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"Emerging Trends, Challenges, and Innovative Practices in Education"

Enhancing Math Skills in Children with Learning Difficulties Using Smartphone Apps

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Abstract

This study aimed to examine the effectiveness of smartphone applications in enhancing the acquisition of mathematical concepts among children with learning difficulties. The research involved 80 students from private schools in northern Jordan, randomly assigned to an experimental group, which received instruction through smartphone and tablet applications, and a control group, which followed conventional teaching methods. Pre- and post-intervention cognitive assessments were conducted over a 12-week instructional period to measure mathematical understanding. The results revealed that students in the experimental group showed a significant improvement in mathematical performance compared to the control group. Furthermore, no statistically significant differences were found between male and female students, and no interaction effect between gender and instructional method was observed, indicating equitable outcomes across genders. The study highlights that smartphone-based educational applications provide an interactive, adaptive, and supportive learning environment that caters to the specific needs of students with learning difficulties. The novelty of this research lies in demonstrating the practical benefits of integrating digital tools into mathematics instruction, supporting constructivist and inclusive learning approaches, and offering evidence-based strategies to enhance student engagement and conceptual understanding. These findings suggest that technology-enhanced learning can effectively supplement traditional methods, promoting improved academic performance and inclusive educational practices.

Keywords:

Mobile Phones;

Smart Applications;

Learning Difficulties;

Mathematical Concepts;

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1- Introduction

The recent fast-paced changes across the globe mean that the advancement of educational systems must be a national and strategic priority for every country [1, 2]. However, it is more than learning new technologies and knowledge systems; it is the value adding of preparing the new generation to access, work, and positively influence the ever more fluid and changing systems of the future [2, 3]. The purpose of education is more than the transmission of knowledge and skills. It is a complete system aimed to train a person in all the capacities of the mind, the society and emotions, and

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to develop in the person the creative power and innovative activity necessary to construct the future and sustain it. This initiative needs a transformational change in educational infrastructures and systems. This includes the provision of new teaching and learning methods, integration of teaching with technology and the creation of new learning environments that become stimulating, inclusive and interactive [4, 5].

Inclusive education is fundamental to any meaningful reform in education [5]. The quality of any education system is contingent upon the tailoring of learning opportunities according to the different education needs of all learners irrespective of their ability, background, and cognitive profile [5, 6]. Inclusive education demands the establishment of educational systems that provide flexible, accommodative adaptive systems to students, particularly those learners who experience barriers to participation in the conventional, traditionally taught educational systems [6]. For example, students with learning challenges in mainstream mathematics (dyscalculia) require special teaching methodologies that facilitate equitable learning and avoid the progressive school disengagement stream that downward intensification of school difficulties [6, 7].

Learning difficulties, especially in Math, significantly affect students' academic performance and are often diagnosed at late stages. These challenges present as issues with grasping numbers, perceiving relation, performing elementary arithmetic, memorizing times tables, and dealing with mathematical symbols and relations, all while possessing normal general intelligence [8]. Students with dyscalculia have problems forming precise mental models of numbers as well as construing related meanings, which affects their problem-solving abilities and conceptual understanding. These learners tend to experience a lack of understanding of mathematical concepts on a higher level which tends to lead to a widening gap of knowledge in comparison to their peers particularly because of the way confidence, motivation, and willingness to learn the subject culminate [9].

Because mathematical concepts can be extremely abstract, learners with such issues need other approaches to teaching than the use of verbal explanations and traditional exercises on paper [8, 9]. These learners need environments that present ideas in concreted forms and other manipulatives that allow for such experimentation. For these learners, understanding a mathematical concept involves abstracting a concept or problem, observing it, and forming hands-on manipulation with tools. There has been a lot of research that focused on the tools of educational manipulatives for teaching specific concepts such as Dienes blocks and Cuisenaire rods and their ability to form a solid understanding of a mathematical concept. This allows learners to form a deeper understanding of the concept or problem and its relation to abstract meaning and representation. Using these tools also creates a safe environment in which students can experiment and make mistakes without fear, thereby enhancing motivation and classroom engagement [10-12].

Concerning educational methods, the importance of multimedia, especially in supporting students, integrates educational technologies and educational methodologies that have smart technologies [1, 2, 6, 9]. However, there are students with challenges such as dyscalculia whose comprehension and assimilation of knowledge pose significant challenges that are educationally driven by the use of traditional technologies alone.

There is a growing interest in the Arab educational context regarding the use of various methods for overcoming primary school learners' mathematical learning difficulties [13]. At the same time, the use of such methods is mostly limited to traditional or partially digital environments. Am El-Jilali & Abdel-Hamid [10], for example, used a multiple-intelligences framework to teach a program to a grade three class and found that students' mathematical achievements and competencies improved. Likewise, Al-Zahrani & Zeidan [11] constructed a multi-modal learning framework and noted that students in this framework outperformed their peers in a traditional learning setting.

Using more advanced technologies, Shanayah & Abu Lome [12] utilized smart mathematical apps to improve mathematical thinking in Jordanian primary students. Their results indicated that students using the apps showed statistically significant improvements, which corroborated the efficacy of technology in learning. However, the lack of focus on students with dyscalculia in this study limits the applicability of its results to the target population of this study. Therefore, while improvements in teaching methods have been documented, Arab studies have not sufficiently addressed the effects of enhanced smart apps on learners with math learning difficulties.

Globally, the research has ranged from design-based projects creating educational interventions for children with dyscalculia to empirical research assessing their practical effectiveness. Some researchers [14, 15] evaluating the influence of mobile technology on the learning of mathematics to children with special needs reported some increase in engagement and motivation, but no statistically significant improvement in the learning outcomes. These results imply that the effectiveness of smart applications goes beyond their mere application to their design and fit to the cognitive needs of the learners. More extensive experimental research [16, 17] documented significant progress in learners' achievement, understanding of the concepts, reasoning, and problem solving, while Berkowitz et al. [18] reported learning outcomes improvements that these studies partially corroborated. However, these studies primarily focused on quantitative achievement, leaving unexplored the core mathematical concepts, the cognitive processes involved, and the overall quality of the insight, which constitutes a significant gap.

