Exploring Usability and Accessibility of Educational Mobile Apps for Mathematics Learning: A Preliminary Literature Review

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Abstract

Educational mobile applications have emerged as powerful tools for enhancing mathematics learning experiences. This literature review synthesizes findings from 22 research papers focused on the usability and accessibility of educational mobile apps for mathematics learning. The study delves into the contexts, investigating the effectiveness of these apps in accommodating the needs of learners with varying abilities. Through a preliminary literature analysis of the selected papers, this review explores the challenges faced by learners and identifies the strategies employed in these applications to address these challenges. The synthesis reveals insights into user preferences, design elements, and pedagogical approaches that optimize usability and accessibility. By evaluating the existing literature, this review not only provides an overview of the current state of research but also offers recommendations for the future development of educational mobile apps, ensuring inclusivity and effectiveness in mathematics education.

Keywords: Educational Mobile Apps, Mathematics Learning, Usability of math apps, accessibility

I. INTRODUCTION

In the realm of education, mobile applications have emerged as pivotal tools, revolutionizing learning experiences. With a specific focus on mathematics education, these applications have the potential to address a myriad of challenges faced by students, ranging from dyscalculia and autism spectrum disorder to difficulties in slow learning processes. As educational paradigms shift towards blended and independent learning, the role of mobile technology becomes increasingly crucial, offering tailored solutions to complex educational obstacles (Sari & Zamroni, 2019). This literature review embarks on an exploration guided by three review questions:

- What are the prevailing patterns and emerging trends in the guidelines for developing educational mobile apps specifically designed for mathematics learning?
- How have these guidelines evolved over time?
- What pedagogical theories and technological advancements have influenced their development?

Within this framework, this literature review analyzes existing studies, unravelling the foundational principles, design strategies, and user experience intricacies embedded in educational mobile apps for mathematics education. The review encapsulates the aspects including challenges faced by students, ranging from dyscalculia to autism spectrum disorder and slow learning capabilities. Each challenge demands specialized attention, innovative pedagogical approaches, and sophisticated technological integration. As educators and developers navigate this complex terrain, the synthesis of existing literature offers a roadmap, illuminating the way forward.

II. METHODOLOGY

A. Formulation of Search Strings

The first step involved constructing comprehensive search strings tailored to the research focus. Utilizing relevant keywords such as "educational mobile apps," AND "mathematics learning".

B. Selection of Databases and Search Engines

As an initial stage of the main research to develop design guidelines for creating a mobile app for mathematics for slow learners, the articles were selected from the Google Scholar database. In selecting Google Scholar as the primary source for this review, practical considerations guided the choice. During the initial stages, it provided a broad perspective, identifying key themes. Its inclusive access to open resources contributed to the review's

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comprehensiveness. Limited access to specialized databases and financial constraints made Google Scholar the most viable option, for overcoming barriers to information.

C. Screening and Selection Process

Upon retrieving the articles, an initial screening process was implemented. Titles and abstracts were reviewed to assess their relevance to the review topic. A total of 22 articles that met the pre-defined criteria, focusing on educational mobile applications for mathematics learning were selected for review.

D. Full-Text Review and Inclusion Criteria

Selected 22 articles underwent a thorough full-text review. Inclusion criteria encompassed studies that specifically addressed the usability and accessibility of educational mobile applications in teaching mathematics.

E. Data Extraction and Synthesis

Data pertinent to the review objectives were extracted from the selected articles. Key findings related to the usability challenges, preferences, and barriers hindering the effective use of educational mobile apps were discussed. The resulting synthesis of findings provides insights into the usability and accessibility of educational mobile applications for mathematics learning, thereby contributing to the field of inclusive education and educational technology.

F. *Inclusion Criteria*

1. Relevance to Educational Mobile App Usability.
2. Focus on Mathematics Education.
3. Publication in Peer-Reviewed Journals
4. Open Access Articles in English.

Figure 01 below illustrate the criteria for inclusion and exclusion of articles choosen for the literature review.

III. DISCUSSION

The study of mobile applications for educational purposes, especially catering to specific learning needs such as dyscalculia and autism, has gained significant attention. This section delves into various aspects of these studies and discusses their findings in relation to the broader context of educational mobile applications. The framework for evaluating children's educational mobile apps underscores the importance of comprehensive usability evaluation, task checklists, and satisfaction questionnaires. It addresses the need for a more holistic approach to assessing novel features, usability, and pedagogical aspects, which are often overlooked in existing evaluations (Hamid et al., 2022).

Moreover, the incorporation of machine learning tools in mobile health technology, particularly for visually impaired individuals, showcases the potential of enhancing accessibility and usability. These advancements simplify UI interactions and improve task accuracy, aligning with the overarching goal of inclusive design in educational apps (Tahir and Arif, 2014).

