Two models of digitizing mathematics textbooks: Lessons learned and innovative perspectives

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Abstract: *The article presents a comparative analysis of the digitization models applied in the development of digital mathematics textbooks for Grades 5–6 and Grade 9. The study highlights differences in conceptual design, levels of interactivity, content personalization options, and modes of access to digital resources, based on clearly defined pedagogical and technological criteria. The results show that the experience gained at the lower secondary education level provides a valuable framework for improving the pedagogical design of future digital textbooks, particularly by expanding the teacher's role and supporting active learning. Finally, practical recomendations are proposed for the flexible integration of multimedia content and for the development of digital mathematics textbooks with enhanced pedagogical value.*

Keywords: Interactive learning, Digital education, Mathematics textbooks, E-learning, Digital pedagogy, Personalization, Feedback, Educational technology.

1. Introduction

The digitization of teaching-learning processes represents one of the most significant challenges and opportunities in modern mathematics education. In this broader context, school textbooks, as fundamental learning materials, have evolved from printed formats to interactive digital formats that enable the integration of multimedia elements, automated feedback, interactivity, and adaptability to students' learning pace (Hoch et al., 2018).

At the same time, mathematics education pedagogy recognizes the role of the textbook not only as a repository of content, but also as an instrument of curricular change, a means of supporting innovative teaching practices, and a tool for assisting students in constructing understanding (Rezat et al., 2021).

The development of digital textbooks must take into account both the existing technological infrastructure and the digital competences of teachers and students. Textbook architecture, accessibility, and interactivity are key factors influencing learning outcomes. Recent studies indicate that learning mathematics in the digital era involves more than the mere digitization of text; it requires learner-centered pedagogical design, flexible platforms, and the integration of digital resources into the instructional workflow (Weigand et al., 2024).

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Moldova: the research project "Innovation in the Design and Use of Interactive Digital Mathematics Textbooks for Lower Secondary Education" (project code 25.80012.0807.42SE) and the project supported by UNICEF Moldova and the Ministry of Education and Research (UNICEF Moldova & MER, 2025). Within these projects, two complementary directions have been initiated:

1. The digitization of existing mathematics textbooks for Grades 5–6 (Achiri et al., 2020) using the MDIR Constructor software (https://mdir.upsc.md/index.php), installable on the user's device, which provides teacher-users with dedicated tools for adding supplementary digital content tailored to students' needs and to the instructional strategies selected by the teacher;

2. The development of a digital mathematics textbook for Grade 9 using the mAuthor platform (https://www.mauthor.com/), based on the printed textbook currently in use (Achiri et al., 2024), accessible online, and built around a different concept of interactivity and pedagogical use.

This article proposes a comparative analysis of these two approaches, highlighting their advantages, limitations, and innovative directions for future development. The study focused on:

- identifying differences in conceptual design, accessibility, and modes of use;
- evaluating the pedagogical, technological, and design perspectives of each model;
- highlighting the specific advantages of each model, with a particular focus on the Grades 5–6 textbooks, which, although not accessible online, allow teachers to personalize and enrich digital content through additional multimedia elements tailored to students' needs and instructional strategies;
- conducting a detailed analysis of the Grade 9 digital textbook by examining the types of digital activities and actions, and identifying errors, shortcomings, and aspects that can be improved;
- formulating methodological and technical recommendations for the development of future digital textbooks that support learning personalization, interactivity, and effective integration into the educational process.

2. Related work and research background

Over the past decade, research in mathematics education has increasingly focused on the transformation of school textbooks into digital resources, driven by the accelerated digitalization of teaching and learning processes. Studies emphasize that digital textbooks should not be regarded merely as electronic versions of printed materials, but rather as complex curricular resources capable of integrating interactivity, automated feedback, dynamic representations, and mechanisms for personalized learning (Pepin et al., 2017; Rezat et al., 2021; Weigand et al., 2024).

A substantial body of empirical research and theoretical syntheses has examined the impact of digital textbook use on students' mathematics achievement. The meta-analysis conducted by Wijaya and Singh (2022) reports a moderate positive effect of digital textbooks on students' performance, with significant variations depending on the level of interactivity and the pedagogical integration of digital resources. Similar conclusions are drawn in recent systematic reviews, which highlight that the benefits of digital textbooks are most evident when these resources foster active student engagement and provide formative feedback (Alshehri, 2024). At the same time, researchers caution that textbook digitalization does not automatically lead to improved learning outcomes. Studies conducted in diverse educational contexts, including during the COVID-19 pandemic, indicate that the effectiveness of digital textbooks depends on the quality of pedagogical design, teachers' digital competencies, and the available technological infrastructure (Alabdulaziz, 2021). These findings underscore the need to examine the models of textbook digitization that are adopted.

