Measuring the Learning Progress of Autistic Students Using the Smart Heuristic Kit: An Experimental Study in the UAE

Ahmed Shuhaiber
College of Technological InnovationZayed University
Abu Dhabi, UAE
ahmed.shuhaiber@zu.ac.ae

Khaled Al-Omoush
College of Business
Al-Zaytoonah University of Jordan
Amman, Jordan
k.alomoush@zuj.edu.jo

***Abstract*—This research embarked on an experimental study to gauge the efficacy of the Smart Heuristic Kit in enhancing learning outcomes for students diagnosed with Autistic Spectrum Disorder (ASD Level 1) in the UAE. Conducted in Abu Dhabi, the study involved 50 students aged 6-12 from a specialized autism center. Throughout a semester (Oct-Dec 2022), teachers integrated the Smart Heuristic Kit into the conventional curriculum, overseeing its use to meet designated educational objectives. The primary results indicate that the kit significantly influenced students' vocal awareness, reading basics, word recognition, speaking fluency, and overall learning performance. However, it did not markedly affect their comprehension related to autism learning. Moreover, the skills appear interrelated, with pronounced relationships between vocal awareness, reading basics, word recognition, and speaking fluency. Comprehension displayed a weaker correlation with the other skills but remained significant. The research findings provide insights into novel methods that could reshape learning paradigms for autistic students in the region. They also highlight various theoretical and practical implications and suggest avenues for future research.**

I. INTRODUCTION

In the realm of contemporary education, there exists a fundamental commitment to the principles of inclusivity and equal access to high-quality learning opportunities. These principles extend to all students, regardless of their individual differences in cognitive, emotional, or physical attributes. One of the most pressing and prominent challenges confronting educators, researchers, and policymakers within this broad framework of inclusive education is the productive and comprehensive educating of students diagnosed with Autism Spectrum Disorder (ASD). This complex neurodevelopmental condition is marked by a diverse array of cognitive and behavioral characteristics,rendering it imperative to develop innovative educational techniques and provide specialized assistance to meet the unique learning requirements and preferences of these children [1], [2].

The advancement of technology, particularly smart devices, on autistic kids' education is diverse and profoundly advantageous. It has the potential to produce more accessible, personalized, and inclusive learning experiences for autistic students, improving their overall quality of life [3], [4]. Smart technology has brought about a remarkable transformation, holding significant potential for enhancing students' educational journeys [5]. This digital transformation has enabled autistic students with visual aids and communication support, the cultivation of social skills, tools for refining sensory perception, enhancements in executive functioning abilities, inclusive educational settings, as well asopportunities for remote and distance learning [3], [6].

The elevate and rise of the positive human perspective of people with special needs have inspired educational institutions, specialists, and technology developers to engagein an ongoing effort to leverage the advancing potential of assistive smart technologies, creating environments in whichautistic students can thrive academically, socially, and emotionally. However, despite efforts to develop novel smartdigital solutions or exploit existing apps and devices, the Smart Heuristic Kit (SHK) technology has remained unexplored, where there have been no experimental studies conducted to assess its potential for enhancing the learning ofautistic students. Furthermore, the experimental literaturereveals a lack of studies measuring the learning progress of autistic students, particularly in terms of vocal awareness, reading, word recognition, speaking, and comprehension,when utilizing smart technologies in general, and the SHK inparticular. Therefore, this experimental study aims to answerthe following question: Does SHK contribute to learning progress of autistic students?

To answer the research question, an experiment will be implemented on the use of SHK on a group of students with autism in the United Arab Emirates. This study spans a duration of three months and involves assessing the progressin their learning before and after the application of thistechnology.

II. LITERUTURE REVIEW

While infantile-onset ASD is on the rise in our societies, the predominant treatment options primarily focus on learning, skill development, cognitive, capabilities, and behavioral interventions [1] [3]. The human and social responsibilities have called upon governments, educationists, psychologists, families, health and autism care institutions, and researchers from different scientific disciplines to contribute to innovating and integrating smart assistive toolsto teach and learn those society members. However, theliterature has confirmed many advantages of technology- aided interventions, such as motivating ASD students tolearn, efficiency regarding staff and time, accessibility and adaptability of technology and interventions, and easy combination with other therapeutic-based approaches [7], [8], [9].

