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PAPER

TaLNA App: An Interactive Numeracy Mobile Learning Application for Children with Autism

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ABSTRACT

In light of the COVID-19 pandemic's disruptions to education, there is a growing need for alternative learning methods, particularly for children with autism who thrive on routine and familiarity. This study aims to enhance numeracy learning for children with autism by using the touchscreen-assistive learning numeracy application (TaLNA) during the post-pandemic period, aligning with Sustainable Development Goal (SDG) 4 (quality education). Our primary focus is to leverage mobile learning through the TaLNA application to provide specialized educational content and remote progress monitoring. Combining mobile learning with SDG 4 principles ensures continuous access to education, promoting inclusivity and equity, even in challenging circumstances. Mobile learning offers personalized numeracy experiences tailored to individual needs, maintaining educational consistency and structure amidst disrupted routines and environments. This research has significant implications for instructors, teachers, and parents of children with autism, providing valuable insights for their pedagogical approaches.

KEYWORDS

children with autism, touchscreen-assistive learning numeracy application (TaLNA), education mobile app, numeracy, COVID-19

1 INTRODUCTION

All aspects of daily life, including education, were disrupted by the COVID-19 pandemic. The pandemic has been going on for several years and has impacted how we live, work, and learn. Children with autism may struggle to adapt to these changes as schools close and remote learning becomes the norm. As the world enters a post-pandemic era, using mobile learning to improve education for children with autism has become increasingly important. The said technology provides a flexible and customizable learning platform that enables the delivery of specialized services and remote support [1]. Even though this learning environment is still in the infant stage here in Malaysia, there is no doubt that the rapid

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advancement of technology influences education in general. Using mobile technology in education, with the support of appropriate pedagogical approaches, sets the learning path for the learners. It protects the right of children with autism to access appropriate and equal education. These sentiments resonate profoundly with Sustainable Development Goal 4 (SDG 4) and quality education. The pandemic's turbulence has had pronounced implications for education, particularly impacting children with autism, who thrive within structured routines and familiar settings. Amid this turbulence, the prominence of mobile learning emerges as a strategic solution in alignment with the core principles of SDG 4. Within this intricate and evolving landscape, a pressing research problem beckons our focused attention: How can mobile learning be strategically harnessed to comprehensively address the multifaceted educational needs of children with autism in the aftermath of the pandemic? The jarring and unprecedented transition to remote learning has laid bare the inadequacies of conventional educational models, particularly in their capacity to accommodate the diverse learning styles and requirements of children with autism. This study is poised to illuminate a path forward, delving deeply into this critical issue.

In the post-pandemic era, mobile learning can provide several advantages to children with autism. It enables the delivery of specialized services by providing a flexible and adaptable platform for learning. Furthermore, according to [2], [3], mobile learning can facilitate the development of social and communication skills, particularly by using dynamic visual, video-based, and interactive games. Mobile learning also fosters engagement and motivation, allowing children with autism to learn at their own pace in a safe and secure environment. Mobile learning is the educational practice of gaining knowledge through mobile technologies, such as smartphones [4]. Children with autism who struggle to learn in traditional classroom settings may benefit from using mobile learning as an effective tool, especially in understanding numeracy skills. Learning numeracy skills is important for every child with autism, as it can significantly impact their ability to succeed academically and in everyday life. Understanding numbers, mathematical operations, and the ability to solve problems using quantitative reasoning are all examples of numeracy skills. Their freedom and capacity to navigate their environment depend on these abilities. Children with autism may struggle with communication, social interaction, and sensory processing, making developing numeracy skills difficult [5]. Children with autism, with the right support and interventions, can learn and improve their numeracy skills, improving their overall cognitive development and quality of life. According to [6], in Malaysia, providing effective education and support for children with autism to develop their numeracy skills is critical to their academic and life success.