An important line of research concerns the comparison between printed and digital textbooks. Recent studies suggest that the differences between these two types of resources are not solely technological, but also involve significant pedagogical and cognitive implications. Brnic, Greefrath, and Reinhold (2024) show that the use of digital versus printed textbooks can differentially influence problem-solving strategies, depending on the types of activities and the support provided to students. Moreover, analyses of task requirements in digital and printed textbooks reveal changes in task structure and an increased emphasis on visual representations and exploratory approaches (Glasnović Gracin & Krišto, 2022). These results support the idea that digital textbooks can create new learning opportunities, but also introduce new constraints, depending on how they are designed. In this context, examining different digitization models becomes essential for understanding the pedagogical value of digital mathematics textbooks.

The literature also highlights the central role of teachers in the effective use of digital textbooks. Theoretical models and evaluation frameworks proposed by Thomas and Edson (2019) emphasize the need to align mathematics teaching practices with technology use, so that digital textbooks support rather than constrain instructional activities. Empirical studies indicate that teachers who are able to adapt, extend, or configure digital content tend to use digital textbooks in a more flexible and effective manner (Utterberg et al., 2017; Thurm & Barzel, 2020). In contrast, digital textbooks that offer fixed content and limited pedagogical control for teachers may restrict instructional interventions and opportunities for personalization. This distinction is particularly relevant for the analysis of digital mathematics textbooks at the lower secondary level, where the diversity of students' prior knowledge and learning needs requires flexible and adaptable solutions.

Recent research further emphasizes the need for a systemic approach to the design of digital textbooks. Pepin, Gueudet, and Choppin (2024) conceptualize digital textbooks as instruments for transforming educational environments, highlighting the importance of coherence between curriculum, technology, and

teaching practices. Analyses of the quality of digital curricular resources identify criteria such as interactivity, automated feedback, reusability and adaptability of content, as well as integration within broader educational ecosystems (Rezat et al., 2021; Fan et al., 2024). At the same time, exploratory studies on teachers' perspectives regarding digital mathematics textbooks reveal both strengths and limitations, including challenges related to automated assessment and the interpretation of students' problem-solving strategies (Wijaya et al., 2025). These aspects confirm that the chosen digitization model directly influences the pedagogical functionality of a digital textbook.

While existing literature examines the general impact of digital textbooks or explores their use in specific educational contexts, few studies explicitly compare different models of digitizing mathematics textbooks for lower secondary education within the same educational system. The present study contributes to this field through a comparative analysis of two distinct digitization models: (a) an extensible and customizable model that allows for content adaptation and pedagogical intervention by teachers, and (b) a model based on the complete digitization of the printed textbook, characterized by a high level of control over structure and content. The analysis focuses on the pedagogical implications of interactivity level, teacher agency, and the flexibility of digital content.

This gap is particularly evident in national-level initiatives, where different digitization models are often implemented in parallel without systematic comparison.

3. Methodology

The study employed a qualitative, reflective approach based on systematic reflective analysis informed by direct professional expertise, which allowed for a detailed analysis of digital textbook prototypes and usage practices, as well as the identification of errors, limitations, and opportunities for improvement.

The sources analyzed included: digital textbook prototypes for Grades 5–6 and Grade 9; evaluation sheets completed by teachers and feedback from the testing process; direct observations of students' and teachers' interactions with the digital textbooks; design documentation; and the digital tools provided to teachers for supplementing and personalizing content. Together, these sources enabled a triangulated analysis of both the design features and the pedagogical use of the digital textbooks across the two digitization models. The main criteria used to evaluate the digital textbooks were:

1. *Level of interactivity* – the extent to which the textbook enabled students to actively participate in the learning process through digital activities;
2. *Accessibility* – online/offline availability and compatibility with different devices;
3. *Content flexibility* – the possibility of adapting lessons and activities to students' levels and needs;

4. *Possibility of adding new resources* – the tools provided to teachers for supplementing the digital content with additional multimedia;
5. *Technological compatibility* – stable performance and integration of the digital platforms used;
6. *Degree of pedagogical support for teachers* – guides, instructions, and digital tools that facilitated lesson planning and delivery.

