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Enhancing Pre-Service Special Education Teachers' TPACK and Attitudes Through a Technology and Mathematics Focused Hackathon

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Abstract

Aim/Purpose	The study aimed to develop a unique program based on a technological hackathon (MATH-HACK) for special education pre-service teachers (PSTs), and to examine its impact on their Technological, Pedagogical, and Content Knowledge (TPACK) as well as on their attitudes toward designing technology-based activities in mathematics for students with special needs.
Background	Integrating technology into mathematics instruction is vital for supporting students with special needs. While special education teachers often express positive attitudes toward technology integration, its actual implementation in practice remains limited, mainly due to insufficient training. Pre-service teachers often report a need for greater support in developing the skills needed to integrate technology effectively.
Methodology	The sample included 63 special education PSTs, exceeding the minimum required size of 52 determined in advance using G*Power. TPACK and attitude questionnaires regarding the design of technology-based mathematical activities were used. The quantitative analysis, conducted using SPSS (Version 29),

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included paired samples t-tests, repeated measures ANOVAs, Pearson correlations, and hierarchical regression analyses to identify predictors of improvement.

Contribution: This study proposes a practical training program for special education PSTs, emphasizing the integration of technology as a core component. It underscores the potential contribution of the MATH-HACK program as a foundation for developing professional knowledge (TPACK) and fostering positive attitudes in this field.

Findings: The findings show improvement in each component of TPACK, with the most notable gains in technological knowledge. Students' attitudes improved, particularly regarding their ability to cope with challenges. Moreover, it was found that PSTs who designed technological activities for students with emotional-behavioral disabilities and learning disabilities showed greater improvement in all areas of TPACK compared to PSTs who designed activities for students with complex disabilities. In addition, most PSTs preferred this method of instruction to classic instructional techniques.

Recommendations for Practitioners: The findings indicate that the MATH-HACK training program contributes to the development of PSTs' TPACK components, while also fostering positive attitudes toward designing technology-based activities for students with special needs. In light of its contribution, it is recommended that similar training programs be developed and implemented further.

Recommendations for Researchers: It is recommended to incorporate interviews to gain a deeper understanding of the improvements experienced by the research participants and to continue with a longitudinal study to assess whether they apply what they learned during the hackathon in their teaching practices.

Impact on Society: The study highlights the potential contribution of this innovative model to the preparation of special education PSTs within a technological-mathematical context, a process that may enhance the mathematical achievement of students with special needs.

Future Research: It would be valuable to assess the program's applicability in other content disciplines, both in special education and general education.

Keywords: TPACK, hackathon, mathematics, pre-service teachers, special education

INTRODUCTION

Academic and economic success relies on mathematically proficient students applying math to real-world problems and thinking creatively from an early age (Richland et al., 2020). However, students with disabilities consistently score lower in national math assessments than their peers (The Nation's Report Card, 2022). This gap is due to challenges in domain-specific mathematical knowledge, cognitive skills, and emotional factors like motivation and learned helplessness (Geary, 2011; Takır & Özder, 2024).

Teachers of students with disabilities need both a deep understanding of math content and the ability to use diverse teaching methods to support these learners (Byrd & Alexander, 2020); this is even more so for pre-service teachers (PSTs) (Massey & Muhammad, 2023) who are at the beginning of their professional careers.

Mathematics instruction in special education in Israel is grounded in a structured teaching process that begins with the comprehensive collection and analysis of student information, encompassing cognitive, emotional, behavioral, and social aspects, as well as the identification of strengths and areas of difficulty. Based on this information, a functional profile of the student is developed, serving as the foundation for designing an individualized, flexible, and dynamic intervention plan that can be adjusted in response to changes in the learner's needs and progress. The plan focuses on defining clear learning objectives and selecting appropriate instructional strategies, incorporating visual aids, educational technologies, and diverse teaching methods to maximize accessibility to the learning material. Implementation is carried out systematically and gradually, adapting the pace, level of difficulty, and nature of tasks to the student's abilities. Finally, ongoing assessment is conducted to evaluate the learner's progress and the effectiveness of the intervention, with the goal of updating the plan as needed and ensuring continuity in both academic and personal development (Ministry of Education, 2014).

One teaching method that has proven effective for students with special needs is the incorporation of technology in their mathematics instruction. It has been found to offer students greater access to knowledge, improve their academic math skills, and foster motivation (Iyamuremye et al., 2023). Inclusion of technology in instruction has also been found to enhance social interaction, reduce learning barriers, and better enable teachers to adapt the content to student needs (Cagiltay et al., 2019; Syahraini et al., 2024). Indeed, adaptation is a central principle in teaching students with special needs: the main goal of utilizing adaptation is to help students overcome difficulties in cognition, behavior, and emotion, and to express their knowledge and mastery of what is being learned (McGlynn & Kelly, 2019).

In addition to professional knowledge and skills, teachers' attitudes play a crucial role in predicting their adoption of technology (Scherer & Teo, 2019; Seufert et al., 2021). Despite special education teachers' generally positive attitudes toward technology, their actual use remains limited due to infrastructure challenges and a lack of specific training (Cagiltay et al., 2019). Moreover, special education teachers who teach math often prefer familiar, general technological tools and use simple interactive resources such as games and presentations (Baglama et al., 2017; David et al., 2023). Thus, given the known advantages of incorporating technology in mathematical instruction, it is essential to improve PSTs training in this area (David et al., 2023). Indeed, research indicates a lack of training programs focused on technology in mathematics instruction for children with disabilities. PSTs often call for more support in integrating technology into their teaching (Baglama et al., 2017; Green et al., 2020).

The study presents the development and implementation of a program that trains PSTs in special education to design mathematical activities for students with special needs. This program was structured in a unique hackathon format.

Technological, Pedagogical, and Content Knowledge (TPACK)

In today's education landscape, the Technological, Pedagogical, and Content Knowledge (TPACK) model equips teachers to integrate technology effectively into instruction. Introduced by Mishra and Koehler (2006) as an extension of Shulman's (1986) framework, TPACK emphasizes the interplay of content, pedagogy, and technology, highlighting their integration as essential for modern teaching (Rodríguez Moreno et al., 2019; Santos & Castro, 2021). Specifically, the TPACK model encompasses seven distinct types of knowledge (Mishra & Koehler, 2006; Santos & Castro, 2021; Valtonen et al., 2020).

1. *Pedagogical Knowledge (PK):* This pertains to the understanding of teaching methods and processes, encompassing classroom management, assessment, lesson planning, student learning processes, motivation, and more. It relates to knowledge about the interactions between teachers, students, learning environments, and learning tasks.
2. *Technological Knowledge (TK):* This involves knowledge about various technologies, including the tools and skills necessary for teaching and learning.

3. *Content Knowledge (CK):* This refers to the teacher's understanding of the subject matter they are required to teach, encompassing facts, concepts, theories, and processes.
4. *Pedagogical Content Knowledge (PCK):* This knowledge integrates pedagogy and content, enabling teachers to teach content in ways that are adapted to the learning needs of students, considering their backgrounds, misconceptions, and prior knowledge.
5. *Technological Pedagogical Knowledge (TPK):* This encompasses knowledge of incorporating technology into teaching and learning activities, thereby enhancing and supporting instruction through various technological means.
6. *Technological Content Knowledge (TCK):* This knowledge combines content and technology, enabling the creation and integration of new representations of specific content, thereby enriching the learning material.
7. *TPACK:* This represents the comprehensive knowledge teachers need to integrate technology into their teaching across various content areas using appropriate pedagogical methods.

