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Research article

Teachers' use of digital textbooks in mathematics and science education

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Abstract: Digital textbooks are rapidly becoming a common feature in mathematics and science teaching. At the same time, there is limited research on teachers' use of digital textbooks for teaching. Our study takes a comparative approach, contributing to the field's understanding of the implementation of digital textbooks in mathematics and science education. Four lower secondary teachers' use of digital textbooks was deductively analysed concerning various features in the textbooks, using data from classroom observations and interviews with teachers and students. Results revealed similarities between teachers regardless of subject, such as using functions to guide students in the digital textbook and recognising the advantages of using videos or animations. One conclusion is that these similarities could be regarded as generic for the use of digital textbooks and important regardless of the subject. A prominent difference concerned the use of digital textbooks as a means of content processing through writing. In the mathematics classrooms, paper and pencil were used, mostly due to the limited possibility of writing mathematics in digital textbooks. In the science classrooms paper and pencil were not used, as this subject is different and to a lesser extent based on being able to represent subject content through calculations, symbols, and figures. Another difference concerns teachers' approach to planning and tracking students' progress, where the science teachers focus on the group and the mathematics teachers on individuals. This implies the importance of including a focus on subject-specific aspects when designing and integrating digital resources in teaching.

Keywords: comparative study, digital learning resource, lower secondary school, mathematics and science textbooks, technological knowledge

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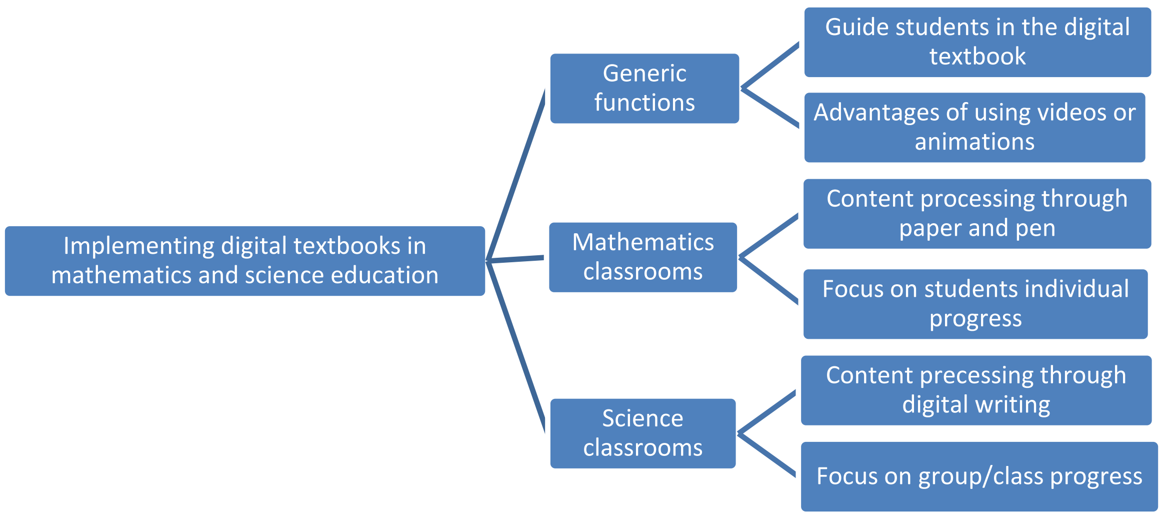

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1 Introduction

Teachers play a central role in the use of textbooks during teaching and learning, and how the teacher uses the textbook is an integral aspect of their didactical choices (Fan et al., 2013). An increased awareness of available learning resources, such as textbooks, can lead to teachers being better able to plan and implement effective learning situations for students (Norberg, 2023). Over the last decade, textbooks as learning resources have shifted from being analogue, printed books to also being textbooks in digital format. The evolution of digital textbooks has advanced from merely being PDF versions of printed books to becoming online platforms that interact with incoming student data (Utterberg Modén, 2021). However, there is limited knowledge of what consequences this may have for teaching and learning. Research focusing on the integration of digital textbooks in mathematics and science and their influence on practice is still rare (Pepin et al., 2017; Vojíř & Rusek, 2019). Specifically, there is limited research concerning teachers' use of digital learning resources (Pepin et al., 2017). Nevertheless, a few studies in mathematics and science education have identified the potential usefulness of digital textbooks and suggested a positive impact on student learning depending on the implementation (Swedish Institute for Educational Research, 2017; Vojíř & Rusek, 2019; Zoellner & Cavanaugh, 2017). Most of the existing empirical research on digital resources (including textbooks) have however focused on comprehensive evaluations (Cayton-Hodges et al., 2015), or on the development of tools for the evaluation of digital textbooks (Harrison & Lee, 2018). Hence, there is a need for more in-depth knowledge regarding specific subject aspects, especially concerning the design of teaching when using digital textbooks (Drijvers, 2020; Hoyles, 2018).

The use of learning resources depends on how teachers perceive their potential. Regarding textbooks as learning resources, an authors' intentions can be realised in different ways depending on the teachers' adoption of the intended curriculum of the book (Olsher & Cooper, 2021). With the digital resources available to today's teachers, the opportunity to design their own learning resources is greater than ever (Pepin, 2018). Pepin (2018) argues that the final teaching design arises from a synergy between the teacher's didactical choices and the attributes offered by the learning resources. When new resources for learning are available, knowledge about their use is needed. In this paper, we focus on how digital textbooks are used for teaching mathematics and science, in Swedish lower secondary education. In Sweden the school subjects within the field of science are biology, chemistry and physics, and syllabuses for the three subjects have common overarching learning goals (Swedish National Agency for Education, 2022). A problem of treating the three subjects as one (science) could be that there could be different traditions in the implementation of the syllabuses (e.g., Andrée, 2007; Lunde, 2014). Something that nevertheless speaks for treating the subjects as one is that we know there are results that show that teachers perceive biology, chemistry and physics to have great similarities (Kaya & Erduran, 2024). Another argument that the topics belong together is that all the three science subjects aim to explain phenomena in the physical world, which distinguishes them from mathematics. The choice to do a comparative study of the subjects, mathematics and science, is further explained and motivated below.

2 Background

There is no single definition of what is meant by the term digital textbook (DTB) and previous research has, for example, included traditional textbooks in pdf formats that are digitally accessible (Norberg, 2021), or digital features in texts such as hyper-links or interactive tools (Aharony, 2015; Brueck & Lenhart, 2015). There has also been variation in the extent to which a DTB covers the entire curriculum content compared to digital learning resources that may only cover some specific aspects of the curriculum content, such as an app to practice multiplication, word processors, spreadsheets, or Google apps for education. In this paper DTB is defined as "coherent (digital) material covering entire curriculums" (Grönlund et al., 2018, p. 1361). DTBs can structure the material according to pedagogical ideas, as well as offer tools to support students in their learning, such as exercises, tests, opportunities to listen to the text, the chance to make notes and annotations, mark text and to communicate with teachers and other students. The use of DTB requires access to various resources such as computers, internet etc. These prerequisites vary greatly between countries, for example, "globally, 40% of primary, 50% of lower secondary and 65% of upper secondary schools are connected to the internet" (UNESCO, 2023, p. 11). In Sweden, access to and use of information and communication technology is high (Lucendo-Monedero et al., 2019; Swedish National Agency for Education, 2016), which facilitates the use of digital textbooks in teaching. For example, a majority of the textbooks sold to compulsory and upper secondary schools in Sweden in 2019 included digital learning materials (Läromedelsförlagen, 2020).