The criteria selected for the analysis of digital textbooks were chosen in accordance with scientific recommendations from the specialized literature. In particular, they align with the dimensions of the 4A framework - Accessibility, Active engagement, Advocacy for inclusion, Accountability (Hoch et al., 2018) - and with validated criteria for evaluating digital educational resources (Weigand et al., 2024; Rezat et al., 2021). This alignment ensured that the selected criteria were suitable for distinguishing between different models of textbook digitization rather than merely comparing isolated digital features.

Within the analysis, the main criteria were further specified through operational indicators, such as the type of digitization, automated feedback, visualization of the solution process, and handling of equivalent responses, in order to more accurately reflect the functional characteristics of the textbooks. This operationalization enabled a clear comparative presentation of the results, supporting the interpretation of differences between digitization models and the identification of the pedagogical strengths and limitations associated with each approach.

4. Theoretical and conceptual framework

In recent decades, the integration of technology in mathematics education has become a central focus of educational research, as digital resources increasingly replace printed textbooks and expand learning opportunities. Digital textbooks, defined as electronic resources that include text, multimedia, interactivity, and automated assessment, are not merely electronic versions of printed materials. They constitute complex learning environments that can support active and personalized learning (Ferme, 2025).

The literature highlights that textbook digitization should go beyond the mere replication of printed pages and leverage the advantages of the digital medium: interactivity, immediate feedback, dynamic representations of mathematical concepts, and adaptability to students' learning pace (Rezat, 2021; Braicov, 2025). In this sense, digital textbooks can become pedagogical tools that facilitate not only content delivery but also students' active cognitive engagement, self-assessment, and the consolidation of understanding through activities specifically designed for online or hybrid environments.

One key aspect identified is the role of automated feedback in the learning process. Unlike printed textbooks, where students receive corrections after the fact, digital resources can provide immediate feedback on calculation tasks or concept exploration, supporting conceptual development and self-regulated learning (Rezat et al., 2021). This feature is considered a differentiating element and, in certain

contexts, an indicator of the pedagogical quality of digital textbooks. However, it should be noted that the design of digital textbooks is still in a transitional phase: many digital resources replicate the static format of printed textbooks without fully exploiting the pedagogical potential of interactivity and personalization. For example, digital exercises may exist in simple or multimedia forms, but not all digital textbooks include sophisticated mechanisms for random data generation, formative assessment, or tools that allow teachers to create new activities.

Analysis of international practices also shows that integrating digital resources into the curriculum involves both technology and a shift in the teacher's role. Regarding the use of digital textbooks in teaching mathematics and sciences, teachers have observed that despite the advantages offered by videos or animations for concept visualization, translating mathematics into a digital format remains challenging, and the use of digital textbooks in instruction depends on teachers' digital competences and the structure of learning activities (Johansson et al., 2024).

In the context of developing digital textbooks for lower secondary education, these findings suggest two complementary perspectives on digitization:

- On one hand, a faithful digital rendition of the printed textbook, which has been previously reviewed and validated, preserving all curriculum-approved tasks and activities. This approach provides both teachers and students with continuity with the printed material and ensures full curriculum coverage, but it risks remaining a static replica if the dynamic features of the technology are not sufficiently leveraged.
- On the other hand, the design of digital textbooks as extended interactive environments, allowing for the addition of cloned tasks, automatic generation of exercises, integration of multimedia resources, and content personalization. This approach aligns more closely with the requirements of modern digital pedagogy and with research-based orientations on technology-assisted learning (Ferme, 2025).

Therefore, the theoretical framework of this study assumes that digital textbooks should be viewed as interactive educational environments capable of supporting active learning, immediate feedback, and adaptation to individual student needs. This perspective forms the basis for the comparative analysis of the digitization models examined in this article and provides a foundation for recommendations for future digital mathematics textbook projects.

5. Results and analysis

It should be noted that the mathematics textbooks for Grades 5 and 6 were digitized using the *MDIR Constructor* platform (https://mdir.upsc.md/index.php), while the Grade 9 mathematics textbook was digitized using the *mAuthor* platform (https://www.mauthor.com/). All three textbooks are based on the PDF versions of the mathematics textbooks currently in use (figure 1), approved by the Ministry of Education and Research (MER).