This study initially adds to the body of knowledge by examining the particular advantages and results of mobile learning interventions in teaching numeracy to children with autism. It provides empirical evidence to support best practices and decision-making. Furthermore, by integrating mobile technology, the study offers a dynamic perspective on instructional approaches, incorporating interactive interfaces, adaptive features, and engaging multimedia content, enhancing engagement and promoting learning outcomes [7]. Also, the study has practical implications for educators, parents, and practitioners, equipping them with evidence-based strategies and resources to effectively utilize mobile learning in their instructional practices. By emphasizing the personalized and tailored nature of mobile learning, this work highlights the potential to meet the diverse needs of children with autism, fostering

individual growth and achievement in numeracy skills. By exploring uncharted territory, providing empirical evidence, and offering practical insights, this study sets a new trajectory for educational interventions that can positively impact the lives of children with autism, their families, and the broader community. Hence, the objective of this study is to enhance numeracy learning for children with autism during an endemic COVID-19 outbreak by using a touchscreen-assistive learning numeracy application.

2 LITERATURE REVIEW

It is estimated that the prevalence of autism spectrum disorder (ASD) in Malaysia is about 1.8%, comparable to rates found worldwide. Research on prevalence of ASD in Malaysia, especially children with autism, is still at the infant level and has concentrated on a wide range of themes, such as epidemiology, the stress experienced by parents, the difficulties encountered by parents, employment opportunities, and public awareness. According to Google Trends, the percentage of Malaysians searching for information on autism is still in its infancy. According to [8], this is due to the general public in Malaysia having limited awareness and understanding of ASD, with many misconceptions and negative attitudes reported. The Google trend also supports this assertion (see Figure 1).

It is the responsibility of all individuals not to ignore but to educate every child [9]. This is identical to the Malaysian government's mandatory school attendance policy for all children. The government of Malaysia provides educational facilities for all Malaysians, including those with disabilities or special requirements. In this country, even those with special needs, particularly children with autism, are encouraged to learn and gain knowledge. Following the National Education Philosophy, the curriculum designed to educate and improve children with autism does not differ from that designed for typical students regarding the emphasis placed on emotional, spiritual, physical, and intellectual development. However, regarding teacher preparation and training, curriculum, and school facilities, educating students with special needs differs greatly from educating typical students.

According to [10], the advancement of technology has produced various creative apps that incorporate numerous visual supports and design models for technology-based autism intervention. It uses mobile, virtual reality, teletherapy, and tablet technology and is widely praised as a successful strategy for fostering the abilities of children with autism [11], [12]. It is believed that using technology in teaching and learning can address several problems associated with numeracy and transform children's perceptions of numeracy as difficult and tedious [13]. In order to fabricate, form, and practical plan an efficient tablet technology intervention program, it is essential to thoroughly personalize a solution so that it is a precise match for the end-users [14]. Literacy and numeracy are foundational skills that absolutely must be mastered by every single child. All children with autism must have a fundamental understanding of numeracy. They will be equipped with core life skills to help them perform successfully in society. This will allow them to create value for themselves, their community, and the nation. The exploration of such innovative avenues for educating children with autism resonates with the spirit of SDG 4, which is quality education. This goal champions equitable and inclusive education for all, fostering an environment where individual differences are valued and harnessed to achieve meaningful learning outcomes.