Many studies have been devoted to develop smart

technologies to enhance learning attention skills (e.g., [10], [11], [12]) and cognitive improvement in children with ASD (e.g., [1], [5]). Significant efforts were intended to develop digital intervention solutions to learn and enhance joint attention skills [13], [14]. On the other hand, the difficulty in perception and weak central coherence has caused spatial challenges and the need to support the daily navigation of children with ASD. These complications have motivated scholars to explore many digital solutions to help them perceive the spaces they live in, facilitate their everyday movements, and map secured places for them [15], [16], [17]. Furthermore, technological advances have also inspired researchers and scientists to innovate digital solutions for children with ASD in dealing with unexpected risks, cues andsafety issues [18], [19].

Since ASD children tend to withdraw from social relationships and prefer mechanical and formal interactions, technology-based interventions can provide effectivelearning tools [20]. The advanced development of innovative technologies has encouraged scholars to design smart digital solutions to learn speech and expressive verbal abilities [9] [21]. A significant line of research has focused on improving language, pronunciation of vocabulary, and learning new words [22], [23]. At the same time, the literature has many examples of developing smart applications to help improve social and emotional communication and interaction [24] [25]. In this regard, the enhancement of understanding of facial expressions to interpret the behavior and feelings of others have gained special attention [26], [27].

The literature confirms the role of smart technologies in teaching ASD children at early ages to minimize their life- long disabilities [19], [28]. Prior research emphasizes the importance of digital aid systems in educating those children as a student with ASD learns best by seeing rather than hearing [7], [29]. However, the human rights of childrenwith ASD in improving their educational level and capabilities have called scholars to develop digital solutions to support teaching basic education [28], [30]. Scholars have also sought to exploit smart technology to teach basic numbers, counting, math, and calculation skills [31], [32]. Cecil et al. [33] have gone beyond that, directing the innovative virtual learning environment to educate science and engineering concepts to children with ASD.

The literature includes a lot of sincere efforts to develop smart technologies that assist and support children with ASD, starting with early detection, treatment, and education, and not ending with improving their quality of life and providingthem with the completion of their daily life tasks. Among many innovative technological tools, novel smart solutions are developed based on artificial intelligence [6], [34], machine learning [23], [35], and the Internet of things (IoT) [1], [36]. Scholars have developed smart digital platforms for ASD students depending on advanced devices. The social robot has been used to teach verbal communication andinteraction skills, joint attention, and emotion and facialexpression recognition ability [11], [37]. Virtual Reality (VR)has also emerged as a novel digital approach with powerful educational and interventional capabilities as it has added a virtual dimension to real-world environments and provided interactive video gaming, where sounds and sights representthe central sensory stimuli [38], [39]. Furthermore, the literature reveals that Augmented Reality (AR) has been employed to improve attention skills, cognitive abilities, socioemotional skills, understanding of facial expression, and reading and writing skills [27], [40].

An overview of the literature implies that the development of smart assistive technologies has mostly been directed to improve social communication and interaction skills, which confirms the need for more academic and practical efforts to explore their capabilities in the education of students with ASD. More specifically, while reading and writing represent the basic skills of education, very fewstudies have intended to discover the role of smart technologies in building and enhancing these skills. Smart assistive technologies in the ASD context do not only mean using the latest developed software and devices. The smartness requirement of these technologies needs toconsider the pathological and demographic characteristics of this segment of students with varying autism levels, capabilities, ages, and needs. Furthermore, it needs to offer the potential for being comfortable, user-friendly, easy to use,simple, improving self-independent, motivating to self- acquire new knowledge, and relatively low-cost.

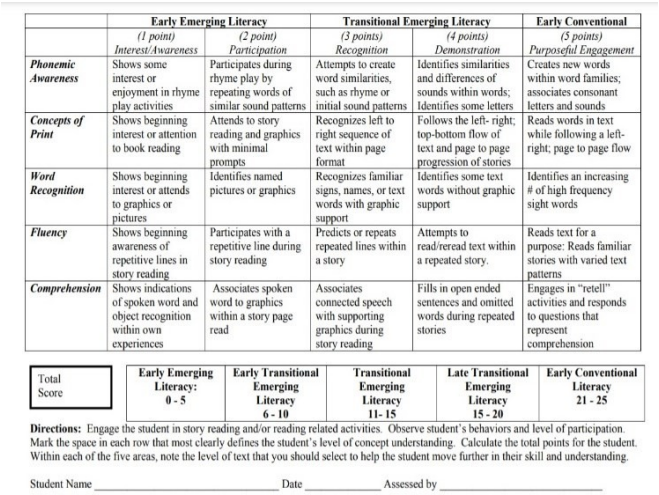
There are inconclusiveness and ongoing difficulties in providing experimental or clinical strong evidence regarding which smart technology is the most validated or healthier for ASD children, in terms of their autism level and age group, and which is most suitable for them from the point of view oftheir teachers, parents, and caregivers. These challengingacademic and practical gaps inspire this study to explore the capabilities of the SHK as a smart assistive device in improving the reading, writing, and listening skills of students with ADS and experimentally evaluate learning outcomes and the progress of students after using this technology. A SHK is a high-tech smart pen that uses a special notepad to record both sound and written words, enabling students to review everything a teacher says and writes. This technology provides multiple intellectual development channels by seeing, listening, touching, and speaking at the same time. Prior research provides evidence that digital pens can effectively assist students with learning disabilities in improving their performance in vocabulary, reading, and writing tasks [41], [42]. Despite the potential of the heuristic smart kit, the literature shows an absence of studies devoted to examining the capabilities of this smart technology in improving the education learning process and reading and writing skills of autistic children.