The introduction of DTB in education can contribute to more effective teaching, and support student learning (Embong et al., 2012; Swedish Institute for Educational Research, 2017). In particular, students seem to appreciate the dynamic and interactive features in DTBs, and these elements have been shown to have a positive effect on student persistence (Dyrvold & Bergvall, 2023). At the same time, Dyrvold (2022) showed that digital learning materials used in Swedish secondary schools largely consisted of static elements, especially those linked to content consisting of theory and examples, and that interactive elements were mostly used in tasks. The author argues that this suggests a traditional view of the student, where the student passively receives information about theory and only becomes active when tasks have to be solved. Nevertheless, there is also a sense of uncertainty among teachers regarding how to effectively use DTBs (Hutchison, 2012; Reints, 2015), implying that teachers still rely heavily on paper textbooks (Reints, 2015). Furthermore, digital technologies can be used in many different ways that are often not obvious to the user, making their appropriate integration into teaching a complex task (Koehler & Mishra, 2009). Findings indicate that teachers do not always actively use the various digital tools available in DTBs to support students' learning, and, in some cases, teachers had not even noticed the available tools within the DTB (Grönlund et al., 2018). It is argued that teachers need to understand both the possibilities and limitations of the DTB, and how this affects the possible design of teaching (Koehler & Mishra, 2009). Thus, teaching with DTBs brings both opportunities as well as challenges, necessitating a deeper understanding of their usage. Additionally, due to the wide range of applications within DTBs, the possibilities and constraints are largely dependent on the specific subject content, and there is more than one way to effectively integrate the use of DTBs in teaching (Koehler & Mishra, 2009). The study reported in this article focuses on DTBs in mathematics and science teaching.

Studies that include more than one school subject can contribute to mutual academic didactic clarifications of each subjects' specific character (Nielsen, 2011) and, by extension, that different school subjects require different didactical approaches. Comparative studies focusing on textbooks in mathematics and science have, for example, shown that there is a higher number of different algebraic symbols in equations in physics textbooks than in mathematics textbooks, and that algebraic symbols are more seldom referred to by words in mathematics than in physics, which highlights the need for different didactical considerations of teachers (Johansson & Österholm, 2023). Moreover, research indicates that teachers design lessons differently based on the subject, which in turn impacts what teachers can observe regarding students' thinking and learning (Jazby et al., 2023). Jazby et al. (2023) saw that even though the teaching was carried out by the same teacher, students' opportunities to represent their thinking differed depending on whether it was a mathematics or a science lesson. These different opportunities led to the teacher being able to observe more of the students' thinking about concepts during the science lesson compared to the mathematics lesson, where the approach focused on features that identified whether students could arrive at the correct answer, giving less consideration to their thought processes along the way (Jazby et al., 2023). Comparative subject didactics, from a research perspective, can be understood as an endeavour to analyse and understand similarities and differences between subjects from a didactical perspective, considering various conditions and dimensions (Nielsen, 2011). We find the use of DTBs to be an example of a given condition and dimension that needs to be understood with respect to different subjects, given that the character of each subject could influence its use. In other words, teaching traditions (incl. learning resources) in different school subjects influence teachers' focus. Mathematics and science are both included in the field of STEM education (STEM: science, technology, engineering, and mathematics) and often investigated together in research studies (e.g., Chiu et al., 2023; Saat et al., 2023), and there are several examples where STEM subjects are integrated in school systems internationally (Larkin & Lowrie, 2023). Thus, a comparative study of mathematics and science contributes to a deeper understanding the characteristics of these subjects. An understanding of differences and similarities for the use of DTBs in mathematics and science teaching can contribute to the development of teaching practices which takes greater account of the specificity of the subjects. Regarding the subject of mathematics, research focusing on DTBs is an emerging field and DTBs influence on teachers, students and teaching is in need of further understanding (Pepin et al., 2017; Education Committee, 2016). Most studies of the existing empirical research studies have focused on comprehensive evaluations (Cayton-Hodges et al., 2015) or on the development of tools for the evaluation of DTBs (Harrison & Lee, 2018).

In similarity with the field of research in mathematics education, research on science textbooks is a growing field, though few studies were found concerning the use of DTBs and their specific features. In a literature review of research on science textbooks from 2000 to 2018, the authors noted that of the 183 studies only 5 percent concerned e-textbooks and open textbooks (Vojíř & Rusek, 2019), and in that category DTBs are only a part. The authors also noted that these studies mainly examined books used in university undergraduate programs. The use of e-textbooks and open textbooks, for example DTBs, among younger students is less explored (Vojíř & Rusek, 2019). The study previously mentioned shows that research into DTBs is rare, and it says nothing about how DTBs are used. Findings from a study that examined this issue revealed that tools within DTBs such as note taking, audio and built-in dictionary features, were increasingly valued by preservice teachers following completion of a secondary science methods course (Zoellner & Cavanaugh, 2017). As can be seen above, the use of DTBs in mathematics and science education is a research field in its infancy. To meet the needs of today's education, where DTB's are regarded as integral elements in both mathematics and science teaching, research in this domain needs to expand and deepen.

3 Conceptual framework

The introduction of digital learning resources in education discussed above, has led to an increased attention on the role of teachers and teachers' technological knowledge (e.g., Hoyles, 2018; Pepin, 2018; Utterberg Modén, 2021). To describe different aspects of knowledge which teachers need, to integrate technology into teaching, the Technological Pedagogical and Content Knowledge (TPACK) framework has proven useful (e.g., Brueck & Lenhart, 2015; Mishra & Koehler, 2006). TPACK refers to the combination of Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK) (Table 1), which encompasses knowledge about how various technologies can be used to represent content-specific concepts and in other ways facilitate students' learning of a particular content (Mishra & Koehler, 2006). To capture the context specific aspects of teaching (e.g., subject), Pareto and Willermark (2019) developed a modified and operational model, *TPACK in situ*, which focuses on descriptions of design instead of descriptions of knowledge. The three basic tenets of both frameworks are described in Table 1.