Despite its introduction in 2006, the TPACK model remains highly relevant. It effectively encapsulates the integration of continuously evolving technologies essential for effective teaching practices.

TPACK AND SPECIAL EDUCATION

The TPACK model is particularly crucial for pre-service teachers (PSTs), the future educators responsible for shaping the next generation of students in general education (Rodríguez Moreno et al., 2019; Santos & Castro, 2021). Given its importance, several interventions have been designed to enhance PSTs' TPACK through targeted training in technology integration for mathematics instruction. For example, an intervention focused on developing TPACK through the integration of GeoGebra technology in mathematics courses and student-centered microteaching tasks, which included the development of interactive teaching materials, practicing multiple representations of concepts, addressing learning difficulties, and applying various teaching strategies. This study found an improvement in PSTs' ability to use GeoGebra for diverse instruction but also revealed challenges such as difficulty in linking multiple representations, limited use of the tool at the beginning of the process, and a lack of dedicated teaching materials and activities (Assadi & Hibi, 2020).

Another intervention was implemented in mathematics courses, in which PSTs were assigned microteaching tasks and student-centered projects. The PSTs focused on developing interactive teaching materials, planning and delivering lessons, and gaining experience in classroom-simulated environments. The study found a significant improvement in TPACK components as well as an increase in PSTs' confidence in integrating technology. However, challenges were identified regarding the deep integration of technology into the curriculum, its use for student-centered active learning, and avoiding teacher-centered technology-based instruction (Aldemir Engin et al., 2023; Durdu & Dag, 2017).

The learning experiences of students who participated in training programs based on the TPACK model have also been examined. Maor's (2017) study found that participation in such a program significantly contributed to strengthening the confidence and understanding of graduate students and PSTs in the effective use of the various knowledge domains comprising the model. Most participants described themselves as "digital pedagogues" who adopted the TPACK model for implementation in their teaching, with practical tasks such as developing an ePortfolio perceived as a significant opportunity to acquire applicable knowledge relevant to both their studies and their professional practice. Their authentic reports emphasized the model's contribution to deepening critical reflection on technology integration, mentoring peers, and enriching pedagogy, while addressing diverse learning styles. Alongside feelings of confidence and empowerment, participants described practical challenges, including managing lessons in technology-rich environments, maintaining students' attention and engagement, and assessing learning within collaborative projects. Integrating a diverse and flexible range of information and communication technologies (ICT) was perceived as a complex task, and some courses were described as "intensive, demanding, and exhausting," which hindered full engagement with digital pedagogies. Another study (Valtonen et al., 2020) found that PSTs in elementary education reported that addressing knowledge gaps between students, both in content and in technological skills, was a major challenge in pedagogical content knowledge (PCK), while technological pedagogical knowledge (TPK) was identified as an area in need of strengthening.

Also, inclusive pedagogies are increasingly supported by digital technologies that enable flexible instructional design, reduce barriers, and provide tailored guidance for diverse learners within the framework of Universal Design for Learning (UDL). The UDL framework, implemented worldwide, aims to ensure accessible learning opportunities for all students by minimizing barriers and fostering optimal learning processes (Rapp, 2014). Technology accelerates this process by offering flexibility and versatility in how learners perceive, process, and express knowledge (Bray et al., 2024; Roski et al., 2024). However, implementation gaps have been identified, particularly in the domains of engagement and action and expression, which require equity-conscious digital design. These gaps include limited use of technologies to support learners' self-regulation and self-assessment, as well as technology-mediated communication and collaboration (Bray et al., 2024). Such findings position technology as a pedagogical infrastructure that enables inclusive planning, equitable monitoring, and the provision of proactive, barrier-preventing accommodations in higher education and other educational systems (Roski et al., 2024).

The TPACK model is particularly crucial for PSTs, the future educators responsible for shaping the next generation of students in general education (Rodríguez Moreno et al., 2019; Santos & Castro, 2021) and particularly those with special needs, who often face additional barriers in traditional learning environments. To address these challenges, educational frameworks combining content, pedagogy, and technology have become increasingly vital. However, while special education teachers generally exhibit positive attitudes toward using technology, its implementation remains limited. For example, Cagiltay et al. (2019) found that although special education teachers believed technology improves educational quality, their actual use was hindered by a lack of infrastructure and suitable materials. Teachers also indicated they do not feel compelled to learn new technologies unless necessary. Similarly, David et al. (2023) found that although teachers consider integrating technology into teaching mathematics necessary, they tend to use general technological tools and prefer "apps" with resource libraries, as they are easier to adjust for specific activities. Also, research by Baglama et al. (2017) found that most special education teachers use simple tools like digital presentations and games rather than more advanced technologies specific to mathematics instruction.

Researchers have recently explored the TPACK model in the context of special education, and it has shown some efficacy. Cahyani et al. (2021) referred to its use by science teachers, Kaplon-Schilis and Lyublinskaya (2019) examined a case involving a master's degree mathematics student, and both David et al. (2023) and Hill and Uribe-Florez (2020) explored its application among math teachers. Notwithstanding, to date, there is a notable lack of research that specifically addresses the integration of TPACK in the combined context of special education, mathematics, and the use of technology.

Therefore, in the current study, we address this gap by researching the training of pre-service special education teachers to implement the TPACK model in the context of designing technological activities for mathematics instruction specifically designed for students with special needs through an innovative teaching method: the hackathon. This choice (the hackathon), among other things, is based on the understanding that in order to enhance PSTs' ability to teach mathematics, education courses should provide opportunities that cultivate a passion for the subject while equipping them with the knowledge, skills, and habits necessary to become competent and confident teaching professionals (Takır & Özder, 2024).

Hackathons

Hackathons are typically defined as short, intensive, and often competitive events in which participants, motivated by a shared challenge, collaborate to develop innovative solutions to complex problems or projects of personal or collective interest (Nolte et al., 2020). These events are technical and function as social and educational spaces, offering participants opportunities for brainstorming, exploration, and learning through experimentation (Page et al., 2016).

In recent years, higher education institutions have increasingly incorporated intensive, collaborative learning sessions that mirror the structure and spirit of hackathons, sometimes explicitly referring to them as such (Gama et al., 2018; Suominen et al., 2018). For example, a three-month classroom hackathon program at the University of Strasbourg for PSTs included a one-day event focused on the challenge "Imagine the Future of Education and Learning," which involved teamwork under the guidance of coaches, followed by three monthly workshops dedicated to developing creativity, assessing achievements, and presenting outputs. The program emphasized five dimensions of collaboration: communication, role clarification, team functioning, shared leadership, and conflict management. The study's findings indicated significant improvement in four of these dimensions, although no significant link was found to innovation performance, suggesting the importance of a dedicated preparation phase for educational innovation (Adinda et al., 2024).

In the field of software engineering, a longitudinal study describing over a decade of hackathons presented various formats ranging from events lasting 24 hours, five days, and 48 hours, to industrial hackathons integrating challenges from academia and industry, team-based work, targeted training, and product presentations, which led to notable improvements in technical skills, teamwork, and university-industry connections, alongside logistical challenges, work-life balance issues, and uncertainty regarding innovation outcomes (Porras et al., 2018). In the health context, 2–3 day hackathons at Stanford University were structured around stages including the presentation of clinical problems, the formation of multidisciplinary teams balanced in skills, the development of prototypes and business models with mentor support, and the presentation of solutions for judging. These led to high satisfaction, increased interest in medical innovation, and improved collaboration in diverse teams, alongside recommendations to strengthen diversity and integrate the model with consistent institutional support (Wang et al., 2018).