III. RESEARCH METHODOLOGY

The method followed in this research is experimental study. We asked the teachers of 50 ASD (Autistic Spectrum Disorder) student (Level 1) at one of the Autism centers in Abu Dhabi (The UAE). The age range of those students was6-12 years to investigate the effectiveness of the smart heuristic kit on achieving better learning outcomes inside classrooms. The teachers supervised the students to use the smart heuristic kit to achieve certain goals in their original curriculum by using this kit in a full semester time period (3 months: Oct-Dec 2022).

The heuristic smart kit used in the experiments includes apen technology which uses a special notepad and a high-techpen to record both sound and the written word, and by using that technology, everything a teacher says, and writes can be accessed by computers later for students to review. Other components of the smart kit include: talking theme pads, magic stickers, phonics books (in English and Arabic), workbooks, and Arabic alphabet pad. More details about the kit can be

found in the following website that provides the comprehensive tool kit under the brand name 'JoyClass' (https://www.huangsest.com/joyclass). In order the measure the learning progress of those participating students, thelearning index (shown in Fig. 1) was utilized, which contains the 4 dimensions: phonemic (sound) awareness, concept ofprint, word recognition, and comprehension.



	Early Emerging Literacy		Transitional Emerging Literacy		Early Conventional
	(1 point) Interest/Awareness	*(2 point) Participation*	*(3 points) Recognition*	*(4 points) Demonstration*	*(5 points) Purposeful Engagement*
Phonemic Awareness	Shows some interest or enjoyment in rhyme play activities	Participates during rhyme play by repeating words of similar sound patterns	Attempts to create word similarities, such as rhyme or initial sound patterns	Identifies similarities and differences of sounds within words; Identifies some letters	Creates new words within word families; associates consonant letters and sounds
Concepts of Print	Shows beginning interest or attention to book reading	Attends to story reading and graphics with minimal prompts	Recognizes left to right sequence of text within page format	Follows the left- right; top-bottom flow of text and page to page progression of stories	Reads words in text while following a left-right; page to page flow
Word Recognition	Shows beginning interest or attends to graphics or pictures	Identifies named pictures or graphics	Recognizes familiar signs, names, or text words with graphic support	Identifies some text words without graphic support	Identifies an increasing # of high frequency sight words
Fluency	Shows beginning awareness of repetitive lines in story reading	Participates with a repetitive line during story reading	Predicts or repeats repeated lines within a story	Attempts to read/reread text within a repeated story.	Reads text for a purpose: Reads familiar stories with varied text patterns
Comprehension	Shows indications of spoken word and object recognition within own experiences	Associates spoken word to graphics within a story page read	Associates connected speech with supporting graphics during story reading	Fills in open ended sentences and omitted words during repeated stories	Engages in "retell" activities and responds to questions that represent comprehension

Total Score	Early Emerging Literacy: 0 - 5	Early Transitional Emerging Literacy 6 - 10	Transitional Emerging Literacy 11- 15	Late Transitional Emerging Literacy 15 - 20	Early Conventional Literacy 21 - 25

Directions: Engage the student in story reading and/or reading related activities. Observe student's behaviors and level of participation. Mark the space in each row that most clearly defines the student's level of concept understanding. Calculate the total points for the student. Within each of the five areas, note the level of text that you should select to help the student move further in their skill and understanding.

Student Name _____ Date _____ Assessed by _____

Fig. 1. Autism Learning Progress Index

IV. Research Findings

The data analysis is performed by using SPSS 28.0 software. Firstly, and in order to understand the learning trends over time for all participating students, we plot the average scores for each category across the months the performance distribution revealed that there seems to be a slight increase in scores from month 10 to 12 for most categories, indicating improvement. More details can be found in Table I.