Table 1. The basic tenets of TPACK and TPACK in situ

Tenet	TPACK (Mishra & Koehler, 2006)	TPACK$_{in\ situ}$ (Pareto & Willermark, 2019)
content knowledge	CK: knowledge about the specifics of the subject in focus for teaching	CK$_{in\ situ}$: which subject-specific curriculum content goals the didactic design is addressing and why these are important in the particular situation's context
pedagogical knowledge	PK: generic knowledge about ways to plan, implement and assess teaching to support students' learning	PK$_{in\ situ}$: which pedagogical strategies are used in the didactic design and why these are relevant in the particular situation's context.
technological knowledge	TK: knowledge about existing standard technologies (incl. hardware and software) and how to use them, as well as the ability to adapt to changes	TK$_{in\ situ}$: which technology usages (i.e., type of activity the technology supports) that are present in the didactic design and why these are suitable in the particular situation's context

Note. This table describes the three basic tenets of the two frameworks TPACK and TPACK$_{in\ situ}$, where TPACK$_{in\ situ}$ refers to descriptions of design instead of, as in TPACK, descriptions of knowledge.

TPACK in situ has been used in previous studies to capture how teachers' knowledge base is manifested in the teaching practice (Pareto & Willermark, 2019). Likewise, this study focuses the teaching, thus builds on the modified version *TPACK in situ*. Furthermore, focus is on teachers' use of DTBs and we have delimited our use to the concept TK$_{in\ situ}$ (Table 1).

When considering DTBs, the technical tools included in a DTB can be separated into four categories: *presentations aids*, *tools for working with texts*, *teacher tools*, and *tools for communication* (Grönlund et al., 2018). Table 2 provides subcategories that are included in the different categories and examples to illustrate what is included in the categories. Technologies in our study are delimited to DTBs (i.e., hardware and other digital resources etc. are not included). To describe different aspects of TK$_{in\ situ}$ related to DTBs, the concepts from (Grönlund et al., 2018) are used. Thus, TK$_{in\ situ}$ focuses on these four categories of technical tools in DTBs.

Table 2. The different categories of TK$_{in\ situ}$ related to DTBs following Grönlund et al. (2018)

Category	Subcategory	Examples of what is included
1. Presentation aids	a) Table of contents b) Search tool c) Animations and/or videos d) Zoom in/out, text-to-speech, font, background colour e) Hide information f) Technical glossary	tools for navigation (e.g., tables of content, bookmarks), multimodality (e.g., video, animations), tools for adaption (e.g., option to change to "easy language", to have the text narrated, to include visual cues, change font size), integrated dictionary to explain technical terms
2. Tools for working with texts	a) Markings in the text b) Take notes c) Make own glossaries d) Type of tasks	text marking, creating personal notebooks, sharing documents for collaborative writing, automated tests etc.

3. Teacher tools	a) Adapt the material, b) Add tasks c) Hide tasks	possibilities for teachers to add and share material or hide pre-produced material, as well as receive online support
4. Tools for communication	a) Synchronous communication b) Statistics c) Asynchronous communication d) Documentation e) Teacher feedback from exercises f) DTB feedback on tasks	various options for collaboration (e.g., teacher and student messages, comments and responses in text, sharing materials between students and teacher)

Note. This table describes the four categories of technical tools in digital textbooks that are used to analyse $TK_{in\ situ}$.

4 Purpose and research questions

As discussed above, the implementation of DTBs is subject specific and although research on DTBs has been conducted in the context of various subjects (e.g., Grönlund et al., 2018; Pareto & Willermark, 2019), most research has focused on more generic aspects and not content-specific aspects. Furthermore, STEM education studies incorporating science and mathematics, have often focused on similarities between the subjects, while findings indicate differences between the subjects, such as different use of representations in textbooks and variations in teacher behaviour when teaching each subject. This underscores the need for further comparisons between the use of DBTs in mathematics and science teaching. The purpose of this study is to contribute to the fields understanding of DBT implementation in mathematics and science education by focusing on how teachers make use of tools provided by DTBs for teaching. Specifically, the following research questions are addressed:

> RQ1: How are categories of $TK_{in\ situ}$ manifested in the mathematics and science classrooms when DTBs are used?
> RQ2: What similarities and differences with respect to these categories can be identified in mathematics and science teaching?

5 Method

In this comparative case study, we did a re-analysis of material collected in a practical research project on DTBs in teaching of mathematics and science. We analysed four teachers' use of DTBs when planning and teaching mathematics and science in in four different classes, grades 7 and 9 (students' age: 13 and 15 years). The methods used were videorecorded lessons, interviews with teachers before and after teaching and interviews with students after the teaching. This is done more precisely to understand how $TK_{in\ situ}$ in DBTs is used in mathematics and science education. It is important to point out that although the data collected in the project is extensive, the focus in this study is on teachers' use of $TK_{in\ situ}$. This can be expressed during interviews with teachers or students, or in the classroom where the teaching has been filmed. In addition, some data has been used to describe the context to set the scene of the studied teaching. This is presented in the section “The Mathematics and Science Classroom”.

5.1 Participants and teaching materials

The participants and the teaching materials are presented in the table below:

Table 3. Participants and teaching materials

Teachers	**DTBs**	**Description of DTBs**	**Students**
Mika	Gleerups mathematics 7-9[1]	- Self-correcting tasks, tests, and discussion tasks. - Possibility of changing the text size and the possibility of text-to-speech. - Built-in calculator, a graphing calculator, and theory videos.	1 class grade 7, 6 students using spy glasses 6 students interviewed
Morgan	Magma Mathematics app[2]	- Self-correcting tasks, tests, and discussion tasks. - Possibility of changing the text size and the possibility of text-to-speech. - A workspace for the students to present solutions, different levels of difficulty for the tasks. - Possibility of translation into 140 different languages. - Documentation in the form of a class overview for the teacher.	1 class grade 7, 6 students using spy glasses 6 students interviewed
Sam	Gleerups Biology 7-9[3]	- Possibilities to change several options, such as text size, font, background colour, and text-to-speech functions. - Questions, assignments, exercises, and diagnoses with automatic correction.	1 class grade 8, 4 students using spy glasses 4 students interviewed
Sonny	DigiLär Science and Technology 7-9[4]	- Possibilities to change several options, such as text size, font, background colour, and text-to-speech functions. - Questions, assignments, exercises, and diagnoses with automatic correction. - The teacher can choose if the answer key should be shown to the students.	1 class grade 9, 6 students using spy glasses 6 students interviewed

Note. This table describes the four participating teachers, the respective DTB they used in the class, and participating students in their respective class.

[1] https://www.gleerups.se/7-9/matematik/gleerups-matematik-7-9-lararlic-12-man-p51101170
[2] https://www.magma.se
[3] https://www.gleerups.se/7-9/biologi/gleerups-biologi-7-9-digital-lararlic-12-man-p40682420
[4] https://www.nok.se/titlar/laromedel-b3/digilar-digilar-no--teknik-7-9/c37c633e-13ba-446b-b5ef-f6b390bb5dda

The choice of school-level is based on that teachers should have a subject-teacher degree, which is the case from grade 7 and onwards in Sweden. The participating teachers worked in different lower secondary schools, with students from mixed socio-economic backgrounds, in two different small municipalities in Sweden. Their participation was based on the fact that the schools already used DTBs to a certain extent, and the teachers had expressed an interest in learning more about the use of DTBs in teaching. All teachers were experienced (5 – 20 years) in both mathematics and science education.

