

Pre-service Teachers' Perceptions of Instructional Design for Early Childhood Mathematics: Navigating an Authoring Tool

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Abstract

This study examines pre-service early childhood teachers' (PSTs) perceptions of a training program designed to integrate technology into mathematics planning through the authoring tool *JClic*. Data from 24 participants were collected through open-ended questions and analysed thematically to identify perceived advantages and barriers during the instructional design process. Participants reported increased confidence and identified skills they believed would support future practice; specifically, they highlighted the benefits of using varied representations, the tool's flexibility in task design, and its potential for student learning control. However, the significant effort required to master the tool's complexity tempered some adoption intentions. Nevertheless, even with this perceived difficulty, the pedagogical quality of the final designs was generally satisfactory, suggesting that PSTs were able to manage technical friction to develop appropriate mathematical tasks. These findings indicate that while the training successfully enabled participants to overcome the initial learning curve and produce quality work, the high technical demand remains a deterrent for spontaneous future use. To enhance future practice, teacher education programs must better address the challenges of technology integration by prioritising intuitive tools that ensure technical mastery does not overshadow pedagogical objectives.

Introduction

Given the growing presence of technology, several studies argue that a key goal of early childhood education is to help children develop the skills needed to navigate a digital society (Mertala, 2019). In many countries, curricula have long emphasised the need to prepare children for a complex technological world (Plowman & Stephen, 2003), and organisations like the OECD recommend integrating technology from early education. Some studies show that teachers often perceive children as naturally skilled with technology, viewing it as a tool that can support learning (Lindahl & Folkesson, 2012). While some remain sceptical, many recognise the importance of familiarising students with digital environments for future academic and professional contexts (Ottenbreit-Leftwich et al., 2010).

In the context of mathematics education, the integration of technology has been endorsed by organisations like the National Council of Teachers of Mathematics (NCTM) since 1989, advocating its role in enhancing understanding through multiple representations (Pierce & Stacey, 2010). As Gejdošová and Velmovská (2024) pointed out, lesson

planning is an integral part of the teaching profession, and lesson preparation is one of the primary tasks of a teacher. Thus, this study explores how pre-service early childhood teachers perceive the integration of technology into mathematics instruction during the planning phase.

To address this, we selected *JClic*, a free educational software for designing interactive multimedia tasks. Ríos Anciani (2020) indicated that *JClic* is a highly versatile tool for improving pedagogical practices. Furthermore, León Trujillo et al. (2022) concluded that its application significantly increased academic performance and user satisfaction. While research in language arts shows increased motivation (Nuñez D'Aversa, 2019; Stelea & Girón-García, 2017), its application in mathematics is particularly promising. Recent findings (Gavilán-Izquierdo & Gallego-Sánchez, 2025) indicate that using *JClic* for instructional planning is fruitful for fostering mathematical representations and reasoning processes, such as defining and modelling, which are crucial aspects of mathematical learning (Njiku, 2024).

Literature Review

Benefits and Specific Impacts of Technology in Early Mathematics

Technology can boost student motivation, engagement, and creativity (Islam & Grönlund, 2016). For students with special educational needs, it facilitates content visualisation (Emre, 2019). However, recent research emphasises that technology is most effective when tied to specific mathematical outcomes. Meta-analyses show that digital tools, such as educational robotics and touchscreens, significantly improve early computational thinking and mathematical learning when they are grounded in pedagogical frameworks (Alonso-García, Fuentes, Navas-Parejo, & Victoria-Maldonado, 2024; Taheryan & Song, 2025).

In the case of educational robotics, Alonso-García et al. (2024) reported a substantial positive impact on young students, finding a large effect size ($SMD = 0.93$). This success, however, is not automatic; it depends on a structured three-phase approach where children first learn the theory, then familiarise themselves with the robot, and finally solve problems. The study also highlights the critical role of ‘scaffolding’—intentional teacher support—which helps bridge learning gaps for students from diverse socioeconomic backgrounds. When these conditions are met, robotics effectively helps children develop a more robust sense of numbers and spatial reasoning.