Moreover, hackathons yield a wide array of benefits, including enhanced collaborative learning and teamwork (Suominen et al., 2018), knowledge acquisition, experiential learning, improved problem-solving abilities, project management and prioritization skills, increased learner motivation and confidence, as well as the development of critical thinking and communication skills. As pedagogical tools, they integrate practical, contextual, and social dimensions of contemporary education while simultaneously promoting creativity and innovation among students (Gama et al., 2018; Suominen et al., 2018). A notable feature of many educational hackathons is their celebratory conclusion: a final event that includes a competition in which participants present their projects, and awards are given for the most outstanding developments. This closing ceremony not only enhances motivation but also adds a festive and rewarding dimension to the learning experience (Nolte et al., 2020).

In the present study, we designed a unique and experiential program grounded in hackathon principles, aimed at enhancing PSTs' TPACK competencies and strengthening their self-efficacy while fostering skills in collaboration, creative thinking, and problem-solving. Despite the growing recognition of the benefits of integrating technology into mathematics instruction for students with special needs, research indicates a gap between special education teachers' generally positive attitudes toward technology and their actual use of it, a gap stemming in part from insufficient infrastructure and a lack of specialized training (Baglama et al., 2017; Cagiltay et al., 2019; David et al., 2023). These findings underscore the need for innovative training frameworks for pre-service special education teachers, enabling them to gain hands-on experience in meaningfully and adaptively integrating technology into mathematics instruction. In response to this need, the present study developed the Mathematical

Hackathon (MATH-HACK) program, an experiential educational intervention aimed at enhancing pre-service teachers' TPACK, strengthening their confidence and sense of self-efficacy in using technology for mathematics instruction, and increasing their motivation to integrate technology in creative and pedagogically meaningful ways. The primary aim of this study was to examine the impact of the MATH-HACK program on pre-service special education teachers' knowledge and attitudes toward implementing technology-based mathematics instruction for students with special needs.

Research Hypotheses (RH)

RH1: An effect of the MATH-HACK program will be observed in PSTs' perceived technological, mathematical, and pedagogical knowledge (TPACK).

RH2: An effect of the MATH-HACK program will be observed in PSTs' attitudes toward designing technology-based activities in mathematics for students in special education.

RH3: A correlation will be found between PSTs' perceived TPACK and their attitudes toward designing technology-based activities in mathematics.

RH4: PSTs' background characteristics, attitudes toward designing technology-based activities in mathematics, perceived TPACK, and their prior familiarity with digital tools for creating educational activities will explain improvements in their perceived technological, mathematical, and pedagogical knowledge.

Method

This study employed a quantitative approach using questionnaires to identify broad patterns and trends in pre-/post-training changes among PSTs in components of TPACK and attitudes toward designing technology activities in mathematics for special education students. The quantitative analysis provided a structured and data-driven method to measure changes in the PSTs' TPACK components.

Participants

A total of 63 Israeli PSTs from a central Israeli teacher education institution, in their third year of undergraduate studies in special education, participated in the study, comprising 61 females (96.8%) and two males (3.2%). The participants, all from average socioeconomic backgrounds, ranged in age between 22 and 28 years (M = 24.27, SD = 2.27). Fifty-six PSTs were specializing in special education only (88.9%), and seven were specializing in special education and mathematics (11.1%). Twenty-eight PSTs had actual teaching experience in mathematics (44.4%), and 35 had not had actual teaching experience in mathematics (55.6%). When asked which students they were teaching in their practicum, 10 responded that they teach students with specific learning disabilities (15.9%), 30 reported teaching students with emotional and behavioral difficulties (47.6%), and 23 were teaching students with complex disabilities. Regarding the PSTs' self-reported amount of technology experience, seven PSTs indicated they had none, 20 indicated "some", 23 indicated a "medium" amount, 12 indicated having a high amount of experience, and one indicated having a very high amount of experience.

Research Tools

The study included two research tools.

1. A questionnaire based on the TPACK framework (Schmidt et al., 2009) was adapted for this study to assess teachers' competencies in three domains: pedagogy, technology, and content. The original scale was modified to reflect the study's focus on mathematics; for instance, questions related to the content knowledge domain were rephrased to refer to mathematics. The modified form of the questionnaire comprised 28 items in seven categories: technological knowledge (TK), 4 items (e.g., "I keep up with important new technologies"); content knowledge (CK), 4 items

(e.g., "I have various ways and strategies of developing my understanding of mathematics"); pedagogical knowledge (PK), 4 items (e.g., "I can adapt my teaching style to different learners"); pedagogical content knowledge (PCK), 4 items (e.g., "I can assess the mathematical understanding of students with special needs in several ways"); technological content knowledge (TCK), 4 items (e.g., "I am familiar with software/technological environments for teaching mathematics"); technological pedagogical knowledge (TPK), 4 items (e.g., "I can choose technologies that enhance the teaching approaches for students with special needs"); and technological pedagogical content knowledge (TPACK), 4 items (e.g., "I can teach lessons that appropriately combine literacy, technologies, and teaching approaches for students with special needs."). The responses were recorded using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." Internal consistency of Cronbach's alpha was found for the 28 items (.93), as well as for the three main components (TK, .81; CK, .91; and PK, .79) and for the four combinations of these three main components (PCK, .89; TCK, .84; TPK, .92; TPACK, .88).

2. A questionnaire adapted from the work of Lipka and Hess (2016) on PSTs' attitudes toward learning statistics was used, focusing on three categories: (a) affect [the original questionnaire solicited students' subjective emotional experience of learning statistics, so it was modified for the current study to refer to designing technology-based activities in mathematics (e.g., "I love the field of designing tech-based activities in mathematics")]; (b) cognition [the original questionnaire solicited students' self-assessment of their cognitive and intellectual competence in understanding statistics, so it was modified for the current study to refer to designing technology-based activities in mathematics (e.g., "It's easy to understand how to design tech-based activities in mathematics")]; and (c) dealing with difficulty [the original questionnaire solicited students' perceptions of the inherent difficulty of learning statistics, so was modified for the current study to refer to designing technology-based activities in mathematics (e.g., "I find it difficult to cope with concepts related to designing technology-based activities in mathematics for students with special needs.")].

Internal consistency of Cronbach's alpha was found for the 16 items (.91) and the three categories (affect, .86; cognition, .72; and dealing with difficulty, .75).

ETHICS

The study received approval from the ethics committee of the academic institution in which it was carried out (approval number: 2024032601). The participants received an explanation of the research, both in writing and orally, and were informed that participation in the study was voluntary and that non-participation would not affect their grades. To preserve participants' anonymity while allowing for comparison across measurement points, each participant was assigned a randomly generated unique identifier, which they used when completing the questionnaire both before and after the hackathon. Questionnaire responses were collected anonymously, and no identifying information was linked to the data.

MATH-HACK PROGRAM

The aim of the program is to equip PSTs with the skills to design mathematical technology-enhanced activities. These activities are specifically tailored for students with special needs who learn within the practicum of PSTs. The program consisted of three main phases, as presented in Figure 1.