The *MDIR Constructor* application (developed by Balmuș et al., 2024) uploads the PDF file and adds interactivity, automated feedback, and multimedia elements, thus providing a primary version of the digital textbook. The teacher-user, using the same MDIR Constructor application installed on their computer, can supplement the primary digital textbook with additional multimedia elements (videos, new items, etc.) to create a personalized version, which can then be used during lessons and shared with students. The digital mathematics textbooks for Grades 5 and 6, created with MDIR Constructor, do not include all exercises and problems from the original PDF textbook; however, they contain additional tasks, exercises, and problems digitized by the teacher-user, adapted to their own teaching experience.

The *mAuthor* platform offers a wide range of tools for creating online-accessible digital textbooks via a user account. The Grade 9 digital mathematics textbook, created with mAuthor, corresponds to the PDF version of the textbook currently in use, in which all exercises and problems have been digitized. However, it does not include additional tasks, exercises, or problems beyond those present in the original PDF.

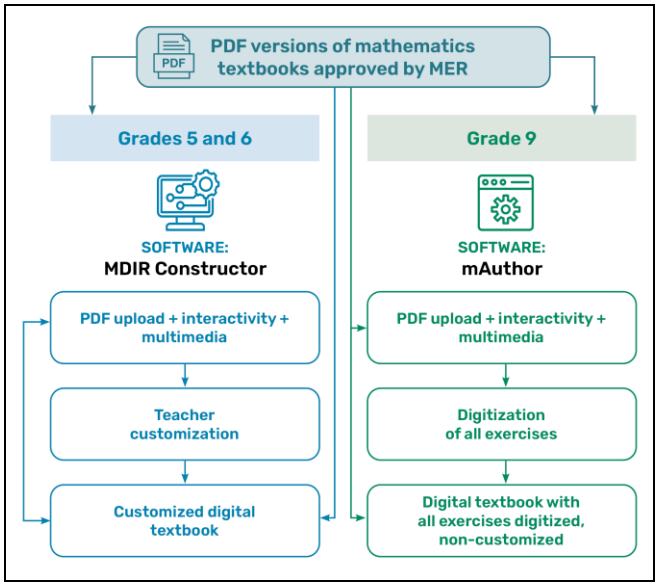

Figure 1. The two models of mathematics textbook digitization

The comparative analysis focused on two distinct models of digitizing mathematics textbooks for lower secondary education: the digital textbooks for Grades 5–6 and the digital textbook for Grade 9. The results were obtained by examining the types of digital activities implemented, the functionalities provided to students and teachers, and the limitations identified during usage. To provide a structured overview of these findings, Table 1 presents a comparative analysis of the two digitization models based on the criteria established in the study methodology.

5.1 Results of the analysis of digital mathematics textbooks for Grades 5 – 6

These digital textbooks incorporated a series of interactive tasks, selected and adapted according to the mathematical content addressed at this level (Figures 2 and 3).

The digitization process did not involve a complete replication of all tasks from the printed textbooks but focused on integrating didactically relevant digital activities, complemented by additional tasks.

Interactive activities included exercises with instant automated feedback, tasks with variable data, the possibility of generating multiple versions of the same type of exercise, and activities designed for learning, assessment, and self-assessment.

An important finding of the analysis was that the digital textbooks for Grades 5–6 provided teachers with tools that allowed them to add new digital content, modify existing tasks, and adapt them to the students' level and learning pace.

These functionalities enabled flexible use of the digital textbook, both within regular instructional activities and in formative assessment contexts.

The analysis also highlighted certain limitations in the use of the digital textbooks for Grades 5–6, primarily related to accessibility. Since the installable model required initial configuration on users' devices, it limited usage in contexts that required quick online access.

Furthermore, the full utilization of content expansion and personalization features largely depended on the teacher's digital competencies and the time available for designing and adapting interactive tasks.