Complementing these findings, a large-scale analysis of touchscreens by Taheryan and Song (2025) found a moderate positive effect ($d = 0.48$) on children aged 2 to 8, with the strongest results appearing specifically in mathematics ($d = 0.56$). These devices are most effective when they provide ‘Augmentation’—where the technology does not merely substitute paper-based tasks but adds new functional features that enhance the learning experience. The researchers also noted that ‘edutainment’ (games combining education and entertainment) sustains higher student motivation. Crucially, the role of the adult must be balanced: while moderate feedback is highly effective ($d = 0.61$), excessive intervention can decrease a child’s independence and overall learning success.

Theoretical Framework: The TPACK Model

The Technological Pedagogical Content Knowledge (TPACK) framework provides a comprehensive model for understanding the knowledge required by teachers for effective technology integration (Mishra & Koehler, 2006). This model is built upon three core domains: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). While the interaction between these domains creates specialised intersections, such as Technological Pedagogical Knowledge (TPK) and Technological Content Knowledge (TCK), the ultimate goal is to achieve a harmonious integration of all domains. This total convergence represents the most advanced level of competence, enabling an understanding of how technology can transform and enhance specific teaching and learning processes in a situated manner.

For pre-service teachers, developing TPACK is essential during the planning phase, as it allows them to identify how specific digital tools can represent mathematical concepts. As noted by Baldinger et al. (2026), although the benefits of digital resources are known, there is a lack of research on teachers' specific perceptions and needs regarding their integration into mathematics lessons. These authors argue that further research is necessary in this area because 'teachers serve as the primary decision-makers regarding the adoption of resources' (Baldinger et al., 2026, p. 1).

Teachers' Perceptions and Training

In light of these needs, teacher preparation programs play a crucial role in shaping future educators' ability and willingness to integrate technology effectively. Beyond providing explicit instruction—a systematic approach of modelling and guided practice that shifts beliefs positively (Rehmat & Bailey, 2014)—these programs must actively encourage PSTs to apply digital practices in their future classrooms. As Lim et al. (2024) argue, it is essential to understand how PSTs experience this training and how these programs can support the specific pedagogical skills needed for the unique context of preschool-aged children. Gathering the perceptions of PSTs at the end of training helps tailor interventions to promote more effective ICT integration (Anwar et al., 2024; Liu & Pange, 2015). Furthermore, the success of such training relies on how participants apply this knowledge during the design of learning environments (Fan et al., 2023), as gaps in TPACK and ICT attitudes remain a significant challenge (Li, 2023).

Given the critical role of teacher decision-making and the specific pedagogical conditions required for effective technology integration, it is vital to understand how future educators perceive their own preparation. Specifically, the research question we have addressed in this study is: *What were the perceptions of pre-service Early Childhood teachers regarding the use of JCllic as a tool for planning mathematics teaching?* This general research question is further refined into two sub-questions:

- RQ1: *What advantages did pre-service early childhood teachers perceive in using JCllic for mathematics education?*
- RQ2: *What disadvantages or barriers did pre-service early childhood teachers perceive when using JCllic in their planning?*

The response to RQ1 will allow us to identify which affordances and benefits of the tool are consciously recognised by the participants, and therefore are likely to be integrated into their future teaching practice. The response to RQ2 will enable us to identify the specific barriers the participants face when using this technology, providing essential data

to inform potential improvements to the training course and the selection of digital resources.

Methods

Context

The study was conducted within a fourth-year unit of the Early Childhood Education degree at a large Spanish university. The course focuses on the design and use of mathematics teaching resources for early education. Students had previously completed curriculum on mathematical content and pedagogy, including modes of representation (Lesh et al., 1987), the classification of arithmetic problems, and Van Hiele's (1986) levels of geometric reasoning. Regarding digital competence, participants had previously completed a general 'ICT in Education' course covering tools such as online discussion forums, Canva, and Kahoot. However, none of the participants had prior experience with *JClic*, ensuring a level playing field for the specific technical intervention of this study.