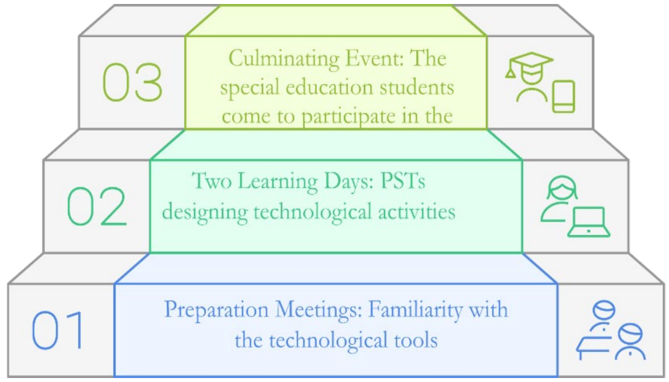

Figure 1. Phases of the MATH-HACK program

First phase: Preparation meetings

Two preparation meetings were held at the academic institution where the research was conducted to prepare for the MATH-HACK program. Each meeting lasted approximately 90 minutes. Three of the technologies were presented during the first preparation session, and the other three during the second (see details below). The presentations were given by techno-pedagogues at the academic institution where the research was conducted. During the preparation sessions, the technologies were explained. The PSTs were divided into work teams according to the schools where they teach in the practicum. Each team had opportunities to engage in initial hands-on experiences with two technologies of their choice from the full set. After these preparation meetings, every team chose two technologies for designing the activities. They were asked to justify their selection based on two criteria: the added value of the technological tool in teaching the designated mathematical content, and how the tool addresses the unique characteristics of their students.

Below is a description of all the technologies presented:

Stop-Motion. Stop-motion animation captures frame-by-frame images of objects or characters until a complete video is produced.

Game Generators. These tools allow educational content to be embedded into structured, ready-made templates, resulting in an educational game.

Location-Based Learning. GooseChase, an interactive app designed for creating and managing scavenger hunts.

3D Printer. 3D printing is a manufacturing technology that allows the production of three-dimensional models directly from a computer. The printing machines create models from various polymers, layer by layer, ultimately producing a final object.

Interactive Storytelling. Interactive storytelling is a genre developed through computer planning. Instead of being passive readers, the learners actively participate in making decisions for the protagonist, thereby functioning as the story's heroes.

Active Floor. An interactive floor system combining movement and play in teaching and learning allows for gameplay while moving.

Second phase: PSTs designing technological activities

A month and a half after the preparatory sessions, we held two intensive hackathon days. Each day lasted from 08:30 until 17:30. The goal was to provide a deeper understanding of the two technological tools selected by the PSTs' work teams and to design math-related activities incorporating this technology. This process required careful consideration of the designated mathematical topic and adaptation of the technological. The PSTs worked with structured planning boards and specific rubrics, such as setting goals and three different difficulty levels (easy, intermediate, and challenging), and they discussed challenges that may arise during the teaching process and strategies for addressing them.

On each day, a general opening discussion was conducted (09:00-10:00), followed by activity development in teams (10:30-13:00, 14:00-16:30) and a reflective analysis of the process within teams and in the plenary session (16:30-17:30). Techno-pedagogical mentors and a pedagogical advisor in math supported the groups during the planning and activity development stages. Throughout both days, experiential breaks, including music and movement activities, were provided, alongside refreshments to maintain engagement.

Third phase: Culminating event

Two weeks after the hackathon, students from the schools where the PSTs are conducting their practical training, comprising individuals with specific learning disabilities, emotional and behavioral challenges, and complex disabilities, visited the campus for a learning event (09:00-12:15). The day began with a warm welcome at the campus gates, where each group of PSTs met their group of school students (09:00-9:30). In designated rooms, the PSTs facilitated the first of two technological math activities they had developed. This session lasted approximately one hour (09:30-10:30) and was followed by an active, multi-sensory experiential break, during which the PSTs guided the students through engaging activities across the campus (10:30-11:15). After the break, the school students returned to their rooms for the second technological math learning activity, again facilitated by the same group of PSTs (11:15-12:15). Each group of PSTs remained with their assigned school students throughout the day, ensuring consistency and personalized attention. After the students left the campus and returned to their schools, a reflective discussion was conducted to evaluate the three hackathon days (12:30-14:00).

DATA ANALYSIS

The sample size was determined a priori using the G*Power software. To conduct a paired sample t-test with the following parameters: medium effect size = 0.40, α error = 0.05, and power = 0.80, the sample size of the PSTs needs to be at least 52 to indicate an effect of improvement. Quantitative data analysis was performed using the statistical software SPSS (Version 29). To investigate *RH1,* we conducted several analyses. First, paired samples t-tests were conducted on the three main components of the TPACK questionnaire and the four combinations of these components. After determining which of the three main components showed improvement, a two-way (2x3) repeated measures ANOVA was conducted to investigate whether the improvements varied significantly across the components and over time. In addition, to investigate whether the improvements varied significantly across the four combinations and over time, a two-way (2x4) repeated measures ANOVA was conducted.

To investigate *RH2,* we conducted several analyses. First, paired samples t-tests were conducted on the three factors of the attitude toward designing technology activities in mathematics for special education students. After determining which of the three factors showed improvement, a two-way (2x3) repeated measures ANOVA was conducted to investigate whether the improvements varied significantly across the factors and over time.

To investigate *RH3,* we conducted Pearson correlation analyses between the three main components of the TPACK questionnaire and the three factors of the questionnaire on attitudes toward designing technological activities in mathematics at each time point.

Finally, to investigate *RH4* regarding which variables explain improvement in technological, mathematical, and pedagogical knowledge after the MATH-HACK program (background variables of the PSTs, their attitudes toward designing technological activities in mathematics prior to the MATH-HACK program, their TPACK measurements prior to the program, and different technological tools for design activities), hierarchical regression analyses were conducted for the three main components and the four combinations of these components.

FINDINGS

In the present study, to detect a medium effect of the MATH-HACK program, a sample size of at least 42 PSTs was required. Indeed, 63 students participated in the study. However, this sample size remains borderline and minimal, considering the relatively large number of measures employed in the current research, including the three main components of the TPACK questionnaire and the four combinations of these components. Additionally, the questionnaire has three factors in attitudes toward designing technology activities in mathematics for special education students. Therefore, to reduce the likelihood of multiple comparisons inflating results, it is advisable to set a more stringent significance threshold of 0.01. Findings with significance levels of 0.05 and 0.01 will be considered marginally significant, and these results will be presented with caution compared to those where the significance level found was 0.001.

RH1: An Effect of the MATH-HACK Program will be Observed in PSTs' Perceived Technological, Mathematical, and Pedagogical Knowledge (TPACK)

The primary research hypothesis was that an effect of the MATH-HACK program would be observed in PSTs' technological, mathematical, and pedagogical knowledge (TPACK). To investigate this hypothesis, paired samples t-tests were conducted on the three main components of the TPACK questionnaire and the four combinations of these components. The results indicate a significant improvement in the PSTs' knowledge across all three main components and their combinations following the mathematics-focused technological hackathon. It should be noted that the size effect of the MATH-HACK program was medium-high with regard to the technological knowledge component and the three combinations: technological and math knowledge, technological and pedagogical knowledge, and technological, mathematical, and pedagogical knowledge (all $p < .001$).

The effect sizes for the mathematical and pedagogical knowledge components, as well as the combination of pedagogical and math knowledge, were low-medium ($p < .01$, $p < .05$, and $p < .05$, respectively). Due to the limited sample size and the use of a restricted p-value to address the multiple comparisons problem, the results regarding the mathematical and pedagogical knowledge components, as well as the combination of pedagogical and math knowledge, should be interpreted with caution.