TABLE I. Performance distribution

	Level1	Level2	Level3	Level4	Level5
October	10	15	5	3	2
November	10	8	10	5	2
December	8	9	10	6	2

Secondly, it was found the using the kit had a significant impact on students' vocal awareness, reading basics, word recognition, speaking fluency and their overall learning performance, instead their understanding (comprehension). This result was expected in such that the visual and auditory stimuli from smart learning kits might be overwhelming or distracting, which could hinder comprehension. Also, the interactive nature of smart learning kits might lead some students to focus more on the technological aspects (like animations or sounds) rather than the content itself. This could detract from deeper comprehension. Also, the simultaneous presentation of text, images, and sounds can lead to cognitive overload for some autistic students, making it harder for them to focus on and comprehend the main message. The results are shown in Table II.

TABLE II. Comparison between categories

		Sum of Squares	Mean Square	F	Sig.
Vocal_awarness	Between Groups	115.658	2.966	2.506	<.001
	Within Groups	94.667	1.183		
	Total	210.325			
Reading_basics	Between Groups	123.992	3.179	2.285	<.001
	Within Groups	111.333	1.392		
	Total	235.325			
Words_recognition	Between Groups	106.633	2.734	2.173	.002
	Within Groups	100.667	1.258		
	Total	207.300			
Speaking_fluency	Between Groups	163.925	4.203	3.408	<.001
	Within Groups	98.667	1.233		
	Total	262.592			
Understanding	Between Groups	42.458	1.089	1.375	.115
	Within Groups	63.333	.792		
	Total	105.792			
TotalGrades	Between Groups	1895.867	48.612	2.577	<.001
	Within Groups	1509.333	18.867		
	Total	3405.200			

In addition, we investigated the inter-correlations amongthe learning dimensions, in order to discover whether the kit is complex impact on autism learning. As for Vocal Awareness, it has a strong positive correlation with Reading Basics (r=0.762) which is significant at the 0.01 level. This suggests that as vocal awareness increases, reading basics also tend to increase, and vice versa. Also, Vocal awareness has a moderate positive correlation with Words Recognition (r=0.678) which is also significant at the 0.01 level. Moreover, it has a moderate positive correlation with Speaking Fluency (r=0.652) significant at the 0.01 level. However, it has a weaker but still moderate positive correlation with Understanding (r=0.410) significant at the 0.01 level.

Another learning dimension is Reading, which was foundto have a moderate positive correlation with Words Recognition (r=0.674), Speaking Fluency (r=0.668), and a weaker correlation with Understanding (r=0.372). All these correlations are significant at the 0.01 level. On the other hand, words recognition had a strong positive correlation with Speaking Fluency (r=0.740), and a moderate correlation with Understanding (r=0.481). Both correlations are significant at the 0.01 level. However, speaking fluency wasfound to have a weak positive correlation with understanding(r=0.295) which is significant, but at a slightly higher p-value (0.001). All other correlations are found in Table III, below.

TABLE III. CORRELATIONS AMONG DIMENSIONS

		Vocal_ awarness	Reading_ basics	Words_ recognition	Speaking_ fluency	Understanding
Vocal_ awarness	Pearson Correlation	1	.762**	.678**	.652**	.410**
	Sig.(2-tailed)		0.000	0.000	0.000	0.000
	N	120	120	120	120	120
Reading_ basics	Pearson Correlation	.762**	1	.674**	.668**	.372**
	Sig.(2-tailed)	0.000		0.000	0.000	0.000
	N	120	120	120	120	120
Words_ recogniti on	Pearson Correlation	.678**	.674**	1	.740**	.481**
	Sig.(2-tailed)	0.000	0.000		0.000	0.000
	N	120	120	120	120	120
Speaking_ fluency	Pearson Correlation	.652**	.668**	.740**	1	.295**
	Sig.(2-tailed)	0.000	0.000	0.000		0.001
	N	120	120	120	120	120
Understanding	Pearson Correlation	.410**	.372**	.481**	.295**	1
	Sig.(2-tailed)	0.000	0.000	0.000	0.001	
	N	120	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

V. DISCUSSION

The experimental results revealed that the SHK contributes to enhancing vocal awareness in autistic students. This smart technology has improved students' ability to create new words within word families and connect consonants andsounds. It has also enhanced their ability to identify similarities and differences in sounds within words, as well as recognize some letters. After three months of using the SHK, students showed more interest in rhyming activities. Ithas encouraged them to attempt to find similarities between words, such as rhyme or initial sound patterns, reinforcing their engagement in rhyming by repeating words with similarsound patterns.