Other studies [19-23] focused on smartphone applications and their ability to enhance the computational skills of children with dyscalculia, reporting improvements on speed and accuracy and the understanding of the relationships within the numbers. However, these studies also had significant shortcomings that should be addressed, namely small sample size, duration of the intervention, and absence of a longitudinal design to measure the impact on conceptual learning.

Research tends to use quasi-experimental approaches to assess the effectiveness of various programs, practices, and mobile technologies on learning mathematics, ranging in instruments and technologies used. Most of those studies assess learning outcomes without investigating the learning of core mathematical ideas that are necessary to cultivate mathematical reasoning in students with dyscalculia. Additionally, the Arab literature, and particularly the Jordanian literature, lacks systematic experimental studies on the impact of educationally designed smartphone applications on concept learning in real-life classrooms.

This study aims to fill that gap. It develops and implements an applied model that integrates smart technologies to teach students with dyscalculia some core mathematical concepts. It aims to achieve improved inclusive, technology-based teaching practices designed to support learning for this population.

To this purpose, this study aims to assess the impact of smart application usage on the learning of mathematical concepts among third-grade students with learning difficulties, considering the gender of students, instructional method, and their interactions. The study attempts to answer the following questions:

1. Are there any significant differences (*at* $p \leq 0.05$) in the mean scores of mathematical concept acquisition among third-grade students with learning difficulties due to the teaching method (smart applications vs. conventional methods)?
2. Are there any significant differences (*at* $p \leq 0.05$) in the mean scores of mathematical concept acquisition among third-grade students with learning difficulties due to gender?
3. Are there any significant differences (*at* $p \leq 0.05$) in the mean scores of mathematical concept acquisition among third-grade students with learning difficulties due to the interaction between teaching method and gender?

In accordance with the introduction, the identified gap in the literature, and the formulated questions, the subsequent section of the study discusses the theoretical literature, ending with the justification of the study. The third section describes the research methods, outlining the quantitative methods used. In the fourth section, the findings are presented and deeply discussed. The final part of the study summarizes the conclusions and offers practical recommendations for future research.

2- Literature Review

Challenges in acquiring mathematical skills are one of the most familiar problems in primary schooling. These challenges affect the development of concepts and the progression from simple calculations to advanced mathematical thinking and problem-solving [24, 25]. One of the most concerning aspects is that these issues are most often not identified in the early stages of school and are attributed to temporary underperformance. In truth, these issues require a comprehensive and timely intervention to prevent them from developing into cognitive problems that are challenging and costly to remediate [26-28]. The absence or delayed provision of support will inevitably lead to a range of difficulties, including comprehension gaps, inadequate progress in learning, and a lack of motivation and engagement in the classroom. In severe and extreme cases, the problems will include the poor psychosocial and social development of the learner [29, 30].

Given the prevalence of challenges and difficulties in learning mathematics [31-33], it is critical to reconsider instructional practices in mathematics, where the learning of new concepts and material is predicated on understanding previous content. The traditional teaching methods incorporating manipulatives, sensory approaches, and direct verbal explanation, are failing to achieve the desired objectives. The limited capacity of students to connect and apply mathematical concepts to new and different problems meaningfully poses challenges to the effectiveness of traditional practices for teaching.

Because of ineffective classroom teaching practices, the use of technologies in classroom that promote more interactive, responsive, and adaptive learning is more common [34-36]. In contemporary education, smartphone and tablet intelligent applications cater to different learner needs and support varied learning preferences [37, 38]. These apps provide considerable support to students with learning challenges, especially within the mathematics learning disability. These applications serve as a valuable resource to supplement conventional classroom instruction [39, 40].

These applications excel in merging visual, auditory, and interactive features, captivating several senses at once, something called multisensory learning [23, 25]. This style assists in changing an abstract concept in mathematics to a mental image that is easier to understand and recall [31, 33]. These applications promote and sustain the educational experience by integrating animations, interactivity, and sound effects which create an ideal environment for deeper engagement [22].

Additionally, these applications are built so that learners can achieve mastery systematically and gradually, from simple to complex concepts in an interesting way, which aids understanding. This approach reduces anxiety by allowing the learner to experience success which, in turn, provides intrinsic motivation, something most important to learners who experience difficulty in mathematics. Unique also is the immediate feedback learners receive; hints, explanations, or reinforcements provide real-time opportunities to engage learners so they can correct their misconceptions. This boosts their confidence and encourages perseverance to take risks, and tackle tasks without a fear of failure [8, 9].

These applications encourage the development of higher-order thinking skills in mathematics which were regularly used such as analysis, synthesis, and strategic problem solving [30, 31]. The flexible and exploratory characteristics of these applications are consistent with the constructivist learning theory [9], placing students as active knowledge constructors. Additionally, the self-paced nature of these tools allows learners to repeat activities as needed, promoting autonomy and reducing the psychological stress associated with academic challenges [31].

Al-Barakat et al. [19] discusses how apps (smartphones) make it easier for learners to engage with the material whenever they want. They allow learners to revisit materials and engage with them to foster learning. Likewise, some educators [10, 11, 30, 31, 33] focusing on the use of educational apps to teach mathematics to students with learning challenges, have the potential to provide flexible and new active learning environments where students can understand abstract concepts and ideas and make them more concrete and approachable.

Numerous researchers [27, 28, 29] stated that the value of such apps results from the unique digital interactivity that is offered to students, with the most notable gaming features that provide students the proper level of challenge and entertainment and incorporate adaptive gamified challenges to foster self-regulated learning. Cabellos et al. and Aina & Abdulwasiu [41, 42] emphasized that these resources tend to be more instrumental for learning when they closely relate to the school curriculum, as they tend to serve as legitimate extensions of what students learned in the classroom, to help reinforce learning, rather than serve as disconnected resources.

Talafha & Bataineh [43] confirm that apps with multimedia features (visual, auditory, and repetitive) and that reduce cognitive load result in better outcomes compared to apps that rely on heavy, unchanging texts. The presence of one or more of the defined mobile learning paradigms improves the educational value of the apps, as the learning environment provides the necessary interactivity and exploratory experiences [44, 45].