While paired samples t-tests provided insight into the overall improvement in the three main components of TPACK, a two-way (2x3) repeated measures ANOVA was conducted to investigate further whether the improvements varied significantly across the components and over time. This additional analysis allowed for a more nuanced understanding of how each component responded to the MATH-HACK program, accounting for potential interactions between time and component. The independent variables included time and component as within-subject factors. The results revealed a significant main effect of time, $F(1,124) = 18.02$, $p < .001$, $\eta_p^2 = .23$, indicating that PSTs' knowledge significantly increased after the MATH-HACK program. A significant main effect of the component was observed, $F(2,124) = 57.85$, $p < .001$, $\eta_p^2 = .48$, showing that PSTs reported higher pedagogical knowledge levels than technology and mathematics.

Furthermore, a significant interaction between time and component was found, $F(2,124) = 3.47$, $p = .034$, $\eta_p^2 = .05$. PSTs reported increased knowledge in all three main components after the MATH-HACK program, with the program having a notably larger effect size on technology knowledge compared to mathematics and pedagogical knowledge. However, it should be noted that the interaction effect was significant at the 0.05 level, and due to the limited sample size, the result of the interaction effect should be interpreted with caution. However, the effect size of time was significant at the

0.001 level, which indicates that in accordance with our first hypothesis, an effect of the MATH-HACK program was observed in PSTs' TPACK.

While paired samples t-tests provided insight into the overall improvement in the four combinations of TPACK, a two-way (2x4) repeated measures ANOVA was conducted to further investigate whether the improvements varied significantly across the combinations and over time. This additional analysis allowed for a more nuanced understanding of how each combination responded to the MATH-HACK program, accounting for potential interactions between time and combination. The independent variables included time and combination as within-subject factors.

The results revealed a significant main effect of time, $F(1,124) = 16.39$, $p < .001$, $\eta_p^2 = .21$, indicating that PSTs' knowledge significantly increased after the MATH-HACK program. Additionally, a significant main effect of the combination was observed, $F(3,186) = 5.79$, $p < .001$, $\eta_p^2 = .09$, indicating that PSTs reported higher levels of knowledge in the combination of pedagogical and mathematical components compared to the combination of technological and mathematical components, and the combination of the three main components. Finally, no interaction between time and component was found, $F(3,186) = 1.41$, $p = .242$, $\eta_p^2 = .02$. The PSTs reported increased knowledge in all four combinations after the MATH-HACK program.

Table 1 presents the means, standard deviations, t-values, and F-values related to the TPACK questionnaire.

Table 1. Mean, SD, t-values, and F-values of Technological Pedagogical Content Knowledge (TPACK) questionnaire

Study measures	T1		T2		t-values		F-values (η_p^2)		
	M	SD	M	SD	t	d	Time	Component	Time* component
Technology knowledge	2.85	0.83	3.44	0.78	5.50***	0.69	18.02*** (.23)	57.85*** (.48)	3.47* (.05)
Math knowledge	3.14	0.95	3.48	0.90	3.13**	0.39			
Pedagogical knowledge	3.96	0.58	4.17	0.61	2.53*	0.32			
Pedagogical and math knowledge	3.32	0.81	3.60	0.66	2.24*	0.28	16.39*** (.21)	5.79*** (.09)	1.41 (.02)
Technological and math knowledge	3.00	0.86	3.52	0.77	5.31***	0.67			
Technological and pedagogical knowledge	3.07	0.89	3.61	0.80	4.90***	0.62			
Technological, mathematical and pedagogical knowledge	2.99	0.76	3.66	0.81	7.67***	0.97			

*p < .05, **p < .01, ***p < .001; d = Cohen's d effect size

Figure 2 presents the mean scores of TPACK components before (pre-intervention) and after (post-intervention) the MATH-HACK program.

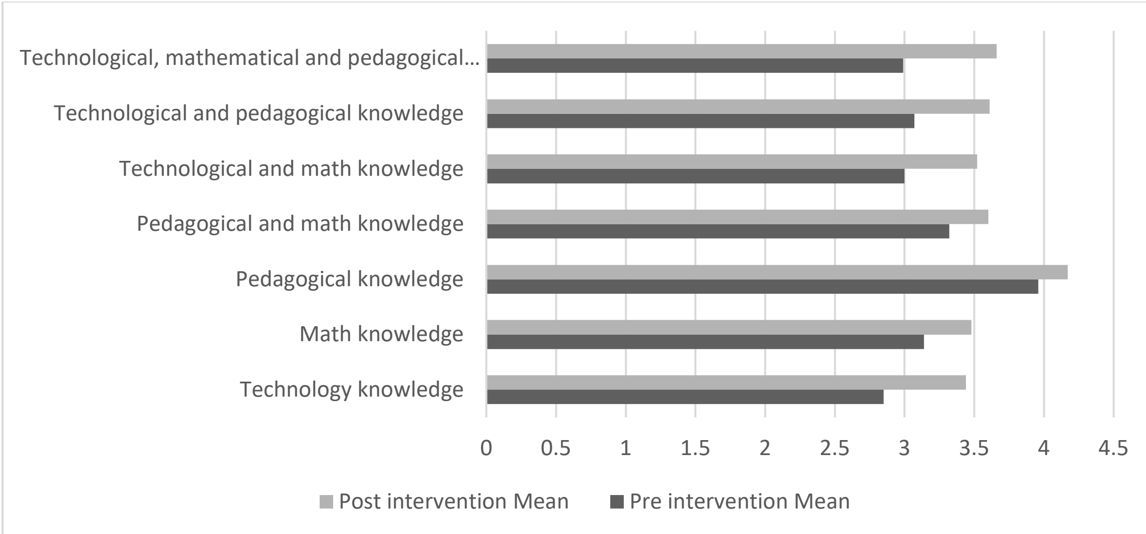

Figure 2. Mean scores of TPACK components before (pre-intervention) and after (post-intervention) the MATH-HACK program

RH2: An Effect of the MATH-HACK Program will be Observed in PSTs' Attitudes Toward Designing Technology-Based Activities in Mathematics for Students in Special Education

The secondary research hypothesis is that an effect of the MATH-HACK program would be observed in PSTs' attitudes toward designing technology activities in mathematics for special education students. To investigate this hypothesis, paired samples t-tests were conducted on the three factors of the attitudes questionnaire (affect, cognition, and dealing with difficulty). The results indicate a significant improvement in PSTs' attitudes toward designing technology activities in mathematics following the MATH-HACK program [$t(62) = 3.55$, $p < .001$, $d = 0.45$ for the affect factor; $t(62) = 3.89$, $p < .001$, $d = 0.49$ for the cognition factor and $t(62) = 6.30$, $p < .001$, $d = 0.79$ for dealing with difficulty factor]. This means that in all three factors of the attitude questionnaire, the effect of the MATH-HACK program was observed at a significance level of $p < .001$.

While paired samples t-tests provided insight into the overall improvement in the three attitudes' factors, a two-way (2x3) repeated measures ANOVA was conducted to further investigate whether the improvements varied significantly across the factors and over time. This additional analysis allowed for a more nuanced understanding of how each factor responded to the MATH-HACK program, accounting for potential interactions between time and factor. The independent variables included time and factor as within-subject factors.

The results revealed a significant main effect of time, $F(1,124) = 30.68$, $p < .001$, $\eta_p^2 = .33$, indicating that PSTs reported more positive attitudes toward designing technological activities in mathematics after the MATH-HACK program. Additionally, a significant main effect of factor was observed, $F(2,124) = 14.65$, $p < .001$, $\eta_p^2 = .19$, showing that PSTs scored higher in the 'dealing with difficulty' factor compared to the 'affect' and 'cognition' factors. The higher scores in 'dealing with difficulty' thus indicate greater confidence among the PSTs in managing the challenges of designing technological activities in mathematics.