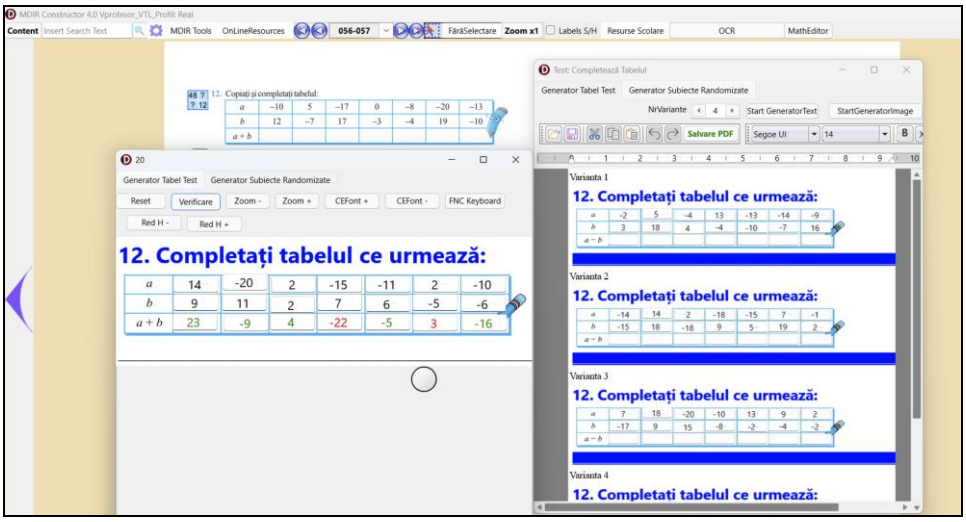

Figure 2. Teacher editing mode in the Grade 6 digital mathematics textbook

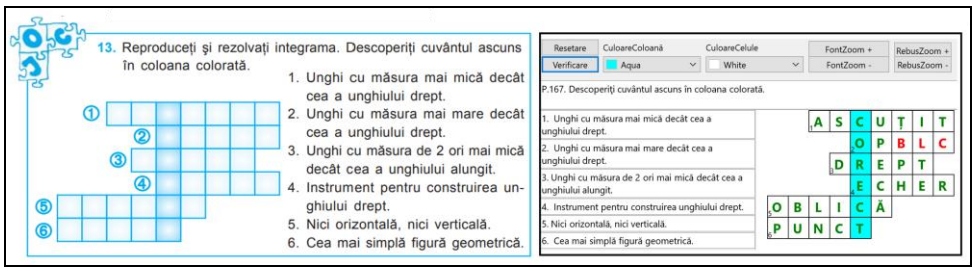

Figure 3. Digitally implemented crosswords in the Grade 5 mathematics textbook

5.2. Results of the analysis of the Grade 9 digital mathematics textbook prototype

The Grade 9 digital textbook prototype was created by digitizing all tasks and activities present in the printed textbook currently in use and aproved by MER. The digital activities included filling in answer boxes, selecting the correct answer from a set of values, creating graphs, manipulating geometric solids through rotation (Figure 4), as well as open-ended items intended for teacher assessment.

For certain tasks, the digital textbook allows students to record their answers vocally, with audio files that can be downloaded and subsequently submitted to the teacher. Additionally, students can reset the task lists, enabling them to redo activities without being constrained by previously entered answers.

For open-ended items, assessment is not automated and is the responsibility of the teacher. For tasks with automated evaluation, the system checks the correctness of students' responses against predefined solutions.

The analysis revealed several limitations associated with the digitization model of the Grade 9 textbook. One limitation concerns the teacher's restricted ability to view the complete process of problem solving by the student, as only the final answer is available (Figure 5). This limitation reduces the opportunity to analyze the strategies employed by students. There were also cases in which the automated evaluation marked mathematically equivalent answers as incorrect when they were entered in a different order than predefined (for example, in equations with multiple solutions). Another limitation is that the Grade 9 digital textbook provides exclusively the tasks included in the printed version, without allowing the teacher to add or modify digital content.