Each teacher used a different comprehensive DTB of their own choice and the teachers themselves decided which topic area within science or mathematics that would be covered in their teaching.

5.2 The mathematics and science classrooms

Below is a brief description of each classroom to set the scene.

Mika uses the DTB for about half of the teaching time and both Mika and the students are quite familiar with the DTB. Mika chose problem solving concerning number sense as a topic for the observed lesson.

Morgan uses the DTB for about 20 percent of the teaching time. Due to a lack of digital working area and the possibility to write down solutions, Morgan considered the DTB most suitable for repetition. Thus, repetition with respect to rational numbers was in focus for the observed lessons.

Both Mika and Morgan started the first lesson in whole class and then the students were instructed to log in to the DTB and Morgan explained how to work with the content. In Mika’s classroom the students were then instructed to “do as usual”, that they could work in pairs with the problem solving if they wanted to and that they could use paper and pen to solve the tasks. During both lessons, Mika spent quite some time helping students with technical issues such as log in information, computers that lost power, etc. and assisted those students that actively asked for help with math-related questions. In Morgan’s classroom the plan was to individually watch videos and then solve associated tasks. All students were provided with a sheet of paper with a structured plan to work on sequentially and with direct links (in the form of codes) to the different tasks in the DTB. In both lessons, Morgan walked around among the students most of the time asking how the work was proceeding and helping where needed.

In Sonny’s classroom, the primary resource is the printed textbook and the DTB is used as a complement. The students are used to working with the DTB. Sonny chose to focus on physics in the observed lessons, particularly on a selection of central astronomic concepts and on the characteristics of different types of stars.

Also in Sam’s classroom, the use of a DTB is common and familiar to the students, as well as the use of other digital resources. Sam had chosen to focus on biology in the observed lessons, in particular the effect of addictive substances on physical and mental health.

Both Sam and Sonny had chosen tasks that forced students to formulate their own explanations for central concepts, as well as to explain the concepts to other students. Both teachers also had a similar structure to their respective lessons. The observed lessons began with whole-class discussions of a task, then students worked individually or in pairs and the lessons ended with another whole-class discussion. During the students' individual or pair work, both teachers circulated in the classroom and helped students whenever someone got stuck or wanted to ask a question.

5.3 Collections of data

The data collected consists of three parts. The first is video recordings of four lessons in each subject, two lessons per teacher, ranging between 40-80 minutes each. Second part is two recorded interviews with each of the teachers; one, between 45-90 minutes long, before the observed lessons and one, 25-50 minutes long, after both lessons were implemented. The third part is group interviews, 30-40 minutes long, with students after the two lessons. Each lesson was recorded using two video cameras placed diagonally in two corners covering most of the classroom. Students without consent to participate were placed out of rage of the cameras. Furthermore, some of the students wore spyglasses[5] with microphones during the lessons and subsequently group interviews were conducted with these students after the lessons were conducted. One group of students was selected from each class for interviews. This selection was made by the teacher on the basis that there should be a variation with respect to grades, and the size of each group ranged from four to six students. Group interviews have an advantage when interviewing children, as it can allow them to feel more comfortable in the company of peers and thus speak more freely. It also provides time-saving opportunities to discover consensus in students' experiences of teachers' use of DTB in teaching, instead of through individual interviews.

The interviews were semi-structured, departing from an interview guide with open-ended questions. Questions for the first teacher interview before the lessons concerned: which content area that would be in focus for the lessons and why (concerning the used DTB); if, and if so, how and why the teacher plans to customise instruction or content for different students (concerning the used $TK_{in\ situ}$); if, and if so, which and why (incl. reasons concerning the used DTB) other resources will be used. Questions for the second teacher interview, conducted after the implemented lessons and after the student interview, concerned teachers' reflections on the conducted lessons with respect to the use of the DTB; as well as specific questions about how various tools in the DTB had come into play in the lessons identified by the researcher by a first brief look at the video recordings of the lessons and in the interviews with the students. Questions for the student interview

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5  Spyglasses look like ordinary glasses, but the frame includes a camera in middle front and a microphone on one side.

concerned their experiences of using the DTB for the particular content in focus, with a focus on how the teacher informed them about and encouraged them to use $TK_{in\ situ}$ in the DTB. For example, if they knew about the “text-to-speak” function, and if they did, how they found out about it. Or, how they acted if they did not know an answer to a question, and how the different opportunities in the DTB had been addressed by the teacher.

5.4 Processing and analysis

Each recording of the interviews and classrooms was transcribed with respect to the teachers’ or students’ verbal utterances in relation to the use of $TK_{in\ situ}$ in the DTBs. This was done in ATLAS.ti, which is a workbench for qualitative analysis of large textual, graphical, and audio-video data (e.g., Friese, 2013). Irrelevant parts were omitted, such as discussion about what was served for lunch or which classroom the students should go to later. Similarly, recordings from the spyglasses were transcribed with a focus on verbal utterances regarding the use of $TK_{in\ situ}$ in the respective subject. Video recorded actions without any verbal communication was also described in ATLAS.ti, such as collecting paper and pencil for the students. No embodied actions were considered.

The analysis focused on characterising teaching with respect to the use of the different tools provided through the DTB and analysed deductively to identify which categories of $TK_{in\ situ}$ (Table 2) were present in the different data materials.

Transcripts of the lessons were analysed regarding teachers’ actions and verbal utterances. In addition, transcripts of students’ spyglasses were analysed regarding verbal interactions with the teacher that concerned the use of any of the tools. Transcripts of teacher interviews were analysed regarding teachers’ descriptions of their experience and use of the different tools in the DTB. Lastly, transcripts of student interviews were analysed regarding students’ descriptions concerning if and how different tools were used by the teachers. Table 3 shows an overview of which objectives of the analysis were identified in the different data resource regarding categories of $TK_{in\ situ}$.

Table 4. Overview of the analysis with respect to the data resources

<table>
<tr><th>Data resources</th><th>Objectives of the analysis
To identify which categories were present in:</th><th colspan="4">Categories of $TK_{in\ situ}$</th></tr>
<tr><td>Video recordings of lessons</td><td>The teachers’ and students´ actions and utterances.</td><td rowspan="4">Presentation aids</td><td rowspan="4">Tools for working with text</td><td rowspan="4">Teacher tools</td><td rowspan="4">Tools for communication</td></tr>
<tr><td>Teacher interviews</td><td>The teachers’ descriptions of their experience and use of the different tools in the DTB.</td></tr>
<tr><td>Spyglasses</td><td>The interactions between student and teacher that concerned the use of any of the tools.</td></tr>
<tr><td>Student group interviews</td><td>The students’ descriptions concerning if and how different tools were used by the teachers.</td></tr>
</table>

Note. This table shows an overview of which objectives of the analysis were identified in the different data resource regarding categories of $TK_{in\ situ}$

The four researchers initially analysed and categorised a data sample together to establish consensus on categorisation. Afterwards, data related to each of the teachers was individually assigned to researchers for categorisation, i.e., one researcher categorised all data related to Mika, and another all data related to Sam and so on. Consistency in the categorisation has been ensured through regular reconciliations in the research team with review of the transcripts and the assigned categories have been discussed and changed when needed. The categories of $TK_{in\ situ}$, as presented in Table 2, are based on Grönlund et al. (2018), and the categorisation was performed according to descriptions below.