Furthermore, a significant interaction between time and factor was found, $F(2,124) = 8.40$, $p < .001$, $\eta_p^2 = .12$. PSTs reported more positive attitudes in all three factors after the MATH-HACK program. However, the MATH-HACK program had a notably larger effect size on the 'dealing with difficulty' factor ($d = 0.79$) than the 'affect' and 'cognition' factors ($d = 0.45$ and $d = 0.49$, respectively). As we hypothesize, an effect of the MATH-HACK program was observed in PSTs' attitudes toward designing technology activities in mathematics for special education students. However, this effect was greater with regard to the 'dealing with difficulty' factor compared to the 'affect' and 'cognition' factors. Table 2 presents the means, standard deviations, t-values, and F-values for attitudes toward designing technology activities in mathematics.

Table 2. Mean, SD, t-values, and F-values of attitudes toward designing technology games in mathematics

	T1		T2		t-values		F-values		
Study measures	**M**	**SD**	**M**	**SD**	**t**	**d**	**Time**	**Factor**	**Time* factor**
Affect	3.08	0.99	3.43	0.95	3.55***	0.45	30.68*** (.33)	14.65*** (.19)	8.40*** (.12)
Cognition	3.07	0.71	3.39	0.57	3.89***	0.49			
Dealing with difficulty	3.23	0.86	3.89	0.58	6.30***	0.79			

Figure 3 presents the mean scores of attitude factors before (pre-intervention) and after (post-intervention) the MATH-HACK program.

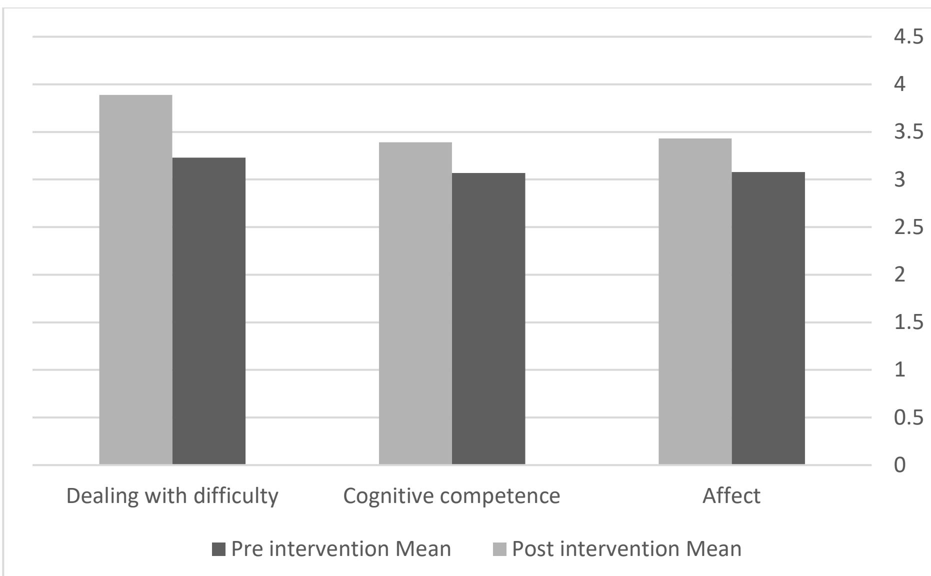

Figure 3. Mean scores of attitude factors before (pre-intervention) and after (post-intervention) the MATH-HACK program

RH3: A Correlation will be Found Between PSTs' Perceived TPACK and their Attitudes Toward Designing Technology-Based Activities in Mathematics

The third research hypothesis was that a correlation between TPACK and attitudes toward designing technology activities in mathematics would be found among PSTs. To address this hypothesis, Pearson correlation analyses were conducted between the three main components of the TPACK questionnaire and the three factors of the questionnaire on attitudes toward designing technological activities in mathematics at each time point.

The results indicate significant correlations between the technology and mathematics components of the TPACK questionnaire and the three factors of attitudes toward designing technological activities in mathematics at the beginning and after the MATH-HACK program time points (except for the correlation between mathematics components of the TPACK questionnaire and the cognitive factor of the attitude questionnaire, possibly because the MATH-HACK program focused more on technological and pedagogical aspects than on deepening mathematical content knowledge). No significant correlations were found at either time point between the pedagogical knowledge component of TPACK and the three factors of the attitude questionnaire (see Table 3).

Table 3. Pearson correlation coefficients between Technological Pedagogical Content Knowledge (TPACK) and attitudes toward designing technology games in mathematics

	Affect		Cognitive competence		Dealing with difficulty	
	T1	T2	T1	T2	T1	T2
Technology knowledge	.30*	.65***	.16	.43***	.28*	.51***
Math knowledge	.41***	.36**	.30*	.20	.46***	.42***
Pedagogical knowledge	.12	.11	.15	.17	.21	.20

*$p < .05$, **$p < .01$, ***$p < .001$

RH4: PSTs' Background Characteristics, Attitudes Toward Designing Technology-Based Activities in Mathematics, Perceived TPACK, and their Prior Familiarity with Digital Tools for Creating Educational Activities Will Explain Improvements in their Perceived Technological, Mathematical, and Pedagogical Knowledge

The final hypothesis of the current study was that the PSTs' background characteristics, attitudes toward designing technology games in mathematics, TPACK measurements, and familiarity with different digital tools for creating games prior to the intervention would explain their improvements in technological, mathematical, and pedagogical knowledge. To explore this hypothesis, hierarchical regression analyses were conducted for the three main components and the four combinations of these components.

In the first block of the regression, the following background variables were entered: gender, age, having a specialization in teaching mathematics (yes, no), actual teaching experience in mathematics (yes, no), self-reported level of technology experience, and the student population of their practical training (specific learning disabilities, emotional and behavioral difficulties, complex disabilities). In the second block of the regression, the PSTs' attitudes toward designing technological activities in mathematics prior to the program, their TPACK measurements prior to the program, and the different technological tools for designing technological activities (stop-motion, game generators, location-based learning, 3D printer, interactive storytelling and active floor) were entered to examine their unique contribution in explaining the improvement in technological, mathematical, and pedagogical knowledge beyond the background variables. The explanatory variables – having a specialization in teaching mathematics, actual teaching experience in mathematics, the student population of their practical training, and the different technological tools for designing technological activities – were entered into the regression model as a dummy variable (yes or no). The explanatory variables in both blocks were entered into the regression model using a stepwise method.

This method was chosen to include only those variables that significantly contribute to explaining the PSTs' improvements in technological, mathematical, and pedagogical knowledge. The stepwise approach was used due to the relatively small sample size of 63 participants, which could present challenges in achieving sufficient statistical power in hierarchical regression. Tabachnick and Fidell (2019) suggest that at least 10 observations per predictor are necessary to achieve adequate power. Table 4 presents the results of hierarchical regression analyses of the TPACK components.