AI educational tools as intelligent apps thoroughly analyzed problem-solving ability, number sense, and personalized learning. All personalized learning experiences where customized content was provided based on learning gaps helped develop problem-solving skills. However, the appropriate digital infrastructure, modern tools, and continuous assistance from teachers and parents, which are pre-requisites, are not available everywhere [31, 33, 35].

Farooq et al. [46] pointed out that the use of educational apps optimally is a determining factor of impact and sustainability. Previous studies [47-51] showed that student performance improved most significantly when app use was accompanied by active teacher involvement, too, which emphasized the guidance of a teacher even more.

St Omer et al. [52] found in their study that digital applications improve the understanding and teaching of fundamental concepts of Mathematics. However, research [53-56] highlights the persistent divide between the availability of devices and the technological proficiency of the teachers showing the need for the training of teachers. This need for training, coupled with the availability of devices, will be able to achieve the best outcomes [40, 57].

Dyscalculia and other learning difficulties require teaching Mathematics to be redefined. Instead of passive learning and rote memorization, the focus should be on interactivity and advanced learner-centered methodologies with the use of smart technologies. This will require teachers to assume the role of facilitators in selecting appropriate apps as well as adapting and modifying learning materials to meet learners in their zones [8-10]. Enhancing this ability will require investment in digital technologies and educators as the designers of integrated technology learning experiences. The investment required goes beyond advanced pedagogical methods; it is also of a moral and social nature. The learner denied the right to an equitable high-quality education suffers an inequitable social consequence as well.

The present study expands on previous meta-analyses on digital mathematics learning in fundamental ways. First, while many previous studies have focused on students in general, this research explores students with learning difficulties in mathematics, a demographic that has largely been neglected in the prior analyses. Second, this research goes beyond assessing general academic success by analyzing the fundamental concepts in mathematics. This provides additional understanding of the impact of digital resources on understanding a concept as opposed to just procedural skills. Third, it uses interactive smart applications constructed on the principles of constructivism as well as multisensory learning. This offers a tangible model for technological inclusion in classrooms. Lastly, the study addressed the local Arab context, and as such, it provides empirical evidence for the region on the geography of technology-integrated mathematics learning for students with learning disabilities. As a whole, these insights contribute to the body of knowledge in the field and the insights gained from the meta-analyses.

3- Research Methodology

3-1-Study Design

The study is quasi-experimental with two groups that were comparable, that is, an experimental and a control group. This study focused on the impact of smart applications on the understanding of mathematical concepts of third graders with learning disabilities. For the experimental group, we used smart apps on tablets and smartphones during the lesson delivery, and for the control group, we used traditional methods of teaching.

Both groups underwent a pretest prior to the intervention to establish baseline knowledge of the mathematical concepts. At the end of 12 weeks of instruction, a posttest was administered to determine the effectiveness of the instructional methods. This design allowed for a direct comparison of the two groups, and it simplified the assessment of the impact that the smart applications had on the learning of mathematics. This design of the study can be described as follows:

- *Experimental group: Pretest (O_1), Intervention (X), Posttest (O_2)*
- *Control group: Pretest (O_1), Posttest (O_2)*
- *Where: O_1 = Pretest, X = Instruction using smart applications, and O_2 = Posttest*

More specifically, the flow of this research design is presented in Figure 1.

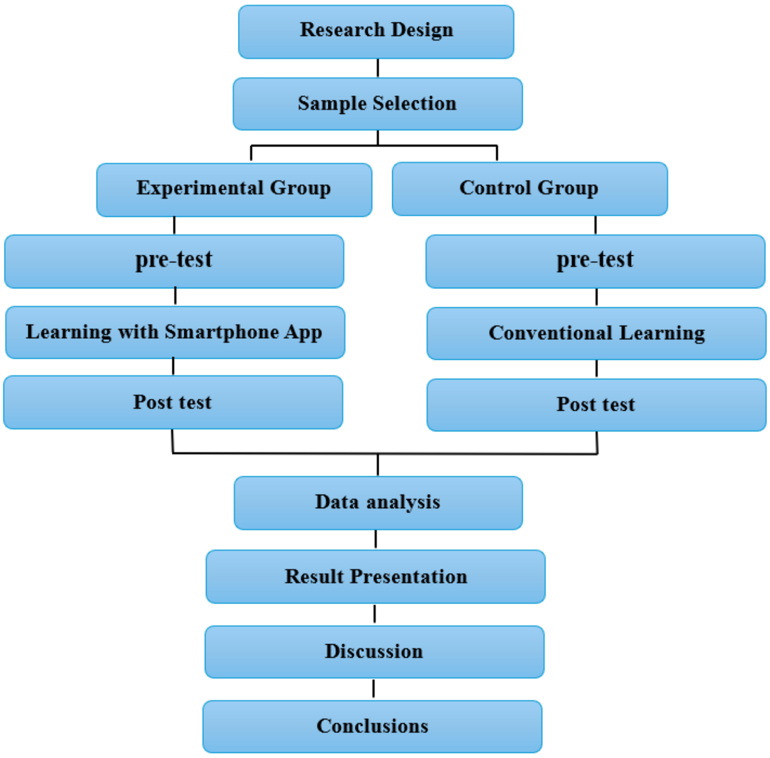

Figure 1. Research design

3-2-Study Sample

Eight private schools in the north of Jordan were chosen in this study, Eighty third-grade students were selected as a sample from these schools. The contextual, social, and economical variance of the participants was documented, and it was made sure that all the participants had smart devices available to them at school and at home. Moreover, equitable learning opportunities were ensured for participants who were less familiar with devices. These measures decreased the impact that the social and economical disparity may have had on the study's results.

These 80 students were randomly split into 2 equal sized groups, with 40 students grouped as the control group, where students learned with conventional methods, and the remaining 40 students as the experimental group, where students were taught with smart applications on tablets and smartphones.

As all participants were recognized by their schools as having difficulties with math, their educational histories and needs were comparable. They also came from similar social and cultural contexts, which helped to minimize other variables that might affect the study's results. A pretest helped to confirm the equivalence of the two groups before the intervention started.