Presentation aids (category 1, Table 2) focuses on the students and teachers as users. For example, providing students with direct links to positions in the DTB that were in focus in the lesson were categorised as related to *search tools* (1b, Table 2), and the use of content specific videos provided in the DTB was categorised as *animation and/or videos* (1c, Table 2). In the categorisation, we also included instances of actions and descriptions that explicitly could be related to aspects of non-utilisation or addressed absence of the tools. For example, when text-to-speech possibilities in DTB were used by students but not considered by the teacher, this instance was categorised and coded as *text-to-speech etc* (1d, Table 2). This example of non-utilisation was shown in the data by an instance when a student was using the text-to speech, and during this asks the teacher "what does exclamation mark means?", the teacher answers "I don't know" followed by "are you listening to the tasks?". When the teacher was asked about this instance in the following interview, it turns out that the teacher is aware of that the text-to-speech tool exists, but nothing that the teacher explicitly informed the students about or encouraged them to use. An example of the absence of tools is when teachers use content-specific videos not provided in the DTB (e.g., "I find it valuable to show the students a lot of short films not included in the DTB"), and instances like these were categorised as *animation and/or videos* (1c, Table 2).

Tools for working with text (category 2, Table 2) concerns possibilities and features in the DTB with a focus on the specific content. As above, both instances with explicit presence and addressed absence were considered. For example, instances explicitly referring to a built-in calculator in the DTB or to use a separate calculator were considered to belong to this category (2, Table 2), e.g., when a teacher informs the class "you are allowed to use calculators on all exercises, there are calculators in the front of the classroom and on the computer". Although not considered included in one of the particular subcategories a – d, calculator is considered a central tool for working with a text/content including calculations. Other examples of instances in this category are the explicit use or non-utilization of a digital workspace provided in the DTB (e.g., a teacher says to a student "you can write on a paper, you don't have to write there" and points to the digital workspace), and the use of paper and pen to work with the content (e.g., a teacher gives a student a sheet of paper and says "you can use this to do 'try-out calculations' on"), and the addressed absence of a digital workspace (e.g., when a teacher expresses "I miss the opportunity for students to write down the steps in solutions in the DTB"), which were all categorised as *possibilities to take notes* (2b, Table 2).

Teacher tools (category 3) focuses on the teacher as content provider. This category contains all identified actions and descriptions related to possibilities for the teacher to adapt the material. For example, cases involving the customisation of instruction through the creation of tasks with different levels of difficulty were categorised as *possibilities to adapt* (3a, Table 2). Examples of this are when a teacher discusses that it is more time-consuming to get an overview of available tasks in the DTB, and thus their different levels of difficulty, compared to a printed textbook. Whereas another teacher considered the DTB's categorisation of difficulty levels useful, and thus that it is quite easy to adapt tasks within a particular content according to levels of difficulty. To *add or hide tasks* (3.b and 3.c, Table 2) is related to instances when a teacher expresses how easy/difficult it is to show all tasks for the students in the beginning of the lesson or to only show one task at the time for students that find mathematics hard and it is good not start with a list of all tasks. For example, one teacher expresses that "it is easy to access student profiles in the DTB and change assigned tasks for a particular student during a lesson", and another teacher expresses "for students that find mathematics hard, it is good to only show one task at the time, and not start with a list of ten tasks".

Tools for communication focuses on possibilities for teachers and students to collaborate through the DTB. As above, instances of actions and descriptions explicitly related to aspects of non-utilisation or addressed absence of the tools were also included. Instances about which data the DTB provided and the usefulness of this data in teaching was categorised as *statistics* (4b, Table 2). One example of such an instance is when one teacher expresses that "I use the statistics at the whole-class level by looking at the colour codes to see if many of the students have had difficulty with the same tasks". Furthermore, instances concerning how students digitally wrote answers to study questions and then submitted them through the DTB to the teachers (e.g., one teacher expressed that "it is an advantage to have all the students' answers in one place, it makes it easy for me to check their answers") were categorised as *asynchronous communication* (4.c, Table 2). Similarly, the use of other digital tools (e.g., Padlet) to examine students' knowledge was also categorised as *asynchronous communication* (4.c, Table 2). Instances highlighting teachers' opinion about the possibility of immediately finding out if an answer is correct or not, as well as about appropriate hints, were categorised as *DTB feedback on tasks*, (4.f, Table 2). For example, "in general it is good for students to immediately know if their solutions are right or wrong, then it depends on how this information is used", and "instead of almost getting the correct answer, students should get hints that lead them stepwise to a solution", or "it is too easy for students to get access to the correct answers".

6 Results

The results presented below are divided into two parts. Firstly, we give examples of how the different categories of $TK_{in\ situ}$ come into play in the mathematics and science classrooms in relation to the use of the DTB (RQ1). Following this, we described the similarities and differences that have emerged in the analysis with regard to how the DTB was used in the mathematics and science classrooms (RQ2). Table 5 summarises the main features of the results and in the following sections we elaborate and provide examples of the data underlying our findings.

Table 5. Main results regarding the most prominent categories from the analysis in relation to the subjects.

Most prominent categories of $TK_{in\ situ}$ (RQ1), and whether the category is prominent for both Math and Science, or not (RQ2).		
Category	**Mathematics**	**Science**
Tools for navigation	X	X
Dynamic and interactive presentations (mainly videos)	X	X
Tools for working with text (no prominent subcategory)	X	X
Tools to adjust the difficulty of the tasks	X	
Features to facilitate readability		X
Use of statistics for planning and adapting upcoming lessons	X	
Tools to inform students of the correctness of their answers	X	
A wish for tools to remove the key		X

Note. This table shows an overview of the main results in relation to the research questions in the study.

In the following section a detailed description is presented in relation to each category of $TK_{in\ situ}$. Afterward follows a development of the most noticeable similarities and differences.