Table 4. Results of the hierarchical regression analyses of the Technological Pedagogical Content Knowledge (TPACK) components

Steps	Explanatory variables	*B*	*SE.B*	*β*	R^2	ΔR^2
Technological knowledge improvement						
1	Technology experience	-.41	.10	-.45***	.200***	---
2	Technology experience	-.06	.10	-.06		
	Technological knowledge at T1	-.64	.12	-.62***	.347***	.147***
	Attitudes toward designing technology games in Mathematics	.46	.10	.42***	.509***	.162***
	3D printer[1]	.59	.26	.20*	.549***	.040*
Mathematical knowledge improvement						
1	Technology experience	-.35	.11	-.38**	.144**	---
2	Technology experience	-.30	.09	-.32**		
	Mathematical knowledge at T1	-.49	.09	-.53***	.423***	.279***
Pedagogical knowledge improvement						
1	---	---	---	---	---	---
2	Pedagogical knowledge at T1	-.57	.12	-.51***	.262***	---
Pedagogical and mathematical knowledge improvement						
1	Technology experience	-.39	.11	-.40***	.207***	---
	Complex disability[2]	-.47	.22	-.25*	.265***	.058*
2	Technology experience	-.24	.08	-.24**		
	Complex disability[2]	-.04	.17	-.02		
	Pedagogical and mathematical knowledge at T1	-.71	.10	-.62***	.603***	.338***
	3D printer[1]	.58	.26	.19*	.636***	.033*
Technological and mathematical knowledge improvement						
1	Technology experience	-.23	.10	-.28*	.081*	---
2	Technology experience	-.07	.09	-.09		
	Technological and mathematical knowledge at T1	-.60	.10	-.66***	.327***	.247***
	Attitudes toward designing technology games in Mathematics	.32	.11	.32**	.413***	.086**
Technological and pedagogical knowledge improvement						
1	Complex disability[2]	-.52	.22	-.29*	.119*	---
	Technology experience	-.23	.11	-.25*	.176**	.057*
2	Complex disability[2]	-.26	.21	-.14		
	Technology experience	-.03	.10	-.03		
	Technological and pedagogical knowledge at T1	-.60	.12	-.60***	.358***	.182***
	Attitudes toward designing technology games in Mathematics	.40	.12	.35**	.462***	.104**
Technological, mathematical, and pedagogical knowledge improvement						
1	---	---	---	---	---	---
2	Technological, mathematical, and pedagogical knowledge at T1	-.34	.11	-.37**	.140**	---

*p < .05, **p < .01, ***p < .001; [1]3D printer: 0 = did not work with 3D printer, 1 = Worked with 3D printer; [2]Complex disability: 0 = No, 1 = Yes.

The analysis of the contribution of background variables to explaining the improvement in technological, mathematical, and pedagogical knowledge indicated that the technology experience of the PSTs contributed to their improvement in technological knowledge, mathematical knowledge, the combination of pedagogical and mathematical knowledge, the combination of technological and mathematical knowledge, and the combination of technological and pedagogical knowledge, after the program. Negative β coefficients suggest that PSTs with less technology experience tended to show greater improvement in their knowledge after the hackathon.

The student population that the PSTs was instructing in their practical training significantly contributed to explaining the improvement in the combination of pedagogical and mathematical knowledge and the combination of technological and pedagogical knowledge, with negative β coefficients indicating that improvement in these combinations was significantly higher among PSTs who were teaching students with specific learning disabilities or emotional-behavioral disabilities compared to those who were teaching students with complex disabilities. No significant contribution of the background variables was found in explaining the improvement in pedagogical knowledge and the combination of all three components.

Unique contributions of PSTs' attitudes, TPACK, and technological tools in designing mathematics activities prior to the MATH-HACK program. The results indicate that PSTs' attitudes toward designing technological activities in mathematics significantly contributed to explaining the improvement in technological knowledge, the combination of technological and mathematical knowledge, and the combination of technological and pedagogical knowledge. Positive β coefficients indicate that PSTs who had a more positive attitude toward designing technological activities in mathematics prior to the program reported greater improvement in these areas of their knowledge.

Additionally, significant contributions of the PSTs' TPACK measurements prior to the program were found for all three main components and all four combinations of these components. Negative β coefficients suggest that PSTs who indicated lower TPACK knowledge prior to the program showed greater improvement in their TPACK knowledge following the mathematics-focused technological hackathon.

Finally, regarding the set of technologies presented to the PSTs during the MATH-HACK program, those who used 3D printer digital technology for designing their mathematical instruction activities showed higher improvement in their technological knowledge and the combination of pedagogical and mathematical knowledge, with positive β coefficients. An additional quantitative finding related to the question: "In retrospect, how would you prefer to have learned?" Seventy-seven percent of the student respondents indicated that they preferred the hackathon, 5% stated that they would have preferred traditional instructional methodology (weekly frontal lectures), and 18% responded that they had not yet decided. Table 5 summarizes the main research findings according to the study hypotheses.

Table 5. Summary of the main research findings according to the study hypothesis

Hypothesis	Description	Main results
RH1	Effect of MATH-HACK on PSTs' perceived Technological, Mathematical, and Pedagogical Knowledge (TPACK).	Significant improvement in all three TPACK components and their combinations after MATH-HACK; larger effect on technology knowledge ($p < .001$); smaller effects on math and pedagogical knowledge ($p < .01$, $p < .05$). Significant main effects for time and component; interaction effect significant at $p = .034$.

Hypothesis	Description	Main results
RH2	Effect of MATH-HACK on PSTs' attitudes toward designing technology-based activities in mathematics for special education.	Significant improvement in all three attitude factors (affect, cognition, dealing with difficulty) after MATH-HACK (all $p < .001$). Larger effect size for 'dealing with difficulty' ($d = 0.79$) compared to affect ($d = 0.45$) and cognition ($d = 0.49$). Significant main effects for time and factor, and significant interaction ($p < .001$).
RH3	Correlation between PSTs' perceived TPACK and their attitudes toward designing technology-based activities in mathematics.	Significant correlations between technology and mathematics components of TPACK and all attitude factors at both time points, except the math component with the cognitive factor. No significant correlations for pedagogical knowledge with any attitude factors.
RH4	Background characteristics, attitudes, TPACK, and prior familiarity with digital tools explain improvements in TPACK.	Technology experience, student population, prior attitudes, initial TPACK scores, and use of 3D printing significantly predicted improvements in various TPACK components. PSTs with less tech experience or lower initial TPACK showed greater improvement, and 77% preferred the hackathon format.

DISCUSSION

The primary aims of the study were to examine whether the MATH-HACK program: (a) advances the technological, pedagogical, and mathematical knowledge (TPACK) of PSTs in designing technology-based mathematical activities for students with special needs; and (b) improves the PSTs' attitudes related to designing such activities. The quantitative findings indicate improvement among our third-year special education PSTs cohort in the three primary TPACK components (technological, pedagogical, and content) and most combinations.

Specifically, the MATH-HACK program is technology-focused. Thus, the PSTs reported increased technological knowledge, an area where they were weakest prior to the program. This low level of technological knowledge can be attributed to the limited number of technology-related courses included in their training. The program provided an in-depth exploration of unfamiliar technological tools, hands-on use of these tools, the design of mathematical activities, and actual teaching. Research indicates that explicit instruction – featuring clear explanations, demonstrations, well-organized concepts, and planned discourse – is essential for effective learning (Tondeur et al., 2020). For example, Harvey and Caro (2017) found that PSTs who received explicit TPACK instruction showed greater technological and content knowledge than those who did not. Similarly, Kartal and Çınar (2024) observed significant improvement in the technological aspect of instruction after PSTs received feedback on their teaching.

The finding that the program benefited PSTs with low prior technology experience is also notable. This underscores the need for teacher training programs focused on the technological-mathematical domain in special education (David et al., 2023; Green et al., 2020), particularly given that technology improves access to knowledge, enhances academic skills, boosts motivation, and reduces learning barriers for students with special needs (Iyamuremye et al., 2023; Syahraini et al., 2024).