The studies on autism care and intervention apps highlight the necessity of bridging behavioural and neuroimaging literature to understand the relationship between visual motion perception and math ability. By utilizing fMRI to assess brain activity, these studies contribute valuable insights into the neurological aspects of learning disabilities and the potential avenues for tailored interventions (Liu et al., 2023; Valencia et al., 2022).

Additionally, the development and evaluation of apps specifically designed for users with Autism Spectrum Disorder (ASD) emphasize the need for formal evaluation methods tailored to the unique characteristics of individuals with ASD. These studies introduce methodologies that encompass diverse factors, ensuring a positive and relevant user experience for this user group (Hersh and Leporini, 2013). In the context of dyscalculia, challenges arise in developing suitable educational apps. The creation and validation of the Calculic Model demonstrate efforts to comprehend dyscalculia challenges and design apps catering to the unique learning styles of dyscalculia children. However, these studies acknowledge the limitations in practical implementation and integration into educational settings (Abd Halim et al., 2018; Laws et al., 2022).

Educational game development also faces challenges related to accessibility, usability, and pedagogy. While guidelines prioritize collaboration, mobile access, and universally accepted heuristics, studies highlight the necessity of considering diverse learners, particularly disabled students. This inclusive approach, demonstrated through real-world engagement with

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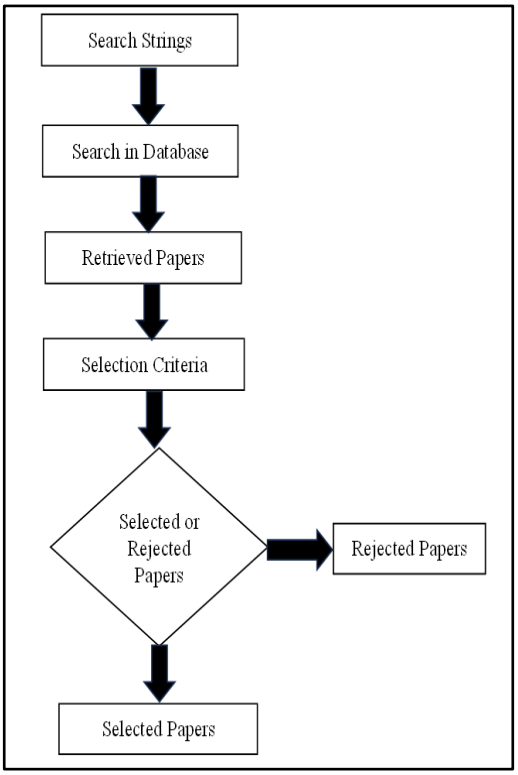

Figure 01: Criteria for Inclusion and Exclusion of Articles

disabled students, parents, teachers, and experts, provides valuable insights into the development of accessible educational games (Gocheva and Somova, 2015). The effectiveness of mobile game-based learning, especially in the context of primary education, is a topic of considerable interest. Studies emphasize the need for adaptability and customization in learning models, integrating micro-lessons and games. Positive feedback from real classroom settings indicates the potential of mobile game-based learning to engage students and enhance their educational experience (Rohizan et al., 2020).

The reviewed scientific studies shed light on diverse strategies, challenges, and solutions concerning the education of students with learning disabilities in mathematics. The scarcity of research addressing the usability of mobile apps in healthcare education is a vital issue that the studies attempted to address (Perera et al., 2014). Various studies focused on different aspects of this problem, highlighting the significance of usability attributes and methods in the context of healthcare education (Orbon & Sapin, 2022). A crucial outcome of these studies was the emphasis on user-centred design principles and the development of comprehensive and inclusive learning tools for children with Dyscalculia (Khaira & Herman, 2020). These findings align with the broader understanding of how technology can be harnessed to support personalized learning experiences for students with learning disabilities.

The integration of Information and Communication Technology (ICT) in special education represents a paradigm shift in the approach towards supporting students with special needs (Maloy et al., 2023). The studies discussed the effectiveness of game-based activities, aiming to provide practical evidence of ICT's impact on the educational outcomes of students with special needs (Gulliford et al., 2021). It was observed that ICT-based learning significantly enhances learning outcomes, emphasizing the importance of customized game-based activities (Gulliford et al., 2021). While these findings are promising, they also underscore the necessity of addressing challenges such as resource constraints and the need for customized approaches for specific disabilities.