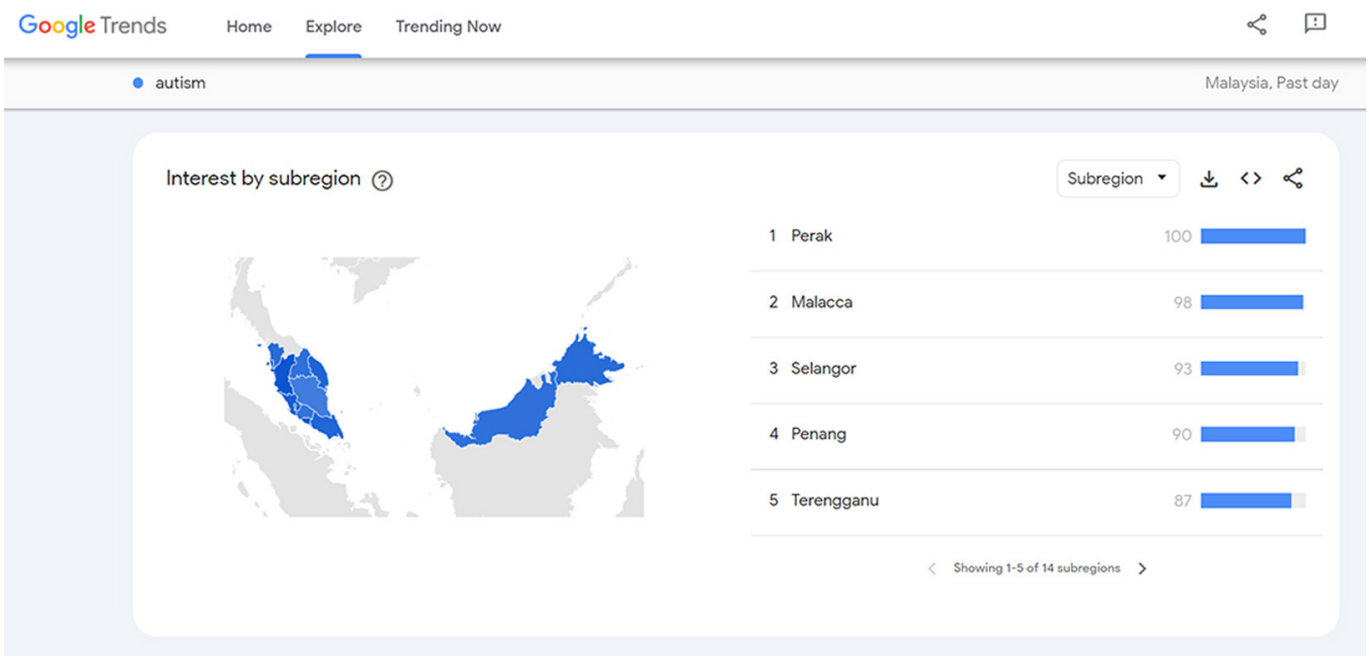

Fig. 1. Malaysians searching for autism-related information by state

Before the COVID-19 pandemic struck Malaysia, the state of the arts indicated that special education schools in the local classroom learning environment should have prioritized using mobile technology as a teaching aid. As a result, most teaching and learning settings for children with autism continue to adopt conventional techniques such as cue cards, static images, and a sequential visual approach. Even though the traditional method is still appropriate for use, the emergence of mobile technology in the open era should be noticed [15]. Children with autism spend practically all their time in special education classes. Mobile learning can bring various benefits to children with autism, including increased engagement, the capacity to learn quickly, and the ability to personalize their education [16]. In addition, children with autism may benefit from visual aids, social storytelling, and other tools that mobile devices can support. Learning in a regular classroom setting can present several issues for children with autism, but mobile learning may alleviate some of these difficulties [17]. For instance, mobile devices offer a less overpowering and more controlled learning environment, which enables children with autism to concentrate on their education without getting sidetracked by stimuli from the outside world.

A rising number of mobile learning apps are built particularly for children with autism, which is expected to continue expanding. These apps can provide various educational content, ranging from fundamental abilities like literacy and numeracy to more advanced skills like social and emotional intelligence [18]. A good number of these applications also offer a high level of personalization, making it possible for guardians and teachers to adapt the material to the requirements of each child. "Autism Colors" is an example of an app that may be used as a learning tool for children with autism. This application guides youngsters through learning basic color names by providing visual and auditory cues. One further illustration of this is the application known as "Autism Timer," which presents children with autism who have difficulty transitioning with a visual countdown timer that may be of assistance to them [19].

Mobile learning apps can also provide a tool for parents, instructors, and caretakers to monitor their child's progress and track the learning their child has

accomplished [20]. Many applications offer feedback on the child's performance, enabling parents to identify areas where their child may benefit from more support or practice [9]. Even though mobile learning has the potential to revolutionize the educational landscape for children diagnosed with autism, several obstacles and constraints still need to be addressed. Children with autism present several unique issues, one of the most significant of which is the requirement that mobile educational applications be useful and easily accessible. Because of this, it may be necessary to conduct further research and development to develop apps tailored specifically for this audience [21]. Incorporating mobile learning into the overall education plan for the child presents another obstacle that must be overcome. Mobile learning should not replace education and support provided in person; rather, it should be viewed as an addition to more conventional learning in a classroom setting. Mobile gadgets can serve as communication devices that can be carried around in a pocket. These learning devices can be used on the move. Affordability, portability, and mobility are also among its benefits, in addition to the adaptability of multimedia content and storage. Because of the touchscreen user interface, it is both appealing and easy to operate, which is especially helpful for people who have poor motor skills. Because of its adaptability and more sophisticated capabilities, mobile technology is creating new openings for additional research in computer-based therapy for children with autism [22].