6.1 Teachers' use of DTBs in mathematics and science classrooms

Regarding *Presentation aids* (category 1, Table 2), the analysis revealed instances related to subcategories a-d, and non that were related to e or f. For example, both Mika and Morgan used tools to direct students to the particular tasks they were intended to work with during the lessons (1a, Table 2). Utterances like "Without this feature students would have to navigate by choosing grade, then content, then specific topic, then particular aspect of the topic, then which task", was interpreted that the feature to direct students to the particular task is considered advantageous by both teachers and students. In Morgan's case, the list of links that directed students had to be created manually outside the DTB, whereas in Mika's case it was created automatically within the DTB. Also Sam and Sonny guided students to relevant sections in the DTB, however they did so by giving verbal instructions specifying the section or paragraph students should navigate to, rather than providing a list of links or codes (e.g., "Start your computers and open [name of the DTB]. You should enter what is called 'Planets, stars and galaxes'.").

In Sonny's classroom the DTBs search tool (1b, Table 2) was an important part for the teaching design. Students were given six astronomy concepts, and they used the search tool to find the concepts in the written text. After reading, the students wrote their own explanation for each concept in the DTBs' dictionary.

Another example from category 1 is the use of dynamic and interactive presentations in the form of short, embedded videos covering specific subject content (1c, Table 2). This is highlighted as valuable by both Morgan (e.g., "Dynamic representations make the subject content clearer.") and Sonny (e.g., "Short informative videos let all students both see and listen to explanations about the content, I wish for even more informative videos."). According to Morgan, the videos let the students experience different explanations of mathematics and allow them to pause and rewind to watch again. Morgan considered this to be beneficial to the students, especially to students who need extra support. The interviews with both Morgan's and Sonny's students revealed that the students also appreciated access to videos in the DTB (e.g., Morgan: "In the videos, the mathematics is explained step-by-step" and Sonny: "You can look at a video several times if you don't understand it the first time"). Mika, on the other hand, used videos from YouTube in lessons because "I find it valuable to show the students a lot of short films not included in the DTB". Morgan also used supplementary dynamic and interactive presentations, such as GeoGebra, which allows for students to "explore relationships between different variables or parameters within a function".

Teachers and students also appreciated features to facilitate readability (i.e., 1d, Table 2). Sam and Sonny pointed out the advantage of the text-to-speech reader in DTBs, particularly for students with reading difficulties; it appears that students use this feature occasionally if the texts are long (e.g. "If it is a very long text - it is like a robot speaking, ok to listen to although"). Student interviews also revealed that Morgan's students had noticed the text-to-speech reader in their DTB and sometimes used this although Morgan did not explicitly mention this tool during lessons or interviews (see quote in analysis section). Another positive feature, related to the same subcategory, mentioned by Sam is the option for students to change background and font settings, as well as the ability to select different settings that enhance readability for students with dyslexia (e.g., "you can listen at the same time as you see, you can set the right background, you can change the font").

Regarding *Tools for working with text* (category 2, Tabel 2) the analysis revealed instances related the subcategories b-d (Table 2). These tools were, for example, concluded to play a significant role in providing opportunities for students to write mathematics. In particular, Morgan emphasised the importance of students writing down the path to a solution (i.e., 2b, Table 2), and that this feature was missing from the DTB used in that classroom. During both lessons, Morgan instructed the students more than once to use paper and pen when working on mathematical tasks (e.g. "it's perfectly ok to use a scratch paper if you find it easier to find a solution" and “you can use this [gives the student a paper] to do ‘try-out calculations’ on”). Analysis of the observations also revealed that Morgan always used paper and pen when helping students during the lessons. The DTB Mika used did offer a digital working space for students to make notes on and derive solutions, which Mika informed the students of during the lessons. Similarly to Morgan, Mika informed the students of the option to use paper and pen as a supplementary tool if they preferred (e.g., “you can write on a paper, you don’t have to write there” and points to the digital workspace). Similar to Morgan, Mika frequently used paper and pen when helping students during the lessons.

Analyses of observations of the science classrooms revealed that *tools for working with text* also were important in the science classroom. In for example, Sonny’s classroom students created their own dictionaries (2c, Table 2) using the digital browser function in the DTB to search for each concept, and then writing their own explanation in the glossary provided in the DTB. During this work it was notices that a lot of discussions took place, and the subject content seemed to be extensively processed.

Furthermore, both Sam’s and Sonny’s students spent time answering study questions in writing (2d, Table 2), which were connected to paragraphs in the text. In the interview, students promoted study questions as a good way to know what you are supposed to learn (e.g. “The questions, as it were, tell you what it is that you should [know]).

The calculator was another common tool used to work with mathematical content that both Mika and Morgan addressed during lessons. Both teachers provided physical calculators that students could borrow. Although in Mika's case there was a built-in calculator in the DTB in a separate toolbox, along with things like a ruler and protractor, access to the toolbox was unreliable according to Mika "sometimes it's available and sometimes not", so Mika felt it was important to bring external calculators.

Regarding *Teacher Tools* (category 3, Table 2), the analysis revealed instances related to all subcategories a-c. For example, both Mika and Morgan adapted the content to suit individual students (3a, Table 2) and expressed that it was positive that the students could work with the same content area but at their own level. Mika selected and combined tasks on three levels according to level of difficulty. Similarly, Morgan found that access to a variety of tasks in the DTB made it easier to select tasks at the right level for a specific mathematical topic. On the other hand, Morgan expressed that it is not possible to individualise tasks for all students as it would be too time consuming. In Morgan’s classes, adaptation is instead done at group level for the majority of students, and at the individual level for those who need extra support or extra challenges. Sonny and Sam, on the other hand, mostly discussed the possibility to adapt the content of the DTB (3a, Table 2) with respect to removing access to the answer key. Several times during the interviews Sonny denounced the problem of students copy-pasting the right answers to study questions without processing the subject content. “They want to skip reading through, [they] only search for answers. And they also like to copy and paste answers.” Both Sonny and Sam expressed concerns about students not processing the content in the texts due to the easy access to the answer key.

Another example is that the mathematics teachers considered it a strength of the DTB that one can easily add easier tasks for a particular student if he/she thinks the tasks are too difficult (3b, Table 2). For example, Mika expressed that “it is easy to access student profiles in the DTB and change assigned tasks for a particular student during a lesson”. Similarly, the possibility to hide tasks (3c, Table 2) were considered positive in mathematics, which is exemplified by the quote “for students that find mathematics hard, it is good to only show one task at the time, and not start with a list of ten tasks”. Mika mentioned one student in particular who had previously struggled to make progress in the mathematic class but who began to show engagement when they started to use the DTB, due to the possibility to adapt content to suit individual students. A similar experience was shared by Morgan.

Regarding *Tools for Communication* (category 4), the analysis revealed instances related to subcategories b, c and f (Table 2). For example, it emerged from the interviews that both mathematics teachers used the provided summaries in the DTB’s of students' activity and details about their performance on various tasks (4b, Table 2). Mika explained that the statistics obtained from the DTB provided a comprehensive view of class level achievement, along with information concerning individual students’ achievement and activity during lessons. Morgan, on the other hand, emphasised that the statistics from the DTB provided information about how students understood the mathematical content on a group level, but to obtain appropriate information of each individual student's understanding and progress, statistics on individual students' work on respective tasks needed to be reviewed and this is time consuming (e.g., “I use the statistics at the whole-class level by looking at the colour codes to see if many of the students have had difficulty with the same tasks”). Regardless of some differences, the analysis revealed that both mathematics teachers found it advantageous to use these statistics as a starting point for discussions with individual students regarding challenging content or inactivity during lessons. The analysis also revealed that none of the science teachers used the provided statistics in any way.