Interestingly, in addition to the PSTs reported on increasing technological knowledge, the MATH-HACK program also contributed to notable gains in pedagogical and mathematics knowledge. The PSTs' pedagogical knowledge was the highest among the TPACK components before the program, likely due to their extensive pedagogical training during their third year of undergraduate studies in special education. However, the program enhanced pedagogical knowledge by encouraging reflection on aspects such as selecting appropriate technological tools and designing activities tailored to students' cognitive, behavioral, and emotional needs. This aligns with the pedagogical principle of adaptation in special education (McGlynn & Kelly, 2019). Moreover, integrating technology in mathematics instruction is known to improve teaching quality and effectiveness, allowing teachers to meet students' needs better (Cagiltay et al., 2019; Syahraini et al., 2024).

As noted, mathematical (content) knowledge also indicates students reported increased knowledge, though somewhat less than technological and pedagogical knowledge. This reported increase appears to stem from the mathematical context required for designing the technological instructional activities. PSTs were tasked with creating technology-based activities in mathematics, necessitating a deeper understanding of the specific content they chose to address. It is possible that when technological knowledge is taught within a specific context, content knowledge also improves.

Another key finding was that most PSTs recognized significant increases in all three TPACK components together – technological, pedagogical, and content knowledge. This is important, as it supports the idea that the MATH-HACK program contributed to their overall TPACK development, addressing the common lack of integrated knowledge in these areas among special education teachers (Anderson & Putman, 2020; David et al., 2023). Furthermore, the study highlights the importance of integrating these components into teacher training, which facilitates the development of mathematical skills for students with special needs (Baglama et al., 2017; Luik et al., 2018). The findings suggest that the more PSTs deepen their understanding of technological tools in mathematics for special education students, the more effectively they can use them to enhance their teaching. The present study offers an innovative, unique, and practical program for PSTs. A similar finding emerged from the quantitative study by Nguyen et al. (2025), which examined the relationship between Game Pedagogical Content Knowledge (GPCK) and the acceptance of digital game-based learning (DGBL) among primary mathematics teachers. The study found that GPCK is a significant predictor of both positive attitudes toward the use of digital games in teaching and behavioral intentions to implement them in practice.

The study's quantitative findings show that the MATH-HACK program indicates students reported increased positive attitudes toward designing technology-based mathematics activities for students with special needs. Three attitude factors were measured: affect, cognition, and dealing with difficulty (Lipka & Hess, 2016). The greatest reported increase was seen in the PSTs' attitude toward dealing with difficulty, suggesting that the program equipped them with the skills to overcome challenges, particularly in integrating technology into math instruction. This reported increase may be explained by the low technological knowledge of the PSTs prior to the program, as technology was seen as a challenge in designing technology-based math activities. However, the program helped them develop the necessary skills to better manage these challenges. Regression analyses further support these findings, demonstrating that PSTs' positive attitudes toward designing technology-based mathematics activities were associated with significantly reported increases in all types of knowledge within the TPACK model. This finding aligns with existing research, indicating that educators' positive attitudes toward teaching play a key role in predicting technology adoption in the teaching process (Scherer & Teo, 2019; Seufert et al., 2021).

Another aspect examined in the study was the type of student population for whom the technology-based mathematics activities were designed. It was found that PSTs who designed activities for learners with learning disabilities or emotional-behavioral disabilities reported more significant increases in technological-pedagogical knowledge and pedagogical-mathematical knowledge than those who designed activities for students with complex disabilities. This difference may be explained by the fact that students with learning disabilities or emotional-behavioral disabilities often have typical intelligence but exhibit significant variation in their cognitive and emotional characteristics (American Psychiatric Association, 2013). As a result, the PSTs that designed activities for this population specifically aimed to address this variability, incorporating higher-order thinking tasks in more complex mathematical topics and using more advanced technologies. These demands required a more profound process of planning and teaching the activity, which may be reflected in their greater reported increases in TPACK components. This may be further corroborated by the finding that PSTs who chose the 3D printer technology to design mathematical instruction activities for their students with learning disabilities or emotional-behavioral disabilities resulted in the highest level of improvement in their technological-mathematical knowledge. This improvement likely occurred due to the complexity and depth required both in understanding how to use the tool and in the advanced mathematical knowledge learned through it, specifically in the design of geometric shapes (Kit Ng et al., 2022).

In contrast, PSTs teaching students with complex disabilities engaged with more basic and structured mathematical content and technological tools, such as the active floor and simplistic game generators. As a result, these PSTs reported less improvement in their mathematical, pedagogical, and technological knowledge. These findings suggest that the MATH-HACK program for PSTs of complex student populations should be expanded and deepened, teaching them how to design technology-based activities using more challenging technological tools. These results align with the findings of David et al. (2023), who emphasize the need for teachers to understand the advantages and limitations of different technologies, which would enable them to select appropriate tools tailored to the unique learning needs of their students. They also argue that many technologies are designed for typically developing learners, thus necessitating adaptations in teaching strategies to effectively support students with disabilities, particularly those with more extensive and complex disabilities.

A final interesting finding from the current study relates to the innovative teaching approach employed in the MATH-HACK program, which revealed that most PSTs preferred this method of instruction to classic instructional techniques. This program enabled the PSTs to explore and select relevant and meaningful technologies for their students. Moreover, aligned with hackathon principles, the MATH-HACK program facilitated social and educational interactions, providing students with an engaging, creative, and supportive environment that fostered active, creative, and collaborative learning (Gama et al., 2018; Page et al., 2016).

Conclusion

Overall, the study demonstrated that the MATH-HACK program significantly improved PSTs' technological, pedagogical, and mathematical knowledge, with the most substantial reported increase in technological knowledge – the area in which participants were weakest prior to the program. The program also contributed to enhancing PSTs' attitudes toward designing technology-based mathematics activities, particularly their ability to address challenges in integrating technology into teaching. The greatest increases in TPACK components were reported among PSTs who developed activities for students with learning disabilities or emotional-behavioral difficulties, especially when using advanced tools such as 3D printers, compared to those working with students with complex disabilities. These findings highlight the program's contribution to developing integrated technological-pedagogical-content knowledge and fostering positive attitudes toward incorporating technology into mathematics instruction in special education. Furthermore, they indicate the need to expand and deepen training for PSTs working with complex populations to ensure they acquire the skills necessary to adapt and effectively implement advanced technological tools. More broadly, the results suggest that incorporating hackathon-based models into teacher training may serve as an innovative and practical approach to bridging gaps in technological readiness, promoting creative and collaborative pedagogies, and improving learning outcomes for diverse learners in special education.

Limitations and Recommendations for Future Research

The current study examined a sample of 63 PSTs; future research should expand the number of participants to obtain a more comprehensive and accurate representation of PSTs. Another limitation refers to the use of self-report questionnaires. It is recommended to incorporate interviews to gain a deeper understanding of the improvements experienced by the research participants and to continue with a longitudinal study to assess whether they apply what they learned during the hackathon in their teaching practices. In addition, given our findings related to the PSTs' high satisfaction with the unique hackathon-based teaching method, future research should explore PSTs' experiences with this instructional approach in greater depth. Additionally, future studies should compare this program to traditional teaching methods or other instructional approaches using a control group. A greater understanding of this teaching methodology would allow for the refinement and expansion of the MATH-HACK program to include additional innovative methods in training PSTs in the context of mathematics, a field known for its complexity and gaps in content mastery by teachers.

The MATH-HACK program was also found to be effective in fostering these skills among pre-service special education teachers. Based on existing knowledge regarding the importance of TPACK-based programs for pre-service teachers and their contribution to promoting the inclusion of students with special needs, and in line with the principles of the UDL model, it is therefore suggested that such programs be adapted and implemented in general education contexts as well, in order to promote flexible instruction, reduce barriers, and provide tailored support for students with special needs integrated into these classrooms.

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