The use of tablet technology in early childhood education, especially for children with learning delays, emerged as a critical area of study (Murdiyanto et al., 2023). Understanding the interactions between the child, the application, the facilitator, and the learning environment played a central role in the effectiveness of tablet-based learning tools (Murdiyanto et al., 2023). The findings highlighted the complexity of technology

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in education, emphasizing the need for a broader understanding of the interaction between technology and context for educational benefits. The development of usable arithmetic platforms using NoCode technology demonstrated the potential of innovative approaches to elementary math instruction (Cabatuan & Dales, 2022). The use of instructional games also emerged as a promising avenue, providing engaging practice and support for students, thereby improving their problem-solving skills (Obina et al., 2022). However, the need for continuous improvements and the importance of covering a broader range of elementary math concepts were acknowledged as limitations in these studies.

Identifying and supporting slow learners, especially in resource-constrained environments, were key themes in several studies (Mukhlis et al., 2023; Sutomo & Herman, 2023). Alternative methods for identifying slow learners, such as teacher interviews, analysis of student report cards, and examination administration, proved to be successful in rural schools (Sutomo & Herman, 2023). The involvement of various stakeholders, including guidance and counselling counsellors and parents, was crucial in supporting slow learners' education (Ilzam & Purwoko, 2023). The study on the Realistic Mathematics Education (MRE) method illuminated the impact of different learning environments on slow learners' performance, suggesting the potential benefits of utilizing MRE at home (Hafidah & Rukli, 2022).

In summary, these studies collectively underscore the importance of comprehensive usability evaluation, inclusive design principles, and tailored interventions in educational mobile applications. While advancements have been made in understanding learning disabilities and designing apps for specific user groups, challenges in practical implementation, long-term impact assessment, and integration into educational curricula persist. Continued research and collaboration between researchers, educators, app developers, and users are essential to address these challenges and create truly inclusive educational mobile applications. These studies collectively contribute valuable insights into the diverse challenges and innovative solutions in the realm of mathematics education for students with learning disabilities.

However, it is essential to acknowledge the limitations of individual studies, such as small sample sizes, specific focus areas, and potential biases in self-reported data. Future research should aim to address these limitations, focusing on longitudinal studies, larger and more diverse samples, and the development of standardized assessment tools. Collaborative efforts between researchers, educators, and policymakers are crucial to implementing evidence-based practices and fostering inclusive mathematics education for all students.

A. Answers to review questions

1) Prevailing Patterns and Emerging Trends in Educational Mobile Apps for Mathematics Learning:

The studies reviewed provide a comprehensive overview of the evolving guidelines for developing educational mobile apps, particularly tailored for students with specific learning needs such as dyscalculia and autism. These studies emphasize the importance of comprehensive usability evaluation, task checklists, and satisfaction questionnaires (Hamid et al., 2022). Usability, pedagogical aspects (Ariffin et al., 2017), and novel features are focal points in the framework for evaluating children's educational mobile apps, emphasizing a holistic approach often overlooked in existing evaluations.

Furthermore, advancements in machine learning tools for visually impaired individuals are transforming the landscape of app accessibility (Tahir & Arif, 2014). Machine learning enhances UI interactions and task accuracy, aligning with the overarching goal of inclusive design. The necessity of bridging behavioural and neuroimaging literature to understand learning disabilities is highlighted in studies focusing on autism care and intervention apps (Liu et al., 2023; Valencia et al., 2022). Utilizing fMRI to assess brain activity provides valuable insights into the neurological aspects of learning disabilities, paving the way for tailored interventions.

Incorporating formal evaluation methods tailored to the unique characteristics of individuals with ASD is crucial in app development for this user group (Hersh & Leporini, 2013). Specialized evaluation methodologies ensure a positive and relevant user experience for individuals with ASD, addressing their unique needs. Despite these advancements, challenges persist in practical implementation, long-term impact assessment, and integration into educational curricula, necessitating continued research and collaboration between stakeholders.

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2) Evolution of Guidelines Over Time

The evolution of guidelines for educational mobile apps is evident in the studies reviewed. Efforts to comprehend the challenges faced by dyscalculia children have led to the creation and validation of the Calculic Model (Abd Halim et al., 2018; Donevska-Todorova et al., 2020; Laws et al., 2022). While these studies contribute significantly to understanding dyscalculia, challenges in practical implementation and integration into educational settings remain, highlighting the need for continuous refinement.

Educational game development, with its emphasis on collaboration, mobile access, and universally accepted heuristics, illustrates the evolving nature of app guidelines (Gocheva & Somova, 2015). These studies emphasize the importance of considering diverse learners, particularly disabled students, ensuring inclusivity in educational games. Moreover, the effectiveness of mobile game-based learning, especially in primary education, is a topic of considerable interest (Rohizan et al., 2020). Positive feedback from real classroom settings indicates the potential of mobile game-based learning in engaging students and enhancing their educational experience, showcasing the evolution of educational strategies over time.