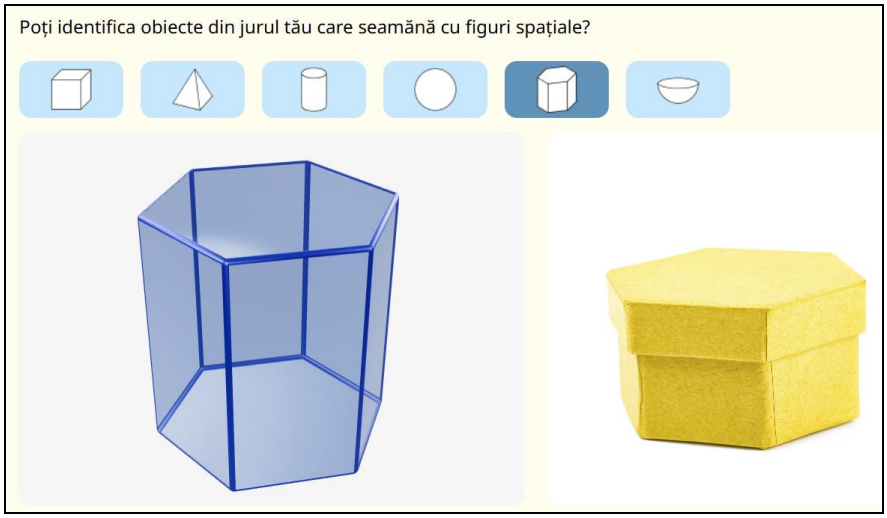

Figure 4. Digitally implemented polyhedra in the Grade 9 mathematics *textbook*

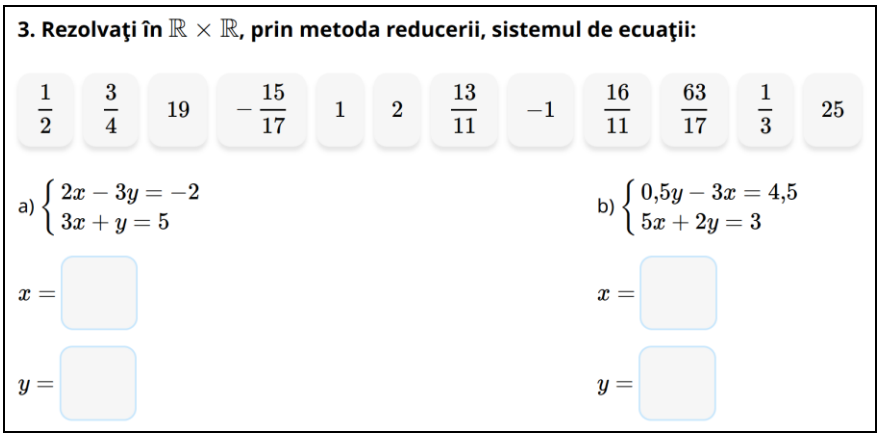

Figure 5. Digitally implemented system of equations in the Grade 9 mathematics textbook

5.3. Comparative summary of the results of the two analyses

To synthesize the obtained results, Table 1 presents a comparative analysis of the two digitization models based on the criteria established in the study methodology.

Table 1. Comparative analysis of mathematics textbook digitization models

Main criterion	**Indicator**	**Digital textbooks for Grades 5–6**	**Digital textbook for Grade 9**
Level of interactivity	Types of interactive activities	Exercises with automated feedback, tasks with variable data, extended activities	Fill-in, multiple choice, graphs, geometric manipulations, open-ended

			items
Accessibility	Availability	Installable model (offline)	Online access via browser
Content flexibility	Adaptation of lessons and activities	High; the teacher can modify and add tasks	Low; fixed content
Possibility of adding new resources	Multimedia, new tasks	Yes; the teacher can integrate videos, interactive exercises, and evaluation sheets	No
Technological compatibility	Stable performance, platform integration	Stable operation on specific devices	Stable online operation
Degree of pedagogical support	Teacher's role	Teacher as configurator and facilitator	Teacher as evaluator
Automated feedback	Availability and type	Most tasks	Only for certain types of tasks
Visualization of solution process	Monitoring students' steps	Possible, depending on configuration	Limited to the final answer
Handling of equivalent answers	Accuracy of assessment	Configurable	Misinterpretation may occur

6. Discussion

The results of the comparative analysis highlight that the digitization of mathematics textbooks is not a uniform process, but can be implemented through different models with distinct pedagogical implications. The differences observed between the digital textbooks for Grades 5–6 and the Grade 9 digital textbook reflect varying choices regarding the role of the digital textbook in the teaching–learning process and the degree of autonomy granted to the teacher.

6.1. Full digitization versus extensible digitization

The model applied to the Grade 9 digital textbook aimed at full digitization of the existing content in the printed textbook, providing students with the possibility to complete all tasks within a coherent and unified digital environment. This approach ensures curriculum continuity and a direct correspondence between the printed and digital versions, facilitating the use of the textbook in diverse educational contexts.