The course implemented a training program based on the TPACK framework (Mishra & Koehler, 2006) to support technology integration. It required PSTs to integrate their Content Knowledge (mathematics) and Pedagogical Knowledge (e.g., Van Hiele's levels) with Technological Knowledge (*JClic* authoring). The assignments specifically targeted the TPACK intersection, as students had to reflect on how technological features (e.g., immediate feedback, visual manipulation) could support specific mathematical learning objectives.

Pre-service teachers (PSTs) worked in self-selected groups (3 to 5 members) to design two Hypothetical Learning Trajectories (HLTs)—one in arithmetic and one in geometry—over a 15-week period. Each HLT included objectives, tasks, and hypotheses about students' learning processes (Simon, 1995). The task was structured around Hypothetical Learning Trajectories (HLT) to ensure that the use of technology was driven by specific learning goals rather than technical novelty, requiring students to anticipate children's thinking processes (Simon, 1995). A collaborative approach was chosen to simulate professional departmental planning, fostering peer-learning and negotiation. This structure allowed PSTs to debate pedagogical decisions and share the technical workload of designing multimedia resources. All the activities were created using *JClic*. A key technical distinction of this tool is that while the design and creation of activities must be performed on a computer, the resulting interactive tasks are cross-platform; they can be accessed and solved by children not only on computers but also on mobile devices such as tablets and smartphones.

Although *JClic* presents a dated interface compared to modern apps, it was selected for three strategic reasons. First, it ensures ecological validity and sustainability, as it is free, open-source, and supported by an official centralised repository ('Zona Clic') which hosts thousands of teacher-created resources (<https://clic.xtec.cat/>). Second, it functions as an authoring tool, compelling PSTs to actively design tasks rather than passively consuming content. Specifically, the software allows authors to configure performance parameters (e.g., time limits, number of attempts, scoring) and provides immediate automated feedback, features that PSTs were required to integrate into their pedagogical planning. Finally, the tool is supported by a vast ecosystem of external tutorials (e.g., YouTube), which facilitates autonomous technical scaffolding for novices. Groups presented and discussed their trajectories with peers and the instructor.

The pedagogical quality of the designed HLTs was assessed following the training period, with the group achieving a strong overall performance ($Mean = 8.5$). Analysis of the final products revealed that PSTs effectively integrated multiple modes of representation and geometric reasoning processes in the designed tasks (Gavilán-Izquierdo & Gallego-Sánchez, 2025; see Appendix 3 for excerpts from an HLT designed by the participants); nonetheless, some difficulties were observed regarding the precise sequencing of activities according to Van Hiele's levels of geometric reasoning. Figure 1 shows an example of a geometry task designed by participants.



Figure 1. Example of a task created with *JClíc* by study participants. The central instruction reads ‘Une las figuras con los objetos semejantes’ [Match the shapes with similar objects]. The bottom toolbar supports autonomous learning: (Left) Navigation arrows (sequence), Green Flag (shuffle), and Help buttons (‘?’ for text, ‘i’ for video) to scaffold the task; (Right) Real-time performance metrics: ‘aciertos’ [hits], ‘intentos’ [attempts], and ‘tiempo’ [time].

Participants and Ethics

Twenty-eight PSTs participated in the training experience, organised into eight groups of 3 to 5 students each. For analysis, data from 24 students (S1–S24) were used; the remaining four were excluded due to incidental absence on the day of data collection. We consider the final sample to be fully representative of the original cohort, as the absentees shared the same demographic profile and training. Participants were typically aged between 21 and 22 years old, corresponding to the standard progression of the degree, with the sample being exclusively female ($N=24$). They generally reported moderate prior experience with general ICT tools but were novices regarding the specific authoring tool used. Practicum placements were located in primarily urban contexts, reflecting the university's school network.