The authors took into consideration that external socioeconomic factors and parental support might impact the learning outcomes of the students involved in the research. Especially since the students in the research sample attended a private school. A couple of methodological measures were then outlined to counter the impact of such factors. Participants were all drawn from the same private school to limit the range of socioeconomic diversity. This meant students would be randomly assigned and evenly distributed to both the experimental and control groups. Equity of assigning students in experimental or control groups was maintained in the school's instructional setting, including the schedule, time instruction, and actual classroom setting. The same educators taught both groups, and prior to the instruction, they were trained on the smart learning applications to be used. In addition, parents were instructed to refrain from any intervention support concerning what was taught in the classroom. These steps were implemented in an effort to manage the influence of external factors, thus increasing the likelihood that the results were a direct effect of the intervention.

3-3- Learning through Smartphone Applications

Jordanian private schools integrate smartphone applications into teaching children with learning difficulties. These children prefer learning methods that offer flexibility, self-paced lessons, and the option to repeat sessions. The apps provide enough continuous aural and visual content that helps children learn fundamental mathematics concepts in an uncomplicated and fun way.

With respect to the study, the intervention that used smart applications was aligned with the national curriculum for grade 3 mathematics in Jordan. The developed apps incorporated essential mathematics concepts and skills targeted in the curriculum, which were designed and presented in an engaging way that fosters a thorough understanding and mastery of the critical underpinning concepts. Furthermore, the intervention was crafted to address all the core topics outlined in the curriculum, and to meet the requirements and standards for formal education in Jordan.

Educational applications showcase content through engaging combinations of visual and auditory components. Integrative components provide students ample opportunities to practice and provide instant feedback. This encourages students to self-correct and learn how to fix their mistakes without feeling discouraged. In the instruction of mathematics, the primary digits of addition, subtraction, and multiplication, and their core operations, remain the primary focus as one of the foundational components.

Kareem and Jana: Our Numbers is one of the flagship programs developed by the Queen Rania Foundation for Education and Development which was also significant in the research. It is aimed at enhancing counting and calculating up to the required level for 8-to-9-year-old students. This program provides the students with famous cartoon characters as an interactive tool as well as an educational environment which is enjoyable. Other applications that were also included in the curriculum were Math Kids and Kids Learning: Math Games, which provide a range of activities for Arabic learners. Teachers and students were able to use the applications in and out of the classroom for the purpose of individual and collaborative learning. These applications were used on Android, iOS, and Huawei smartphones and tablets, and even computers that used Android emulators like BlueStacks. The range of devices made accessing the applications convenient.

To complement the learning experience, the students used and interacted with video content that explained concepts on YouTube. This use of technology enabled students to take control of their learning (independent learning) and work on their math skills with increasing confidence.

3-4- Teacher Training on Using Smart Applications

To equip the teachers in the experimental group with the necessary skills to integrate the use of smartphones in arithmetic operations instruction for students with learning difficulties, the instructors designed a comprehensive training program that combined theory and practice. The first training sessions focused on the educational apps that were used in the study, like Kareem and Jana: Our Numbers, and other educational apps like Math Kids and Kids Learning: Math Games, explaining how to access the apps and install them on Android, iOS, and Huawei smartphones and tablets.

Incorporating educational applications in instruction was discussed in training sessions in which these apps were demonstrated as an interactive educational tool for educators as a means of fostering engagement and encouraging active practice. Participants were trained in the use of the applications and how best aids and audio learning stimuli help in engaging and motivating practice. Moreover, educators were trained in guiding students in inquiring multiple activities in the applications. The use of educational games and educational interactive exercises were also demonstrated as an effective means of practice for varying skills of educational games and exercises.

Furthermore, the educators receive training on accessing and using apps for educational interactive exercises and the real time evaluative features of the educational applications. This teaches them how to evaluate students, guide them with ongoing practice, and expose students to appropriate challenges. They also receive training on using evaluative features and performance reporting tools for assessing educational outcomes which enables identification of areas in teaching which need to be adjusted for better learning outcomes for the targeted audience for teaching.

In this study, the same teachers instructed the experimental and control groups. This technique was adopted to minimize the impact of varying teaching styles so that the differences in outcomes could be attributed solely to the intervention. The teachers were chosen based on appropriateness and proficiency for teaching third grade mathematics and were also trained in advance on the smart applications. This training made sure that the intervention was delivered in a reliable and coherent manner for the experimental group, while still keeping the teaching strategies for each group distinctly separated to avoid crossover impacts on the results.

To oversee the definite control of the 12-week intervention for the experimental group, the study design included a system for monitoring teacher performance to ensure the focused and continuous application of smart mathematics tools. This was achieved through classroom observation and touchpoint weekly check-ins purposeful to deliver on-the-spot assistance and mentoring, thereby increasing the probability of positive outcomes for the intervention.

3-5- Mathematical Concepts Test

This test was developed to evaluate the students' grasp of the fundamentals of mathematics which included whole number multiplication and subtraction. It included word questions to show the application of the mathematics operations for the learners to appreciate the relevance of the mathematics operations in real life. Originally the test had 23 multiple choice questions, after rigorous test validation and reliability analysis, 3 questions were omitted, it was established that this test with 20 questions would yield better results and more accuracy.

Careful item writing and test design ensured that items would be spread appropriately across all levels of the cognitive domain in the Revised Bloom's Taxonomy cognizant of the 4 levels of the cognitive domain- recognition, comprehension, application and analysis. This offered the essential balanced coverage needed to provide a comprehensive assessment of the core mathematical concepts.

Recognition level questions were meant to evaluate students' capacities to memorize and recall the facts of subtraction and multiplication. Understanding the function of the operations within simple word problems looked at questions at the comprehension level. The evaluative questions at the application level aimed at assessing students' capacity to use the given operations of mathematics to solve the more complex problems and different real life situations. For the analysis level questions, students were expected to decompose and analyze a problem into different parts, understand the interrelationship among the parts, and carry out a logical plan to solve the problem.

To ensure that the questions aligned with the specified cognitive levels and covered the right concepts, an expert educational review was conducted. The strongest performing questions were retained for the test finalization. Detailed statistical analyses provided evidence for the test validity and reliability.

