classrooms. For future design work, the thesis outcomes should be further studied, by involving teachers more in the design process.

The design encompasses only one learning objective from the elementary school nature studies curriculum. The topic could be explored for future projects with variations of other school subjects. Because children's metacognitive level and critical thinking are slowly building abilities, a more comprehensive study about digitally supported development of those skills would also be an aspect of future exploration.
9 Conclusion

This thesis aimed to explore how contemporary educational values and pedagogical approaches could manifest in digital learning materials through Interaction Design.

The exploration identified the challenges of technology-mediated education, and constructivist theory and Bloom’s Taxonomy were used to determine different factors that facilitate an optimal learning experience. Freire’s (1970) philosophy of pedagogy also inspired the exploration by providing a deeper analysis of the purpose of education and a critical view of the traditional education model.

Limitations related to the context of this study were also recognized in the discovery phase, which affected the decisions made later in the design process. Firstly, just as practicing teachers, digital materials are limited to following Freire’s philosophy because they must address learning objectives stated in the national curriculum. Secondly, although technology offers many possibilities to build learning experiences supported by the latest enhancements, the cost and technological infrastructure are fundamental causes for schools not investing in digital materials.

Four components of digital materials were explored through an iterative design process (Organization of learning, Knowledge, Feedback, Implementation). Each component was considered through its role in the learning process, with an evaluation of how it can be designed to follow the principles defined in a first diamond. The final strategies were formed to describe each component’s representation and role in digital materials during the design process. During the process, an ideological perspective of design in educational contexts emerged:

> Before designing complex digital learning experiences, we should consider the core purpose of learning material and the fundamental design questions to be answered. Design affects more than just the intended function but also promotes certain behaviors and mentalities. Although technology offers endless opportunities for creating interactive learning experiences, we should consider how our design practice serves the core values of contemporary education and society as a whole.

This thesis work provides an example of how abstract concepts such as values and theories can be transformed into concrete manifestations within the constraints of contextual circumstances through design. This design project’s
outcome presents a framework that can be used in the future development of digital materials and concrete examples represented in the prototypes. This thesis also aims to bring forth a critical perspective towards the contradiction between principles and practice in the education system that should be considered when defining the voices to be heard in education design.
10 References


https://doi.org/10.1080/10508406.1999.9672075


https://doi.org/10.1080/0300443981410101


https://doi.org/https://doi.org/10.1145/264044.264045

https://doi.org/10.1016/b978-044481862-1/50082-0


Lavonen, J., & Salmela-Aro, K. (2022). Experiences of Moving Quickly to Distance Teaching and Learning at All Levels of Education in Finland. In *Primary and Secondary Education During Covid-19.* https://doi.org/10.1007/978-3-030-81500-4_4


https://doi.org/https://doi.org/10.1037/11193-000