This study complies with institutional guidelines and the Declaration of Helsinki. Data were processed anonymously, and all participants provided written informed consent.

Data Collection

Data were collected via an individual open-ended questionnaire administered during class with a time limit of 30 minutes. The instrument included two prompts designed to capture perceptions of the training experience (presented here in the original Spanish and English translation):

Indique cuáles son las ventajas y dificultades del uso que se ha dado a JClic como herramienta [*Indicate the advantages and difficulties of using JClic as a tool*]

- a) Ventajas (potencialidades) [*Advantages (potentialities)*]
- b) Dificultades [*Difficulties*]

This focus aligned with the aim of exploring perceptions of technology integration. Responses referring to difficulties were categorised according to Ertmer's (1999) first- and second-order barriers.

Data were collected in Spanish. Representative quotes included in this manuscript were translated using a combined approach (AI-supported translation reviewed by the authors) and finally verified by a proficient English speaker to ensure conceptual equivalence rather than a literal word-for-word translation.

Data Analysis

Unit of Analysis

The unit of analysis was the 'meaning unit' (or item-level segment). Narrative responses were segmented into conceptually coherent units (see Appendix 1 for examples of item codification). When participants produced multiple items, these were coded independently while retaining participant identifiers to account for within-participant clustering.

Data Coding and Analysis

Inductive thematic analysis (Braun & Clarke, 2006) was used because it allows patterns and themes to emerge directly from the data, making it appropriate for exploratory work and for capturing participants' authentic perspectives on technology use (see Appendix 2 for the inductive thematic analysis codebook). To provide greater theoretical depth, the emergent codes were mapped onto the subdomains of the TPACK framework (Mishra & Koehler, 2006). This secondary categorisation allowed us to align the participants' perceptions with Technological, Pedagogical, and Content Knowledge, as well as their intersections (e.g., TPK, TCK). The specific justification for the classification of each subdomain is presented alongside the findings in the Results section. All data were independently coded by two researchers (Gavilán-Izquierdo, J. M., Professor and PhD and researcher in Mathematics Education, and Gallego-Sánchez, I. Associate Professor with a PhD in Applied Mathematics and researcher in Mathematics Education).

The analysis proceeded through three stages. First, open coding was used to identify salient concepts across all items. Second, axial coding grouped related codes into broader categories by examining conceptual links and co-occurrences. Finally, theme development involved integrating these categories into higher-level themes linked to the TPACK framework dimensions.

Interrater agreement was assessed using Cohen's kappa ($\kappa = 0.82$), indicating substantial agreement. Discrepancies were resolved through consensus meetings. Saturation was operationalised through sequential review of all data. After each coding iteration, emergent segments were compared with the existing coding framework. Given the dataset size, we describe the results as 'themes prevalent across participants' rather than claiming full theoretical saturation.

Results

Positively Valued Aspects

Table 1 presents the positive themes, item frequencies, and their TPACK classification. Participants primarily emphasised the pedagogical and curricular possibilities of the tool. The most frequent theme, *Fosters Student Learning* (46 items, mentioned by 19/24 students), highlights the software's capacity to support motivation (PK) and diverse learning needs (TPK). Building upon this, the *Flexibility of the Software* (42 items, 18/24 students) was highlighted, with the creation of customised activities identified as a core strength, reflecting a high level of TPACK integration.

Notably, *Curricular Potential* (22 items) and the *Training Program Assessment* (6 items) were categorised under the central TPACK domain. This suggests that despite being pre-service teachers, participants were able to understand how the software (Technology) can be specifically aligned with mathematics concepts (Content) using appropriate instructional strategies (Pedagogy). Technical aspects such as *Accessibility* (10 items) were less prominent, indicating a focus on educational application rather than mere operation.