3-6- Validity and Reliability

To verify the validity of the Mathematical Concepts Test, an initial 23 item version was presented to a scientific review committee of thirteen expert academics from different Arab universities in Saudi Arabia, Jordan, and the United Arab Emirates. The committee members had a variety of different yet important and necessary disciplines including measurement and evaluation, educational technology, learning difficulties, curriculum development, as well as mathematics teaching methods. This made it possible to review from a variety of dimensions, thereby enhancing the scientific and educational quality of the review.

Reviewer feedback centered on the content of the test, the phrasing of the test items, alignment to the intended objectives, and the characteristics of the target learners. As suggested, we removed three items that did not convincingly connect to the targeted mathematical concepts. We also modified the wording of several items to enhance clarity and more precise linguistic and conceptual alignment. After these changes, the test contained a total of 20 items, organized per a specifications table that balanced coverage of several levels of cognitive demand as articulated in Bloom's taxonomy - recognition, comprehension, application and analysis.

In order to ascertain the reliability of the test, the test-retest method was utilized on a pilot sample that was separated from the main study sample. For this, the test was given to a combined twenty female students with learning difficulties from a pair of other complementary schools. The test was repeated after a span of two weeks, and the Pearson correlation coefficient on the two score sets was calculated to generate a coefficient of 0.96. This is considered a very high reliability score and portrays that the test is in fact consistent and stable over the determined length of time.

Moreover, test item analyses were done, and it was determined that the difficulty indices ranging from 0.42 to 0.81 suggested an appropriate range given the students' abilities. Discrimination indices were at 0.45 and at 0.79, implying that the items were able to separate high and low achieving students from each other. This shows item quality, and their functionality gets to the purpose of the assessment.

To ensure the factorial construct validity, the test was administered to the participants of the pilot study, and a confirmatory factor analysis (CFA) was performed to assess the extent to which the test questions fit within their respective dimensions. Thus it was also determined the loading values of the test questions on their dimensions, as illustrated in Figure 2. The loading factors of the questions needed to meet the criterion that questions with loading factors less than 0.40 should not be accepted. The results indicate that all questions have loading factors greater than 0.40.

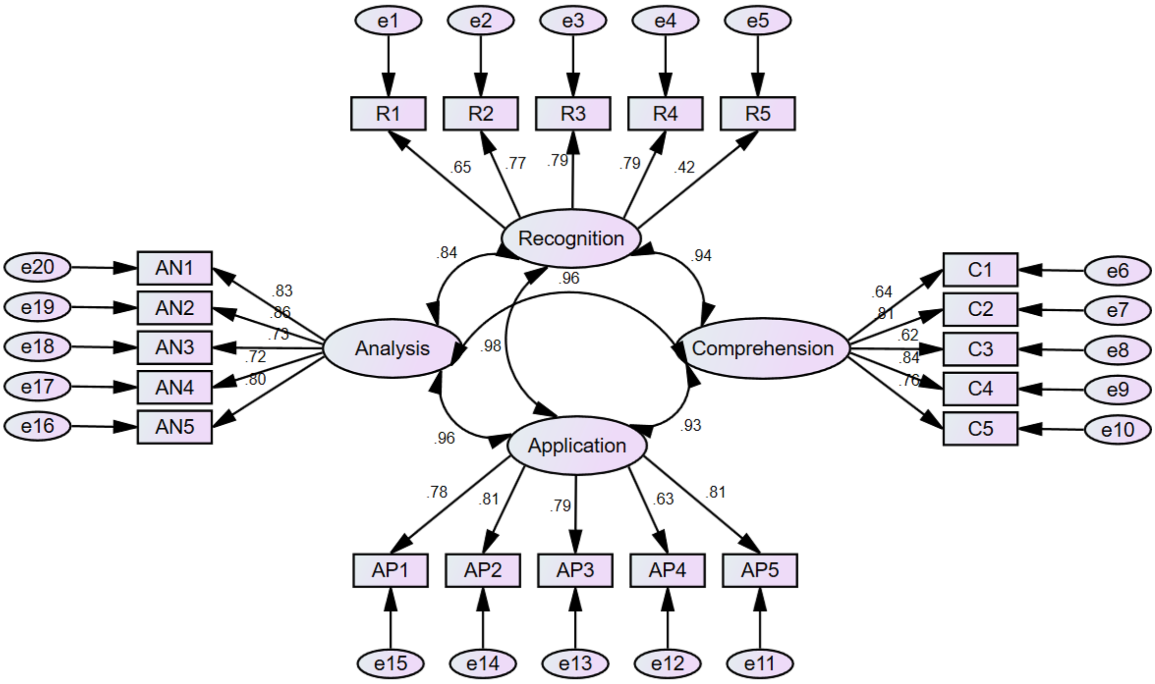

Figure 2. **Results of the CFA of the model adopted for the relationship between the test items and dimensions**

The time students spent completing the test reflected the 45 minutes given was appropriate. This provided ample time for students to think and analyze. To summarize, the Mathematical Concepts Test reflects a good level of construct and criterion validity as well as reliability. Formally benchmarking the associated test and other relevant materials indicates it captures what is needed to measure the fundamental concepts of mathematics, and assists the evaluation of third graders, and especially those with learning disabilities. Hence, it is defensible for use in educational evaluations and for educational diagnostic purposes.

3-7- Data Collection and Analysis

Preceding the actual data collection, a training program was carried out for the teachers of the experimental group. This training was focused on the integration of smart mathematics applications within the teaching of mathematical concepts for the third-grade curriculum. Moreover, the training focused on the effective use of digital resources as part of the lessons to achieve a deeper understanding of the concepts.

In the context of data collection for this study, it should be noted that all ethical principles were strictly adhered to when working with students with learning difficulties in private schools. Parental consent was obtained prior to their children's participation, and the confidentiality of all participants' personal information and data was ensured. Participation was entirely voluntary, with students retaining the right to withdraw at any time without any impact on their academic evaluation. Furthermore, the educational activities and smart applications were designed to accommodate each student's individual abilities, minimizing stress or frustration and ensuring a safe and supportive learning environment that meets the students' specific needs.