Another prominent tool used by Sam and Sonny was that the students sent answers to study questions to the teachers (4c, Table 2). Sonny saw a great advantage in having all the student responses gathered in one place in the DTB, e.g., “it is an advantage to have all the students’ answers in one place, it makes it easy for me to check their answers”. However, Sonny did not use the feature to provide feedback to the students’ responses even though this feature is available in the DTB. During the lessons observed, Sam used a Padlet as a supplementary digital tool to allow students to write down what they remembered from the previous lesson, and their responses were then collected by the teacher (4c, Table 2) and summarised in a whole class discussion.

Furthermore, features that provided direct feedback on whether answers were correct or incorrect (4f, Table 2) were seen as a positive aspect by both Mika and Morgan, and by their students (e.g., “in general it is good for students to know immediately if their solutions are right or wrong, then it depends on how this information is used”). Sonny and Sam, on the other hand, expressed concerns about the easy access to the answer key on tasks in the DTB (e.g., “it is too easy for students to get access to the correct answers”). Furthermore, if students in the mathematics classes answered a task incorrectly, feedback was sometimes available in the form of a hint that the student could choose to look at before answering again (4f, Table 2). However, Morgan experienced that these hints are sometimes too supportive and remove the opportunity for the student to come up with the solution themselves (e.g., “instead of almost getting the correct answer, students should get hints that lead them stepwise to a solution”).

6.2 Comparisons between mathematics and science classrooms

A comparative analysis of the data with respect to RQ1 (i.e., which and how the different categories of $TK_{in\ situ}$ are manifested in the mathematics and science classrooms) revealed both similarities and differences (RQ2), which are described below

6.2.1 Similarities

As shown above, teachers in both subjects used different tools to guide students to the “right” place in the textbook, regardless of which DTB that was used. If there was a tool provided in the DTB, teachers used this, otherwise they constructed their own method to guide students. Another prominent similarity among teachers in both subjects was the importance of using writing as a way for students to process content. It also became evident that all teachers considered it desirable for the DTB to include appropriate tools for processing content in relevant written formats. Additionally, all teachers appeared to consider hints to be beneficial, nevertheless, they wanted the option to customise the “helpfulness” of the hints so that students are given suitable opportunities to engage with the content. Yet another similarity was that teachers in both subjects used various ways to be able to collect or see students’ solutions, and where this possibility was available in the DTB it was seen as positive. In addition, all teachers highlighted the benefits of using videos or animations to present content to students. Sometimes these videos were provided in the DTB and sometimes the teacher used videos from external sources. Furthermore, all teachers expressed that working with DTBs requires significantly more planning time in comparison with traditional textbooks. Overall, the analysis clearly shows that there are prominent similarities between how $TK_{in\ situ}$ is manifested in mathematics and science classrooms regardless of which DTB that is used.

6.2.2 Differences and subject-specific characteristics

As seen above, a prominent difference lies in teachers' use of tools within the DTB, regardless of which DTB that is used, to differentiate their teaching. In mathematics, access to tasks at various difficulty levels is considered valuable and is regularly used by mathematics teachers to provide individual students with appropriate tasks for the content being taught. In science, on the other hand, teachers highlight other tools for accommodating individual students' needs which are not linked to difficulties understanding the subject content. These tools include options to have the text read or translated, as well as adjusting font-size and other layout elements. Furthermore, the analysis showed that the preferred design of the desired "writing tools" in DTBs differed according to the subject. In mathematics it was considered important to be able to use different representations (e.g., mathematical symbols, graphs, images). Those opportunities were limited in the DTBs, thus the mathematics teachers used paper and pencil to a greater extent. Whereas in science, it was sufficient to use written words. Another difference is the use of statistics generated by the DTB. Teachers in mathematics use data, for example, to see how active students have been during the class and their progress. This information is used, among other purposes, for planning and adapting upcoming lessons. The science teachers did not indicate any use of the statistics provided, nor did it seem that they followed up on individual student responses, despite having collected answers through the DTB. Moreover, it became evident that in mathematics, it was considered valuable that students were promptly informed of the correctness of their answers on specific tasks. This was not the case in science lessons, on the opposite, the teachers wanted to remove the key.

7 Discussion

In this section we discuss how teaching is manifested when digital textbooks are used in mathematics and science classrooms. We discuss the most prominent patterns for how teachers make use of tools in DTBs in relation to different categories of $TK_{in\ situ}$, focusing on the similarities and differences between science and mathematics. These patterns are concluded to not depend on which DTB that was used or which content that was in focus in the classroom. The section ends with the study's conclusions and limitations.

In our study we found that the teachers recognised DTB to offer new ways for students to process the subject content, but we also find subject specific limitations. Teachers use *tools for presentation* so students can experience the subject content in a variety of ways, including for example short, embedded videos. Students also saw potential in DTBs and mentioned for example videos as supportive. The results also show how teachers use *tools for working with text* to let students to process subject content, with making their own glossary as one example. The study's results also show differences between how DTB's are used to process the subject content in mathematics and science. In the mathematics classroom, the teachers did feel that DTB was limiting, and paper and pencil were often used. Processing mathematics digitally presents challenges, as the digital format imposes limitations on how mathematics can be presented, with paper and pencil having a clear advantage. When working with mathematics tasks, students need the opportunity to write both formulas and symbols which was more challenging in the digital format. So, in this case it is not about the fact that the available tools in the DTB had not been noticed by the teachers, as noted in (Grönlund et al., 2018). Instead, it relates to limitations in the DTB. In the science classroom this was not an issue, as this subject is of a different nature and, to a lesser extent, based on being able to represent subject content with the help of calculations, symbols and figures. From this follows that although there are similarities in processing content through writing in both subjects, the approach needs to be subject-specific. This result is supported by results from Jazby et al. (2023) showing that students required different opportunities to represent their thinking depending on whether it was a mathematics or a science lesson. This is important to consider both in the creation of DTBs and in teaching as it affects students' ability to express knowledge and learn. Given this, we assert that different subjects possess distinct characteristics, and therefore that different types of DTBs are necessary to meet these diverse requirements. It is therefore of great importance that the subject's specific character be taken into account in the work of designing and/or choosing DTBs and, by extension, in teaching the students.