Note on TPACK Analysis

The categorization of codes within the TPACK framework is based on the specific intersection of knowledge required to leverage the described advantages. *Curricular Potential*, the creation of customised activities (from *Flexibility of the Software*), and the *Training Program Assessment* are assigned to the central TPACK domain. These codes represent the highest level of integration, where the teacher understands how the software (Technology) can be specifically tailored to teach mathematical concepts (Content) using appropriate instructional strategies (Pedagogy) for different developmental levels. Other codes within *Flexibility of the Software*, such as those regarding the variety of task types, are classified as TCK, as they focus on how technological features structure and represent specific content. The theme *Fosters Student Learning*—specifically regarding special needs and learning control—and *General Evaluation/Suitability* fall under TPK, as they describe using technology to support general pedagogical strategies and classroom management, independent of specific subject matter. Finally, *Motivation* is categorised as PK, representing fundamental pedagogical knowledge about student engagement, while *Accessibility and Usability* is labelled as TK, referring strictly to technical knowledge of the hardware and software interface.

Table 1. Summary of themes, codes, and representative items related to the perceived advantages of *JClic*, classified by TPACK subdomain.

THEME	CODES ASSOCIATED	SAMPLE ITEM (ONE FOR EACH THEME)	Freq. (items)	Freq. (students)	TPACK subdomain
CURRICULAR POTENTIAL	Possibility of working on a variety of mathematical content	<i>“JClic is a tool that can be used to work on various subjects or content”</i> (S24)	22/135	16/24	TPACK
	Can be used at different educational levels				TPACK
	Allows working on any subject				TPACK
FLEXIBILITY OF THE SOFTWARE IN ACTIVITY DESIGN	Creation of customised activities	<i>“It allows for varying the level of difficulty, which is good for using with both younger and older children”</i> (S19)	42/135	18/24	TPACK
	Variety of options in tasks (use of different modes of representation, help...)				TCK
	Variety of types of tasks				TCK
FOSTERS STUDENT LEARNING	Motivation	<i>“It’s a resource that can spark interest in children and increase</i>	46/135	19/24	PK

THEME	CODES ASSOCIATED	SAMPLE ITEM (ONE FOR EACH THEME)	Freq. (items)	Freq. (students)	TPACK subdomain
	Attention to special educational needs	<i>their motivation to learn, as it's very dynamic" (S3)</i>			TPK
	Student learning control				TPK
ACCESSIBILITY AND USABILITY	Accessibility	<i>"It is available to anyone with a computer." (S18)</i>	10/135	9/24	TK
	Easy to handle (for teachers and students)				TK
GENERAL EVALUATION / SUITABILITY	Suitable software for introducing ICT in preschool education	<i>"Introduce students to the use of ICT" (S9)</i>	9/135	8/24	TPK
TRAINING PROGRAM ASSESSMENT	Advantageous aspects of the training program	<i>"Not only have we learned an application... but we have also reasoned and argued how preschool students acquire knowledge" (S7)</i>	6/135	4/24	TPACK

Note. N = 24. 'Items' refers to individual meaning units coded from the participants' narratives. See more examples of items in the Appendix 2. 'Freq. (Items); indicates the relative frequency of mentions (reflecting the volume or intensity of the theme), while 'Freq. (students)' indicates the number of distinct individuals who addressed the theme. All participant quotes have been translated from Spanish by the authors.

Negatively Valued Aspects

Difficulties were reported less frequently (45 items), yet they point to specific barriers in implementation (see Table 2). Unlike the positive aspects, which were pedagogically focused, the primary difficulties were rooted in Technological Knowledge (TK) limitations. *Technical Aspects of the Software* (17 items) was the most cited barrier (14/24 students), referring to outdated interfaces and management issues (aligning with Ertmer's first-order barriers).