After the training, a mathematical concepts pre-test was administered to the experimental and control groups and teaching interventions were compared based on the results of the pre-test. Based on the pre-test results, the experimental and control groups were regarded as comparable in terms of level of cognition to obtain the data. This was input on the computer for statistical analysis using the SPSS software. The means and standard deviations were used in descriptive statistics, and an Independent Samples T-Test was used to determine the existence of significant differences between the groups on the pre-test.

Table 1. **Pre-Test Results for Overall Mathematical Concepts by Group**

Group	N	M.	SD	t	df	p
Experimental	40	3.10	0.81	1.12	78	0.264
Control	40	3.28	0.93			

Table 1 shows the pre-test results for both the experimental and control groups. The groups were statistically the same pre-intervention with a t-value of 1.12 and a significant value of 0.264 (0.264 > 0.05). Thus, both groups were equal regarding the mathematics concepts before the experimental treatment. The experiment spanned twelve weeks with five 45-minute sessions per week for a total of 60 sessions. The experimental group received treatment with smart math applications compared to the control group which was taught using conventional methods. After the instructional period, both groups were given the same post-test for the mathematics concepts.

The post-test data were analyzed using SPSS software. Descriptive statistics, including means and standard deviations, were calculated. An Independent Samples T-Test was performed to determine the differences in post-test achievement between the two groups. Additionally, a Paired Two-Way ANOVA was used to assess the effects of the teaching method, gender, and their interaction on student performance in the post-test

3-8- Ethical Considerations

Ethical considerations were addressed and integrated while working with students with learning difficulties in private schools. For example, the researchers received approval from parents before including their children in the research, and all students' personal information was kept confidential. Students' participation in the research was voluntary, and they were free to withdraw from the study at any point in time without risking their grades. Moreover, the educational activities and smart applications were flexible enough to fit each individual student's abilities, thus reducing the possibility of stress or frustration and providing a safe and supportive learning environment which addressed the students' learning needs optimally.

4- Results

This study examined the impact of smart mathematics applications on the development of mathematical concepts for third-grade students with learning difficulties. It also examined whether this effect varied by gender (male/female) and whether there was an interaction between the teaching method and gender. To achieve these objectives, the participants were divided into two groups:

- **Experimental group**: 40 students (20 males and 20 females) who received instruction using smart mathematics applications.
- **Control group**: 40 students (20 males and 20 females) who received conventional classroom instruction.

A post-test consisting of 20 items (*maximum score = 20*) was administered after the intervention. Means and standard deviations for post-test scores were represented in Figure 3:

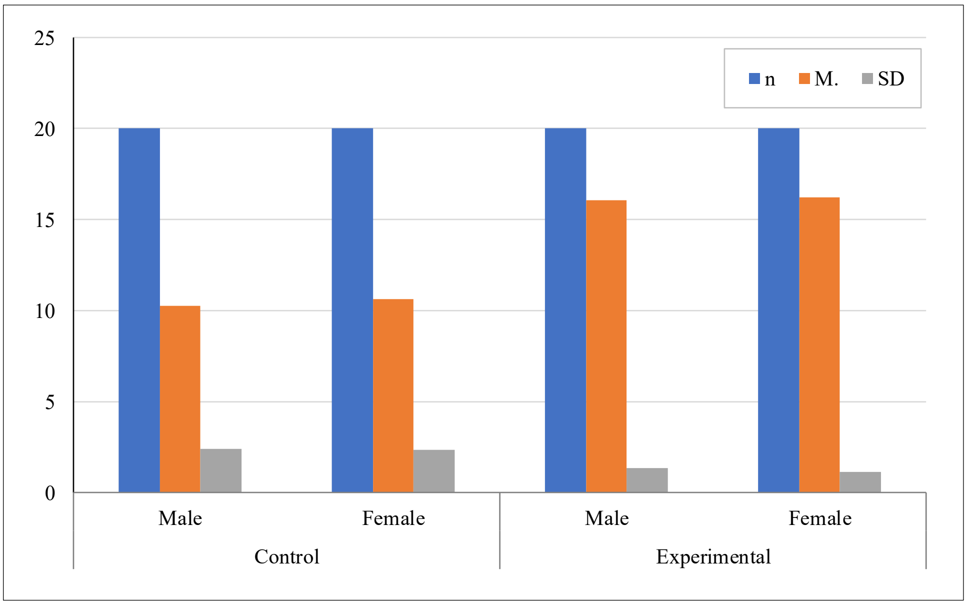

Figure 3. The performance of the experimental and control groups on the post-test

Moreover, the details of the statistical values supporting these findings are presented in the statistical analysis in Tables 2 and 3.

Table 2. Means and Standard Deviations of Post-Test Scores by Teaching Method and Gender

Group	Gender	*n*	M.	SD
Control	Male	20	10.25	2.41
	Female	20	10.60	2.35
Experimental	Male	20	16.05	1.35
	Female	20	16.20	1.12

The results presented in Table 2 indicate a clear difference in performance between the two groups in favor of the experimental group. Students who used smart applications to learn mathematics experienced a 16.05-16.20 mean score range on their assessments out of 20, which demonstrates the level of improvement they experienced. In contrast, the control group mean scores were between 10.25 and 10.60 which is considerably lower than the experimental group, signifying poor performance. This further demonstrates the positive influence educational technology has to offer in teaching mathematics, especially for learners who have difficulty with the basics of arithmetic.

There is also an equity of performance between the sexes in the experimental group. No substantial differences were noted between the genders, which may suggest that the smart applications improved academic performance for all learners, irrespective of their gender. This further reaffirms the capacity of such applications to improve all students' mathematical competencies, irrespective of gender, as a prominent feature of the educational value of such technology.

To examine the significance of the differences in the mean scores of the two groups, a Two-Way ANOVA was applied. This determines the impact of the teaching method (smart applications versus traditional instruction) and the students' gender (male and female) and the interplay of these elements on the post-test performance. This allows for the assessment of the value of each variable on its own and determines whether the combined teaching method and the gender had any effect on performance. These findings are summarized in Table 3 and Figure 4.