Mobile learning has become increasingly popular in Malaysia for children with ASD, particularly during the COVID-19 pandemic. As a result of the closure of schools and the implementation of other social isolation measures, many children with autism have been unable to obtain the in-person support and services they require. According to [23], mobile technology, including mobile learning applications, has been shown in studies to provide benefits such as portability, accessibility, and customized learning experiences. The challenges, however, include the need for individualized and personalized approaches to meet the diverse needs of children with autism, parental involvement, and technical support. In Malaysia, reviews of mobile applications for children with autism have emphasized the importance of features such as social skill development and sensory stimulation, as well as the need for evidence-based research [24].

This study holds immense significance and makes substantial and novel contributions to the existing literature in multiple impactful ways. Investigating the potential of mobile learning to enhance numeracy skills in children with autism addresses a critical gap in the special education domain. It expands the understanding of effective interventions for this population. Considering the evolving educational landscape, shaped by remote and hybrid learning models, this study places emphasis on the post-pandemic perspective, which adds timeliness and relevance. By focusing on integrating mobile learning, the study pioneers creative techniques that use technology to meet the learning needs of children with autism, pushing the boundaries of educational interventions. Furthermore, thorough research methodologies and empirical evidence contribute to the evidence base, providing factual findings that can inspire evidence-based practices and improve outcomes for children with autism.

3 METHOD

As inert and dynamic images and videos can be incorporated into the learning process, remote systems are a natural fit for many children with autism who are visual learners and gravitate toward digital technology. Children with autism are

becoming more receptive to mobile learning devices due to the compact dimension of the screen, and the touchscreen interface helps children concentrate by providing intuitive interaction. According to [25], a mobile application is designed to assist children with autism and enhance their emotional and social communication skills [26]. A need analysis has been performed to seek the benefit and usage of mobile technologies to support children with autism in learning environments. However, we identified a gap in this context and addressed it by conducting a needs analysis that combined a literature review with observations and interviews at an autism center in Selangor, Malaysia. Our purposive sampling approach involved selecting five children with autism and two special needs teachers, with sample selection criteria outlined in Table 1.

Table 1. Selection criteria for the implementation and evaluation phases

No	Selection Criteria
1	High Functioning Children with Autism
2	Special Education Teacher
3	Volunteer

Touchscreen-assistive learning numeracy application is a mobile learning application based on Android phones and tablets established for children with autism here in Malaysia. The application incorporates improved Treatment and Education of Autistic and Related Communication-Handicapped Children (TEACCH) programs, Discrete-Trial Training (DTT) procedures, and behavioral principles of ABA to train receptive verbal communication targets across different numeracy programs. The application uses modified TEACCH and DTT procedures to introduce and randomly rotate targets with rules that affect when a target is considered learned. The TEACCH and DTT procedures, based on those described by [27], were adapted for a gamification framework to improve learning outcomes.

In data collection, this research adopted a dual-pronged approach rooted in direct observation and semi-structured interviews. The central focus of this inquiry rested on five high-functioning children on the autism spectrum. To underpin the investigative process, a meticulously crafted fieldnote instrument was employed, designed with precision to ensure impartial analysis, free from potential sources of bias or discrimination. To enhance the validity of the observations, select interactions were diligently recorded, creating a repository of primary data for subsequent reference and scrutiny. The study's unwavering focus remained on these five high-functioning children with autism. A comprehensive panorama of their behaviors and emotional responses was meticulously captured through observations and recordings, spanning five sessions, each lasting approximately thirty minutes.