Pedagogical barriers were also noted under *Learning the Software for Task Design* (13 items, 13/24 students), classified as TPK. This highlights the friction teachers experience when trying to master the technology for instructional design (a first-order barrier related to the time and skill acquisition required for novice users). In contrast, a minority of participants (6/24) noted that the tool could *Hinder Student Learning* (TPK) by limiting collaborative work, emphasizing the vital role of physical manipulatives in the process. This reflects a second-order barrier: although the technology can be used collaboratively or complementarily with other means—specifically through the use of manipulatives—participants perceived a conflict between the tool's format and their pedagogical beliefs regarding the necessity of social interaction and tangible engagement.

Note on TPACK Analysis

The classification reflects the nature of the barriers identified (Ertmer, 1999). Codes related to *Technical Aspects* and *Context* are first-order barriers (extrinsic technical limitations). Similarly, *Learning the Software for Task Design* (TPK) is classified as a first-order barrier because participants described it as an operational constraint related to the steep learning curve and the significant time investment required for novice designers, rather than a rejection of the technology itself. In contrast, *Hinders student learning* represents a second-order barrier (intrinsic). Although the technology affords collaborative or complementary uses, participants perceived a conflict between the tool's structure and their pedagogical beliefs regarding the necessity of social interaction, suggesting that the barrier lies in the alignment of the tool with their teaching philosophy rather than a hard technical limit.

Table 2. Summary of themes, codes, and representative items related to the perceived difficulties of *JClic*, classified by TPACK subdomain.

THEME		CODES ASSOCIATED	SAMPLE ITEM (ONE FOR EACH THEME)	Freq. (items)	Freq. (students)	TPACK subdomain
TECHNICAL ASPECTS OF THE SOFTWARE	THE	Outdated software / technical limitations	<i>“It is an outdated application, which causes problems when trying to upload a lot of external content” (S19)</i>	17/45	14/24	TK
		Software management				TK
LEARNING SOFTWARE TASK DESIGN	THE FOR	Learning the software for task design	<i>“Creating activities with <i>JClic</i> requires time and effort from the teacher... if they do not know how to use the software” (S8)</i>	13/45	13/24	TPK
HINDERS STUDENT LEARNING		Hinders student learning	<i>“It focuses tasks on an individual level... but does not allow for more group actions or sharing” (S10)</i>	9/45	6/24	TPK
CONTEXT		Lack of ICT resources	<i>“It is computer software, so for children who do not have access to a computer, learning from it is difficult” (S12)</i>	6/45	3/24	TK

Note. N = 24. Metrics follow the same definition as Table 1.

Discussion

Responding to the need highlighted by Lim et al. (2024), this study examined pre-service teachers' (PSTs) perceptions of a training program designed to promote technology integration in early childhood mathematics. While Lim et al. (2024) utilised a mixed-methods approach to demonstrate broad improvements in PSTs' attitudes and TPACK, our study complements this by focusing closely on the specific friction between pedagogical intent and technical execution. We offer empirical insights into the challenges of aligning these dimensions within initial teacher education.

Regarding RQ1, participants generally perceived technology integration positively. The findings suggest that the training environment was conducive to fostering positive attitudes, effectively addressing typical internal resistance. Research indicates that explicit instruction—defined as the direct teaching of technical skills combined with pedagogical modelling—can support this by increasing self-efficacy (Rehmat & Bailey, 2014). Participants highlighted technology's potential to enhance learning through flexible task design, indicating emerging TPACK. These findings align with Lim et al.'s (2024) qualitative results regarding positive attitudes but add a crucial nuance: highly positive pedagogical beliefs can coexist with significant technical frustration if the digital tools are not intuitive. This supports Valtonen et al. (2023), who emphasise that developing TPACK requires a delicate balance between technical mastery and understanding pedagogical opportunities.