Table 3. Two-Way ANOVA: Effects of Teaching Method, Gender, and Interaction on Post-Test Scores

Source of Variation	SS	*df*	MS	*F*	*p*	η^2
Teaching Method	148.12	1	148.12	42.51	0.000**	0.35 (Large)
Gender	2.83	1	2.83	0.81	0.371	0.01 (Small)
Teaching Method × Gender	0.51	1	0.51	0.14	0.709	0.002 (Negligible)
Error	270.40	76	3.56			
Total	421.36	79				

***Note**. p ≤ .05 indicates statistical significance.*

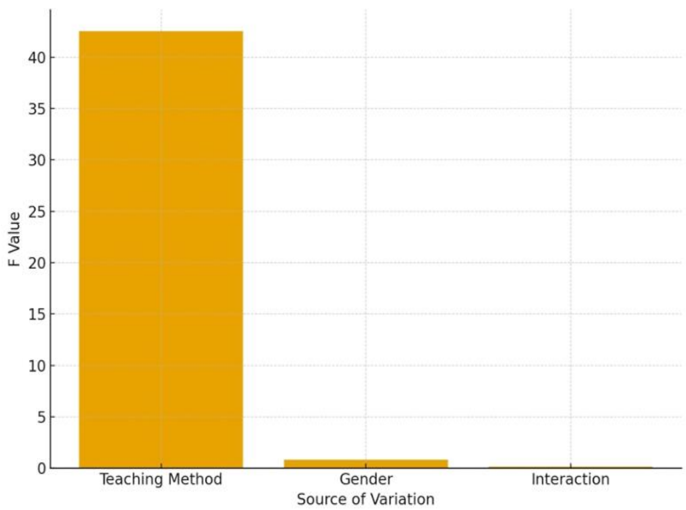

Figure 4. F Value from Two-Way ANOVA (Post-Test Scores)

Table 3 and Figure 4 demonstrate the effect of different teaching methods and gender on students' performance in mathematical concepts. First, the results show the effect of the teaching method is statistically significant. The ANOVA analysis indicates that there is a statistically significant difference with an F value of 42.51 and a p value of 0.000. Additionally, it indicates a large effect size of η^2 =0.35 such that about 35% of the variance in students' achievement could be explained by the teaching method used. This demonstrates the effectiveness of smart applications in mathematics to enhance the performance of students with learning difficulties as compared to the traditional methods of teaching. The results emphasize the role of smart applications in helping students with difficulties in learning mathematical concepts.

In terms of effect of gender, the analysis showed there were no statistically significant differences between male and female students with an F-value of 0.81 and significance of 0.371, which is above the 0.05 threshold. The effect size was small ($\eta^2 = 0.01$); therefore, it could be concluded that gender had little impact the achievement level of students. It was evident that male and female students equally benefited from the teaching interventions, which indicates that the smart mathematics applications were equitable and inclusive in facilitating the learning outcomes.

The impact of interaction between teaching method and gender was also non-significant, $F = 0.14$, $p = 0.709$ and the effect size was negligible ($\eta^2 = 0.002$). This means that the impact of the teaching method, whether traditional or application-based, was the same regardless of gender. The smart mathematics applications meant to promote positive learning outcomes were equally effective for male and female students, which indicates that the applications were fair and universal in their effectiveness.

From the results, a few important conclusions can be drawn. To start, intelligent math apps are a useful educational tool for teaching math concepts to third graders with learning difficulties. Additionally, the approach to teaching proved to be the most important aspect affecting student performance compared to the influence of the student's gender or any combination of gender and teaching approach. The substantial effect size relevant to teaching approach justifies its use as a core strategy within supportive or remedial teaching. The results also confirm that all students, irrespective of gender, are able to utilize the advantages of these apps, thus reinforcing the importance of technology in math teaching and the equitable opportunities for learning formed.

5- Discussion

The study demonstrated that compared to traditional instruction methods, the use of smart mathematics applications greatly helped students unable to grasp basic mathematics concepts. The improvement was large enough to be statistically significant. The students taught with advanced mathematics applications outperformed the students taught with the traditional methods. The smart applications allowed students to control the pace of learning and receive constant reinforcements, auditory and visual. The applications also helped abstract concepts with immediate feedback.

The smart applications presented complicated mathematical concepts, specifically subtraction and multiplication, with engaging real-life examples and verbal scenarios. This allowed children to scaffold their understanding of the abstract symbols and create meaningful and mental experiences. This construction of the concept was more advanced than previous attempts. This type of technology enhanced instruction helped avoid learning obstacles created by abstract concepts by providing sensory support that children with learning difficulties often need.

A large effect size of the teaching method in this study ($\eta^2 = 0.35$) proves that individual differences and chance could not account for the improvement in student performance. Most of the effect must be attributed to the teaching method. The smart applications were a main factor, not just an instrumental tool, in improving performance. This is explained by the applications' interactive and adaptive features that foster self-paced learning and provide immediate feedback along with reinforcement of concepts through visual, auditory, and tactile stimuli which are critical in learning abstract concepts. Students with learning difficulties need a supportive teaching environment that is engaging and stimulating, a condition that smart applications provide. The applications provide repeated practice of concepts with opportunities to refine performance under low pressure, which is needed in mathematics.

The results align with earlier research [9, 19], which stated that the use of digital instruments is an invaluable addition to improving learning outcomes, especially in settings where differing individual learning needs significantly challenge the teacher. The results also agree with earlier research [30, 31, 33] which suggests that students can learn more readily through intelligent apps that enable them to create, explore, and experiment with math concepts. This is in contrast to learning that is purely prescribed. Providing verbal and contextualized real-life situations to mathematical concepts makes them meaningful and relevant to students' lives, which fundamentally strives to improve the learning environment of mathematics for students with learning difficulties.

The results also indicate that the learning environment provided by the applications was equitable, as there were no significant differences in performance between boys and girls in the experimental group. This implies that the tools are unbiased and offer equal learning opportunities to all students. Due to the personalized and private nature of the applications, students are likely able to avoid some of the social and psychological pressures placed on them in the conventional classroom, particularly those students who are anxious or afraid of failing.