The implementation phase, spanning five weeks, was characterized by intensive engagement. During this period, the researchers committed eight hours to interviewing the participants. This immersive approach significantly enriched the data pool, facilitating a profound understanding of the intricacies underpinning each child's learning journey. Detailed information regarding the observation sessions can be found in Table 2. By providing insights derived from structured observation and direct interaction, this research method offers a comprehensive understanding of the intricacies that define the engagement between children with autism and the TaLNA application. This approach is rooted in the Malaysian context and capitalizes

on cutting-edge educational principles and methodologies, underscoring its real-world relevance and significance.

Prior to the commencement of the experiment, the researchers took meticulous steps to ensure a responsible and informed approach to implementing the TaLNA app. They provided comprehensive training to the teachers, divulging all the intricate details of the application well in advance. This thorough briefing equipped educators with the knowledge and expertise necessary to guide and support children with autism effectively. Once the teachers had acquired a profound understanding of the application's functionalities and capabilities, they were entrusted with the touch-screen devices. Their pivotal role in facilitating the experiment for children with autism was instrumental in creating a conducive learning environment.

The experiment seamlessly integrated the activities outlined in the theoretical framework, encompassing a triad of carefully curated tasks. The first task aimed at acquainting the children with numbers, laying the foundation for numeracy learning. The second task entailed guided learning, where children followed a sequence of numbers, connecting them by using dots, fostering cognitive development and problem-solving skills. Lastly, the third task revolved around arithmetic, encompassing addition and subtraction exercises and cultivating essential mathematical competencies. Please refer to Figures 2 and 3.

Table 2. Observations and interviews conducted during the implementation phase

Children with Autism	Observation and Interview	Time
1	Sessions were held with the respondents.	0900 – 0930 hrs.
2	Sessions were held with the respondents.	0930 – 1000 hrs.
3	Sessions were held with the respondents.	1000 – 1030 hrs.
4	Sessions were held with the respondents.	1030 – 1100 hrs.
5	Sessions were held with the respondents.	1100 – 1130 hrs.

Note: The time allotted for each respondent throughout each session is between twenty and thirty minutes.

Children with autism were furnished with variations of instructions to experiment with the learning application. Children with autism were given a response time after each instruction to identify and complete each activity. For instance, children with autism must listen to the voice-over, which articulates the number in words, and then repeat after the voice-over. This level teaches the user to recognize and pronounce the most fundamental numerals. Additionally, children with autism must connect each dot to create a number. Please refer to Figure 4. For the benefit of end users, reinforcement and error correction are provided throughout all activities. All correct responses are rewarded with verbal praise via voice-overs (e.g., "Good job") and visual animations that appear across the screen with accompanied sound effects. Please refer to Figure 5. Although the type of reinforcement provided is limited (i.e., visual animation with sound effects), a preference assessment is administered before learning cycles to individualize the reinforcement animations.

The researcher engaged in a series of five sessions with each of the five children with autism, during which caregivers assumed an integral role in facilitating the implementation process within the home environment during intervals

of their children's leisure. In an effort to comprehensively capture the nuances of these interactions, videos were recorded to document the child's active engagement during the implementation sessions and subsequently shared with the research team.