In contrast, the digital textbooks for Grades 5–6 were designed according to an extensible model, in which selective digitization was complemented by additional interactive activities and the possibility for teachers to extend the content. This difference suggests two distinct perspectives on the digital textbook: one focused on faithful reproduction of existing content, and the other oriented towards adaptation, personalization, and pedagogical reuse.

The literature emphasizes that the pedagogical value of digital textbooks is not determined solely by the degree of digitization of the content, but by the way they support teaching practices and active learning (Weigand et al., 2024; Rezat, 2021).

6.2. Teacher role and pedagogical control

A central element in this discussion is the role of the teacher in using digital textbooks. In the case of the Grade 9 textbook, the teacher primarily acted as an evaluator of student responses and a user of a predefined set of tasks. The lack of access to the students' problem-solving process and the impossibility of modifying or extending the content limited real-time pedagogical intervention and adaptation of tasks to students' specific needs.

In contrast, the digital textbooks for Grades 5–6 allowed teachers to directly intervene in the digital content, add new tasks, and configure differentiated activities. This feature aligns with current perspectives on digital textbooks as tools of pedagogical mediation rather than merely content delivery supports (Rezat et al., 2021).

These results suggest that the degree of pedagogical control afforded to the teacher is an essential criterion in evaluating the effectiveness of a digital mathematics textbook.

6.3. Automated feedback and the limits of digital assessment

The analysis showed that automated feedback was implemented differently across the two models. In the textbooks for Grades 5 – 6, feedback was extensively used for learning, assessment, and self-assessment activities, supporting repeated practice and consolidation of basic skills. In the Grade 9 textbook, automated feedback was available only for certain task types, while the assessment of open-ended items remained the responsibility of the teacher.

The limitations identified in the automatic evaluation of equivalent responses highlight a recurring issue in the literature, namely the difficulty of digital systems to correctly interpret the diversity of students' mathematical strategies (Rezat et al., 2021). These findings confirm the need to combine automated assessment with human evaluation, especially for tasks that require reasoning and argumentation.

6.4. Accessibility, flexibility, and sustainability

Another important aspect concerns the accessibility of digital textbooks. While the Grade 9 textbook was accessible online, facilitating rapid use and broad distribution, the installable model for Grades 5–6 posed certain logistical constraints. However, the results suggest that online accessibility alone does not guarantee more effective pedagogical integration.

Content flexibility and the possibility of personalization proved to be at least as important as online access, particularly in educational contexts characterized by

diversity in student preparedness and available technological infrastructure. This observation aligns with recent studies on mathematics teaching in the digital era (Weigand et al., 2024).

6.5. Implications for future digital textbook design

Overall, the discussions derived from this analysis indicate that the design of digital mathematics textbooks should go beyond the mere transfer of printed textbooks into digital format. High-pedagogical-value digital textbooks are those that provide teachers with tools for adapting, extending, and configuring content, support formative feedback, and allow flexible integration into teaching strategies.

The results support the idea that a digitization model focused on flexibility and personalization, even if not exclusively online, can offer significant pedagogical advantages and contribute to more effective use of the digital textbook in the educational process.

7. Conclusions

The comparative analysis highlighted fundamental differences between two models of digitizing mathematics textbooks: the digital textbooks for Grades 5–6, based on an extensible and customizable model, and the Grade 9 digital textbook, created through full digitization of the printed textbook. The results indicate that, although online accessibility facilitates rapid use and broad distribution, content flexibility and the ability to personalize tasks are essential factors for the pedagogical effectiveness of digital textbooks.

The Grades 5–6 textbooks demonstrated high potential for supporting active learning, instant feedback, and adaptation of content to students' individual needs, due to the tools provided to teachers for adding and modifying digital resources. In contrast, the model applied to the Grade 9 textbook ensures curriculum continuity and faithful reproduction of printed tasks, but limits pedagogical intervention and content flexibility. The qualitative nature of the study and its focus on two national projects constitute limitations that should be addressed in future research.

These findings suggest that future models of mathematics textbook digitization should combine online accessibility with tools for personalization and configuration provided to teachers, in order to maximize pedagogical impact. Furthermore, the continued development of software for creating interactive digital textbooks, with support for automated feedback, formative assessment, and random task generation, represents a priority direction for future projects in this field. Thus, the experience accumulated in lower secondary education can provide a valuable framework for designing digital textbooks for higher grades and for promoting active learning.

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