In addition, the findings not resulting in a significant interaction effect between gender and the teaching method implies that the advantages of the smart mathematics applications are equally applicable to any gender. This bolsters the generalizability of the findings and indicates that these tools can be utilized in a mixed-gender classroom without the need for gender-targeted modifications. As a result, smart applications are aligned with the inclusive educational practices described in literature, which highlights the need for flexible, personalized learning environments that are designed to promote equity.

As explained previously, these applications aid in the implementation of the Cognitive Load Theory by limiting extraneous cognitive overload through organized instructions, the simple, gradual presentation of materials, and the use of multimedia substitutions [30, 31, 40, 43]. This helps students focus on and understand the fundamentals without distractions. Furthermore, the Self-Determination Theory explains this focus on satisfaction based on the autonomy, competence, and relatedness. The control over the process and the immediate feedback enhance self-efficacy and motivation [25, 46].

The result stems from the equitable and impartial nature of smart applications that help students from all stratums without the educational gender bias typical of many conventional systems. The apps provided students of all gender identities and expressions the space to learn within a calm, encouraging, and positive environment, without the social evaluation anxiety that usually distracts from the focus on the performance of the task at hand. The situation fostered the freely bottom-up exploration of the learners because they deeply cross the calculation and problem-solving parts that are ideal to the understanding of the mathematics concepts. The learners cantered constructivist learning. The situation highlighted the supportive role smart applications are taking in integrating students into the learning process. The applications enhanced equitable social interaction, thus, deflating the impact of real life performance social bias, especially on the girls.

These results correspond with more recent studies. For example, Al-Barakat et al. [19] claimed that the use of digital tools leads to increased achievement and motivation, and Al-Hassan et al. [13] talked about the reduction of the digital divide, inequity of gender, and the encouragement of self-directed learning. Also, regarding the previous research, this study relates to the research [8, 9, 44, 48, 50] that claims interactive tools improve understanding and motivate learners, particularly in mathematics which is often regarded as an anxiety-provoking subject. This is in line with the theoretical foundations of this study which is constructivism and multisensory learning, which posits that the inclusion of visual, auditory, and kinesthetic modes of instruction helps learners understand complex and abstract ideas and brings them down to the concrete level. This is also in line with Tetzlaff's study [14] which states that the use of technology helps lessen the performance gap between groups. In this study, it was the gender gap that was most significantly reduced, further supporting the constructivist approach to technology-enhanced active teaching strategies and learner engagement.

Finally, there is a new educational philosophy seeing smart mathematics applications as foundational in an education system. These applications change education in all three dimensions: what, how and for whom and, more importantly, made education moldable around the individual needs and abilities of students thereby fostering equitable education. This positions equity and educational effectiveness.

This is more than just confirming an instructional model; it corroborates that purposefully designed technology integration delivers significantly better educational results for students with learning challenges [2, 7, 15, 44]. These findings highlight the need for a shift in classroom teaching methods and emphasize the importance of flexibility, alongside the integration of proven teaching methods, in order to meet the educational aspirations of the 21st century and equity in educational opportunities for all students.

6- Conclusion

The results of of this research show the central role that learning applications can contribute in supporting students with mathematics learning difficulties. The analysis shows that well-designed digital tools do more than enhance students' conceptual understanding - they also provide flexible, self-paced learning environments that enable students to adapt their learning experiences to their individual needs. The interactive and adaptive features of these applications help capture students' attention and sustain their engagement, which is essential for developing deeper and more meaningful understanding. In addition, the integration of multimedia elements - such as visual representations, animations, and interactive activities - was found to support information processing and improve knowledge retention. These results are closely aligned with cognitive learning theories, including constructivism and information-processing models, both of which emphasize the importance of active participation, meaningful engagement, and hands-on experience in building solid mathematical understanding.

Moreover, the study highlights the broader influence of educational technology within modern learning environments. Globally, digital tools contribute to strengthening inclusive education by providing equitable access to learning opportunities, especially for students with disabilities who benefit from individualized support. One of the most valuable aspects of these applications is their ability to promote students' independence and self-management. Encouraging students to take responsibility for their own progress not only enhances their academic performance but also builds confidence, autonomy, and positive attitudes toward learning. Overall, the findings of this research suggest that integrating adaptive educational applications into mathematics instruction can be an effective approach to meeting the diverse needs of learners while supporting both their academic development and personal growth.

6-1- Limitations

Limitations need to be mentioned. Only 80 students in private schools from northern Jordan were included in the study, which restricts the extent to which the findings can be applied to other areas, public schools, or different educational contexts. Data collection was based solely on a cognitive achievement test, which excludes qualitative approaches like classroom observations or interviews, that could capture broader learning behaviors and students' interactions with digital tools more fully. This study was also limited in that it focused on educational apps alone without other integrated instructional strategies and was only 12 weeks long which captures a short period in instructional practice. Future studies could expand the sample size and representational diversity, address the gaps in qualitative data collection, and pursue other prospective research designs such as the longitudinal approach to studying education. Also, layered with the educational apps, more active teaching approaches such as cooperative learning, collaborative problem-solving, and other active pedagogical strategies would be highly beneficial, particularly for students with learning difficulties, and would help inform the design and construction of integrated teaching frameworks that are appropriate for the 21st-century classroom and address the needs of diverse learners.

7- Declarations

7-1- Author Contributions

Conceptualization, A.A.A., R.M.A., and O.M.A.; methodology, A.A.A., R.M.A., and B.A.A.; validation A.A.A., R.M.A., O.M.A., and Y.Z.A.; data collection and analysis, A.A.A., R.M.A., O.M.A., and A.K.A.; writing—original draft preparation, A.A.A. and R.M.A.; writing—review and editing, A.A.A.; supervision, A.A.A.; project administration, A.A.A. All authors have read and approved the final version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7-3- Funding and Acknowledgements

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7-4- Institutional Review Board Statement

This study was reviewed and approved by the Deanship of Scientific Research at King Faisal University with the approval number: KFU-REC-2024Mar-EA000678, dated 15/3/2024.

7-5- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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