Fig. 2. An activity centered around the identification of numbers

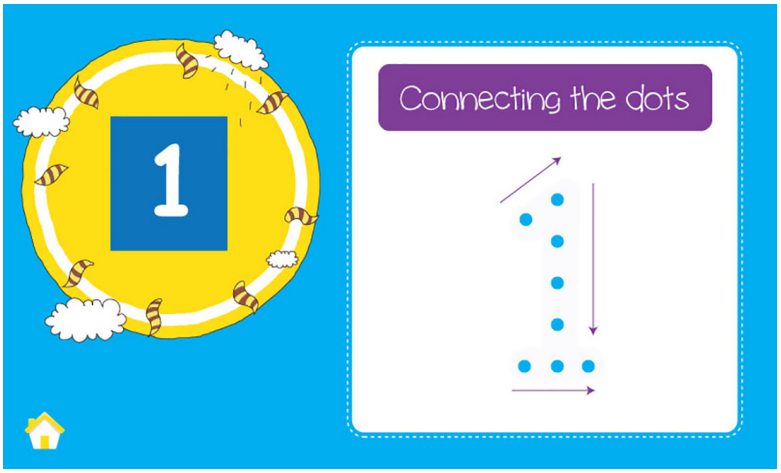

Fig. 3. An activity centered on connecting dots to create a numerical shape

Fig. 4. An activity centered on addition and subtraction

Fig. 5. Verbal praise for any activity that has been completed

As the culmination of the five sessions approached, the researcher conducted targeted, semi-structured interviews with the caregivers. This phase of one-on-one interviews aimed primarily to validate and affirm the data gleaned from direct observations, lending an added layer of assurance to the research findings.

4 RESULT AND DISCUSSION

Learning style or learning process refers to how children prefer to learn new information, including plans and approaches used in teaching and learning. Children with autism learn in various ways, even though there are numerous theories about cognitive learning and the theory of mind [28], [29]. Although the learning approach is important, using appropriate teaching and learning aids in education is also important [30]. According to [31], in their study, special needs children would learn quickly if they could use their preferred technique. Consequently, it emphasizes the significance of technology reform, which may assist teachers and instructors in delivering a modern educational strategy for children with autism [14], [25]. To determine the acceptability of the TaLNA application, the said application has been evaluated with children with autism. Five children with autism participated in the experiment. The University Research Committee has authorized this research project, and according to [32], research ethics is a critical foundation for conducting proper research. It guarantees that participants are handled ethically, their rights are safeguarded, and any possible harm is minimized. Researchers can retain public trust, contribute to the advancement of knowledge, and safeguard the integrity of their findings by adhering to research ethics.

The children with autism were under the observation of their instructors who guided them. Direct observation involves physically being present in the same environment as the children with autism, allowing the instructors and guidance to observe their behaviors and interactions in real time. This method offers several advantages. Firstly, it enables the collection of rich and detailed data about the children's actions, communication patterns, and engagement in activities. Observing the children directly allows a more accurate and nuanced understanding of their strengths, challenges, and specific needs. Furthermore, direct observation allows instructors and guidance to intervene and provide immediate support or guidance when necessary. They can observe and assess the effectiveness of different

instructional strategies, interventions, or accommodations in real time, allowing for prompt adjustments to better meet each child's specific needs. This personalized and dynamic approach enhances the quality of instruction and support provided to children with autism. Please refer to Figures 6 and 7. Most children diagnosed with autism exhibited motivation, excitement, and enjoyment while using the touch-screen numeracy learning program, as determined by direct observation and the feedback provided by their instructors. Children with autism who participated in the experiment and used the TaLNA apps exhibited improvements in their positive attitude, increased concentration, motivation, and passion for learning more about the mathematical topic, as seen in Table 3. The results of the experiment indicate that these improvements occurred. Using mobile devices rather than traditional learning approaches has many important benefits. To begin, utilizing them is straightforward because children with autism can interact adequately with mobile devices, their programs, and their senses by touching the screen. Second, mobile applications are very popular. They are well-suited to the learning needs of children with autism because they are visually appealing and provide a consistent, predictable learning environment. Finally, mobile devices are simple to transport because they fit in any individual's pocket and can be used anywhere and anytime. The study also revealed that systematic instruction is the most effective method for assisting children with autism to learn numeracy.

According to Table 3, four children with autism exhibited the ability to engage with the TaLNA app, although some activities presented challenges for full participation. However, one child was unable to utilize the app due to a lack of mental readiness. The special education teacher posited that cognitive exhaustion might contribute to this scenario. The comprehensive outcomes of the experiment underscore that the majority of high-functioning children with autism effectively communicated through the learning app and actively engaged in all three numeracy tasks embedded within the program.