3) Pedagogical Theories and Technological Advancements:

The incorporation of pedagogical theories and technological advancements is a central theme in the studies. The integration of ICT in special education represents a paradigm shift, emphasizing the effectiveness of customized game-based activities (Maloy et al., 2023; Gulliford et al., 2021). These studies underscore the importance of adapting pedagogical methods to technological advancements and tailoring interventions for specific disabilities.

Tablet technology's introduction in early childhood education represents a significant technological advancement, emphasizing the need for a broader understanding of the interaction between technology and context for educational benefits (Murdiyanto et al., 2023). The development of usable arithmetic platforms utilizing NoCode technology showcases innovative approaches, providing engaging practice and support for students (Cabatuan & Dales, 2022). However, continuous improvements and the need to cover a broader range of elementary math concepts are acknowledged, highlighting the importance of technological advancements in pedagogical tools.

Identifying and supporting slow learners, particularly in resource-constrained environments, necessitates innovative solutions (Mukhlis et al., 2023; Sutomo & Herman, 2023). Alternative methods for identifying slow learners, such as teacher interviews and examination administration, have proven successful, demonstrating the integration of technological tools in pedagogical approaches (Sutomo & Herman, 2023). Additionally, the study on the Realistic Mathematics Education (MRE) method provides insights into the impact of different learning environments on slow learners' performance, emphasizing the need for adaptability in pedagogical methods (Hafidah & Rukli, 2022).

IV.CONCLUSION

In this preliminary literature review, the diverse studies explored have provided invaluable insights into the intricate realm of educational mobile apps for mathematics learning. The trajectory of this field is marked by innovative research endeavours, deeply rooted in the principles of inclusivity and accessibility. These studies have illuminated specific facets of this dynamic landscape, addressing the unique needs of students with dyscalculia, autism, and slow learning processes. One of the prominent trends discerned is the growing emphasis on comprehensive usability evaluations and holistic approaches, filling gaps overlooked in previous assessments. The integration of machine learning tools and the synergy between behavioural and neuroimaging research have significantly enhanced app accessibility and interventions for students with learning disabilities, heralding a transformative era in the field. Moreover, the tailored evaluation methods designed for students with ASD exemplify a steadfast commitment to crafting meaningful and relevant learning experiences for diverse user groups.

The evolution of guidelines for educational mobile apps is evident in the strides made by these studies. From innovative solutions stemming from an understanding of dyscalculia challenges, as showcased by the Calculic Model, to the collaborative and inclusive approach in educational game development, these studies have highlighted the adaptability and engagement that form the core of effective pedagogy. The integration of

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pedagogical theories with technological advancements is at the heart of these endeavours, demonstrated by the integration of ICT in special education, the introduction of tablet technology in early childhood education, and the development of importance of adaptability and customization in pedagogical strategies.

but also underscores the imperative of sustained collaboration among researchers, educators, app developers, and policymakers. The journey toward truly inclusive mathematics education continues, with challenges serving as stepping stones toward innovative solutions. As technology advances and pedagogical theories evolve, the future of educational mobile apps holds the promise of equitable learning opportunities for all, regardless of learning abilities. Through persistent research efforts and a collective commitment to inclusivity, the transformative potential of educational mobile apps in shaping the educational landscape for students with learning disabilities becomes increasingly tangible, paving the way for a more inclusive and accessible educational future.

A. IMPLICATIONS AND PATH FOR FUTURE RESEARCH

In light of the insights gleaned from the reviewed studies, several key areas merit attention in future research endeavours. Longitudinal studies with extensive and diverse participant pools should be conducted to unravel the sustained impact of educational mobile apps on students with learning disabilities. Standardized assessment tools, tailored to accommodate various learning abilities, are essential in gauging app effectiveness accurately and guiding educational strategies. Collaborative efforts between researchers, educators, and policymakers are vital to the successful implementation of evidence-based practices, ensuring inclusive mathematics education for all.

Also, exploring emerging technologies, such as virtual reality and artificial intelligence, holds promise for creating personalized, adaptive learning experiences. These technologies can be harnessed to meet the unique needs of diverse learners, ushering in a new era of inclusive education. Furthermore, the dissemination of successful app implementations and best practices should be prioritized, fostering widespread adoption and maximizing the positive impact of educational mobile apps on diverse learning communities.

usable arithmetic platforms using cutting-edge NoCode technology. Furthermore, alternative methods for identifying and supporting slow learners, such as the MRE method, underscore the

In conclusion, this review not only illuminates prevailing patterns and emerging trends in educational mobile apps for mathematics learning

B. CONTRIBUTIONS AND BENEFITS

This review consolidates diverse studies, providing a deep understanding of educational mobile apps for mathematics. It not only highlights challenges and innovative solutions but also offers practical implications for educators and developers. By emphasizing usability, inclusivity, and tailored interventions, it guides future research and underscores the transformative role of mobile apps in inclusive education.

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