Furthermore, we observed that teachers design their teaching and utilise the new possibilities provided by DTB when they find it useful, but also includes other resources when they find it appropriate. In the study, teachers use *teacher tools* to, for example, let students meet the subject content on suitable level in mathematics, and to remove answer key in science. However, the teachers express concerns about not being able to customise the DTB sufficiently. Overall, our results give a picture of that the teachers' conscious selection of resources for both their teaching and for their students' learning from the resources offered in the DTB. As Pepin (2018) states, the final design of teaching arises from a combination of the teacher's didactical choices and the properties that the learning resources offers. In our study, the teachers' instructional designs extend beyond the tools available in the DTB. When teachers encounter limitations in the DTB, they seek additional resources elsewhere, such as YouTube or other visual presentations. Previous research has reported uncertainty among teachers in how to use DTBs (Hutchison, 2012; Reints, 2015), but that is not what was observed here. On the contrary, the teachers in this study express how they choose tools from the DTB and combine them with external resources. We cannot ascertain the reasons behind teachers' choices to use external resources or whether the DTB could offer more in the context of our study. One explanation for the choices made could be that teachers in the study had not detected suitable tools in the DTB, in alignment with the study by (Grönlund et al., 2018). Teachers may choose external resources because they are already familiar and searching for the same functions in the DTB would require additional planning time. Another possible explanation is that the use of DTBs has become more common in recent years, leading to teachers who are more accustomed to their usage and are aware of the limitations associated with DTBs. Our results demonstrate that teachers make deliberate choices based on their knowledge of what DTBs offer, and when necessary, they also turn to other resources. We can also see that teachers' choices vary, in part depending on the subject being taught. Our findings provide insight into teachers' perceived opportunities and limitations of DTBs, demonstrating the understanding that Koehler and Mishra (2009) argue is necessary.

We also find distinctions between the different subjects in how teachers approach planning with a focus on the individual or on the group. In science classrooms, teachers tended to plan at group level, while in mathematics planning was more at individual level. There could be several reasons for this. It could be due to the design of the DTB, differences in curriculum objectives, or individual differences between teachers or classes. But it could also be due to the different nature of the subjects, where individual performance may be more important in mathematics. At the same time, in science, there may be more focus on collaborative learning. However, this was not studied but is something that would be interesting to dig deeper into. The results also showed that differentiation can be based both on the teacher's and the students' actions. The teacher can, as in the mathematics classroom, select tasks for differentiation and also make further adjustments during the lesson by handing out new tasks. Adaptations can also be initiated by the student, who can choose, for example, to listen to the text, to read shorter texts, to change the language and also to ask the teacher for supplementary tasks (in mathematics classrooms). Thus, there is a difference between being a student in the mathematics classroom and in the science classroom. This can be compared to what (Jazby et al., 2023) describe concerning how the design of educational materials can impact what teachers can notice about students' thinking and learning.

Another difference between the subjects is how teachers collect students' answers and track students' progress using *tools for communication*. When working with DTBs, it is possible to gain relatively easy access to statistics concerning students' activities, response rates, etc. The results displayed a significant difference between the subjects, where the mathematics teachers made use of the statistics, on individual or group level, while the science teachers focused on teaching for the whole class and did not make use of the statistics. This difference may partly be due to variations in how work in the classroom is organised. In the science classroom, collaboration is common and different digital resources are used, while in the mathematics classroom individual work dominates and mainly the DTB was used. This is in line with (Jazby et al., 2023) who stated that there was greater focus on concepts during science lessons while mathematics lessons focused more on coming up with the right answer. In our case this can be the reason for the use of *tools for communication* in the different subjects. Again, we can see that the specific nature of the subject affects both teachers and students.

Finally, the results revealed similarities that could be understood as generic, namely that: (1) the teachers guided their students in the DTB; (2) expressed the advantages of using videos or animations and (3) considered hints to be beneficial but desired the option to customise the level of help provided. As a teacher, guiding students through the material, presenting the subject content in different ways and giving just the right number of hints can be seen as universal, regardless of subject. Another similarity concerned writing, namely that all teachers used writing in their teaching as a means for students to process content. The teachers would also like to see this option included in the DTB.

7.1 Limitations

This study is based on qualitative data from a few different classrooms. However, the data is rich as it consists of observations, interviews with teachers, and interviews with students and can be seen as inspired by a case study design. This means that the results are not generalisable with quantitative measures. Instead, in a qualitative study, researchers aim to gain an understanding of a phenomenon, in this case, how DTBs can be used in mathematics and science classrooms. Each classroom is different, with different DTBs, teachers, and students, and the work in each classroom is therefore unique and situated. This means that the results of the study cannot be generalised and applied to all students' work with DTBs. However, the results of this study can provide a certain degree of generality, as work with DTBs in these classrooms, which can be seen as common classrooms, can be given some ecological validity. The study's result thus constitutes a scientific contribution that adds new knowledge to the research field about using DTB in mathematics and science education, both what can be considered subject specific and what may be more generic

8 Conclusions

The study was based on a comparative approach which revealed both similarities and differences between mathematics and science teaching. One conclusion that can be drawn is that the similarities observed could be regarded as generic for the use of digital textbooks, and important regardless of subject. As shown above, although teachers experienced work with DTBs as time-consuming regardless of subject, they recognised the potential of DTBs. The students also spoke positively about DTB's potential as a learning resource. However, the teachers were not willing to delegate full teaching responsibility to the DTB. A conclusion drawn from this is that teachers value their autonomy and ability to maintain control over the teaching process. This suggests that DTBs should be designed to offer versatile learning resources, allowing teachers to utilise DTBs in a variety of ways, and more easily adapt the use of DTBs for different groups of students in favour of all students' learning.

Moreover, the subjects investigated have inherently different characteristics. The previously highlighted differences in how the DTBs are utilised in mathematics and science teaching underscore the importance of including a subject-specific approach when designing and integrating digital resources in teaching. In other words, it emphasises the need for a digital subject-matter knowledge focus. This implies that the design of DTBs should align with a subject-specific content, such as a digital writing area adapted for mathematics. How DTBs can be more subject-specific is a question for further investigations. This becomes particularly important when, as is the case in many Swedish schools, a single teacher is responsible for both mathematics and science. In such instances, the teacher needs to be able to adapt their approach to DTBs for the different subjects to teach in a subject didactically adequate way and thus favour student learning.

Research ethics

Author contributions

H.J.: conceptualization, data curation, investigation, methodology, project administration, writing—original draft preparation, review and editing

A-K.W.: conceptualization, data curation, investigation, methodology, project administration, writing—original draft preparation, review and editing

M.N.: conceptualization, data curation, investigation, methodology, writing—original draft preparation, review and editing

N.E.: conceptualization, data curation, investigation, methodology, writing—original draft preparation, review and editing

All authors have read and agreed to the published version of the manuscript.

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Institutional review board statement

In accordance with the Act concerning ethical review of research in Sweden (The Ethics Review Act SFS 2003:460, 2003[6]), the research has not been subjected to ethical review since this is not required for data of this nature.

Informed consent statement

Informed consent was obtained from all research participants.

Data availability statement

Data is unavailable due to ethical restrictions.

Conflicts of Interest

The authors declare no conflicts of interest.

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