Table 3. Experimentation observation analysis on the TaLNA app towards children with autism during post-pandemic COVID-19

Number of Children with Autism	Children with Autism, Behavior, Motivation, and Attitude Response Towards the TaLNA App.	Engagement Level		Completion of Activities	
		Yes	No	Yes	No
Children 1	Positive	√		√	
Children 2	Positive	√		√	
Children 3	Positive	√		√	
Children 4	Not Positive		√		√
Children 5	Positive	√		√	

This innovative tool played a pivotal role in empowering children with autism to grasp essential numeracy skills. From a technical standpoint, TaLNA supports the conventional teaching strategies that are still frequently employed in schools today. This innovative approach seamlessly aligns with SDG 4, highlighting the lifelong pursuit of quality education. The TaLNA app shines as a ray of hope, supported by concrete data and steered by committed educators. It increases numeracy instruction for children with autism while simultaneously igniting a larger discussion about the relationship between technology and pedagogy, promoting high-quality education for all.

Fig. 6. One of the respondents hands-on experience of using the TaLNA app

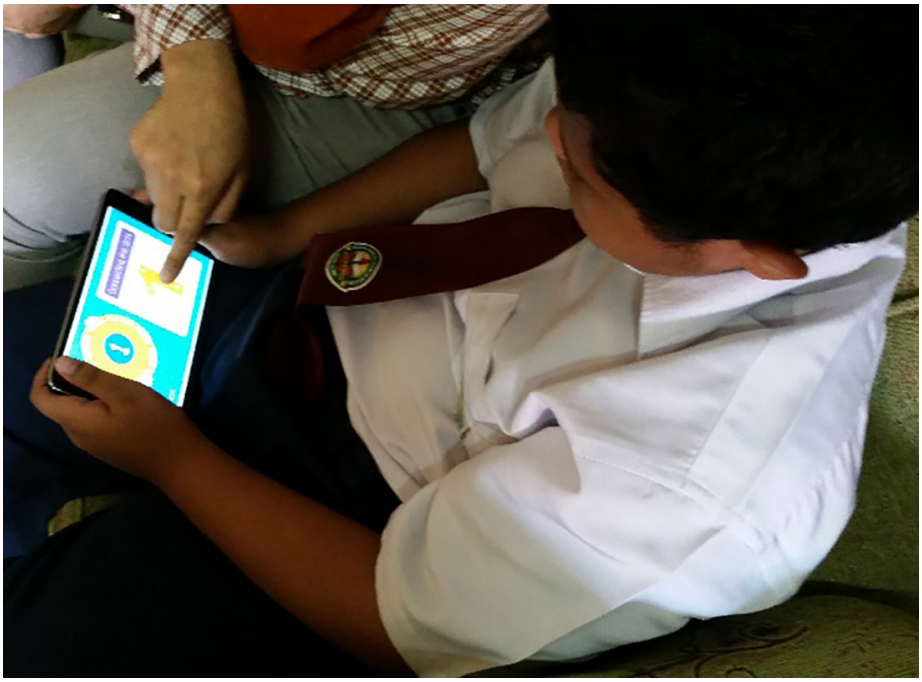

Fig. 7. A respondent being taught how to use the TaLNA app

5 CONCLUSION

Children with autism find mobile technology to be quite alluring. The children have a more playful attitude and feel more secure when they receive predicted responses from a mobile device. Mobile learning has many advantages, one of which is that it may be adapted to meet the specific needs of children with autism. This is of utmost significance for children with autism since they may have specific educational requirements that call for a more tailored approach to their educational experience. Learning that

could be done on a mobile device has the additional benefit of being accessible at any time and from any location. Children with autism sometimes have difficulty adjusting to new environments and routines, so this might be a very effective strategy. Mobile learning, especially the TaLNA app, allows students to access their numeracy educational resources and lessons from the convenience of their own homes or in a setting that is already familiar to them. This helps students feel less stressed and anxious.

To summarize, mobile learning for children with autism during the post-COVID-19 period could revolutionize how children with autism are educated. The transformative impact extends beyond academic growth, fostering the development of crucial social skills and empowering these children to unlock their full potential. However, it is crucial to emphasize that mobile learning should complement traditional teaching methods rather than replace them, ensuring a balanced and comprehensive approach to education. As we stand at the crossroads of technological innovation and educational inclusivity, the integration of mobile learning stands as a promising step forward in alignment with the principles of quality education in SDG 4.

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