Addressing RQ2, the analysis revealed a specific interaction between first-order (external) and second-order (internal) barriers (Ertmer, 1999). Contrary to traditional literature which often cites second-order barriers (beliefs) as the most obstinate obstacle, our participants expressed high motivation (low second-order barriers) yet struggled significantly with first-order barriers posed by the software's usability. Specifically, technical difficulties with *JClic* were frequent concerns. While early literature often centred first-order barriers on the lack of hardware access, our findings demonstrate that even in equipped contexts, *software complexity* acts as a formidable extrinsic obstacle. Our findings suggest that the technical friction PSTs experience while using *JClic* may act as a 'bottleneck' during planning. If future teachers are overwhelmed by the software's complexity, they may struggle to reach the 'Augmentation' level ($d = 0.54$) identified by Taheryan and Song (2025) as being more effective for STEM learning; instead, they might settle for simpler, less effective tasks simply because they are easier to program.

Nevertheless, despite these challenges and some difficulties encountered with task sequencing, the instructional designs produced by our participants were of relatively good quality. This indicates that while the usability of a tool is a pedagogical factor that can potentially limit a teacher's ability to design high-quality mathematical representations, the PSTs in this study demonstrated the capacity to navigate these technical demands successfully. Ultimately, ensuring that digital tools are intuitive is essential to prevent technical effort from overshadowing the pedagogical excellence that recent research (Alonso-García et al., 2024; Taheryan & Song, 2025) identifies as crucial for early mathematics.

Regarding the training methodology, unexpected themes emerged. While focused on mathematics, participants noted the software's adaptability to other subjects. Furthermore, although technical struggles were dominant, some participants explicitly valued group work and the use of the HLT tool. This also reinforces current research highlighting the need for authentic experiences that articulate technological knowledge with pedagogical reflection (Tondeur et al., 2025).

Implications for Teacher Educators

Based on these findings, we propose specific pedagogical adjustments:

- *Scaffolded Technical Training.* To prevent software complexity from overshadowing pedagogical goals, it is critical to decouple technical learning from design tasks. A dedicated 2–3 hour hands-on technical workshop early in the course would allow PSTs to master the tool’s mechanics before facing the cognitive load of mathematics planning.
- *Tool Evolution & Collaboration.* The friction caused by *JClic* suggests a need for modern alternatives. Educators should select authoring tools that *support real-time collaboration* and leverage emerging technologies. Tondeur et al. (2025) highlight the potential of Generative AI to support teacher design; in line with this, we suggest exploring *vibe coding methodologies* – a term used to refer to accessible, personalised app creation via natural language. Furthermore, promoting real-time collaboration is proposed to facilitate flexible teamwork across different times and locations, transforming the individual struggle with technical complexity into a peer-scaffolded learning opportunity.
- *Pedagogical Connection.* Given that participants predominantly focused on general software features (e.g., adaptability, multimedia), training should embed reflection prompts explicitly linking tasks to mathematics content. This strategy aims to leverage the participants’ positive perception of the HLT tool to deepen their focus on the specific mathematical affordances of the technology.

Limitations

Several limitations must be considered. First, the study was conducted at a single institution with a small convenience sample, which restricts generalisability. Second, the focus on *JClic* may have skewed perceptions regarding technical difficulty compared to modern apps. Third, data collection relied on brief written responses rather than in-depth interviews or observations. Finally, the absence of a long-term follow-up prevents determining whether the training effects persisted in professional practice.

Conclusion

This study adds to the literature by highlighting that while explicit training can successfully foster positive internal dispositions towards technology integration, external barriers posed by complex software remain significant. The findings confirm that resolving the issue of hardware access does not eliminate first-order barriers if the software remains counter-intuitive.

To enhance future teacher training, we recommend three implementable actions derived from these findings: (1) Include a dedicated 2–3 hour hands-on technical workshop early in the curriculum to build confidence; (2) Select authoring tools supporting real-time collaboration to mitigate technical frustration through peer support; and (3) Integrate digital tasks with manipulative materials and reflection prompts, ensuring a balanced approach that connects technical skills directly to early childhood mathematics.

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Data availability statement

The full anonymised dataset is available from the corresponding author upon reasonable request.

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