The experimental results reveal that the SHK plays a significant and multifaceted role in in the development and progress of reading skills among autistic students. Theseresults confirmed an improvement in word reading from left to right within a page layout, top-down, and the development of the story's events from one page to the next. The results ofthe post-use test showed increased interest in reading books and improved ability to independently prepare for reading stories and interpret graphics, with minimal external prompting and insistence.

The outcomes of the experiment indicate that the SHK has a substantial and versatile impact on the advancement and improvement of word recognition skills in autistic students. Students' abilities to identify a large number of the most frequent sight words have improved. The students were ableto recognize signs, names, and familiar text words with support with drawings. They were also able to detect new text words without graphics support. Furthermore, according to fundings, this smart technology It helped students enhance their ability to recognize labeled drawings/pictures and also increased their interest in them.

The findings confirm a significant role of the SHK in the progress of speaking fluency in autistic students. Students' abilities to read text with purpose and familiar stories in various text styles have improved. Students became more willing to attempt reading or rereading the text within a repeated story. They have demonstrated improved initial awareness and an increased ability to predict or repeat recurring lines within the story. Moreover, students became more likely to participate repeatedly in story reading.

The experimental results did not support a significant rolefor the SHK in improving the understanding ability of autistic students. Scholars confirmed that enhancing theunderstanding ability requires engaging in a range of cognitive processes, including comprehension, inferencing, and critical thinking [1] [5], [26]. While the SHK has the capacity to assist in certain aspects of reading, writing, vocal awareness, and speaking fluency, it may not have the depth and complexity necessary to exert a substantial influence on understanding, especially in more advanced or abstract content areas. Studies claimed that autistic students exhibit diverse learning styles and preferences [23], [31], [42-45]. Prior research also confirmed that while some students may find technology-assisted learning helpful, others may prefer alternative educational settings or under different instructional approaches. However, the varied nature of these preferences highlights the importance of offering a range of teaching methods to accommodate the individual needs of autistic learners.

VI. THEORITICAL AND PRACTICAL IMPLICATIONS

This experimental study contributes to the development of a theoretical framework for incorporating smart technologies into special education. Its outcomes improve our theoretical understanding of technology-enhanced learning for autistic students. This study deepens our understanding of the various learning requirements of autisticstudents and how cutting-edge smart technologies can be employed to support autistic students. This study contributes significant empirical evidence to our understanding of the impact of the SHK on enhancing educational outcomes for individuals with autism. Through a meticulous examination of advancements in vocal awareness, reading abilities, word recognition, speaking, and understanding ability, this study augments the existing body of literature by providing precise insights into the multifaceted effects of this smart technologyon different facets of learning process for autistic students.

This study contributes to the existing academic literatureby conducting a thorough examination of the potential benefits of SHK and recognizing that the educational needs of autistic students encompass various domains, such asreading, writing, vocal awareness, and speaking skills. Through this comprehensive analysis, this study broadens ourunderstanding of how advanced technology can address the multifaceted challenges associated with autism. The results of this investigation provide a solid groundwork for further studies delving into the intricacies of employing smart technology for interventions aimed at assisting individuals with autism. Moreover, this study opens up new avenues forfuture studies. These include investigating the long-term impacts, identifying the ideal implementation approaches, and considering the unique characteristics of students with autism.

The results of this experimental study hold promise for providing valuable practical insights and implications. Educational institutions, technology developers, and policymakers stand to gain substantial advantages from these findings. Educational institutions can acquire valuableinsights into how to adapt SHK to better align with the uniquelearning needs of students with autism. This newly acquired knowledge can then serve as a foundation for developing customized interventions and educational programs with the goal of enhancing overall learning outcomes. This studyhighlights the significance of providing educators with adequate training and opportunities for professional growth to effectively utilize SHK in assisting autistic students' educational requirements. The results of this study can also be a valuable asset for educational institutions striving to promote increased inclusiveness within their learning environments.

The study can inform technology developers about the specific needs and preferences of autistic students, enabling them to refine and enhance the SHK. In the realm of technology development, there is a potential avenue for innovation that involves enhancing the functionality of SHK. This could be achieved by integrating more sophisticated speech recognition capabilities, tailoring content toindividual users, and employing advanced data analytics. These improvements aim to enhance the SHK's effectiveness in assisting individuals with various aspects of language and communication, including vocal awareness, reading, word recognition, speaking skills, and understanding ability. Policymakers can utilize the results of this study to develop policies and guidelines firmly grounded in empirical evidence. These policies and guidelines would aim to facilitate the seamless incorporation of assistive technologies such as the SHK within educational environments for individuals with autism. These policies have the potential to facilitate funding efforts, encourage the integration of smart technology, and provide training opportunities for educators. Furthermore, policymakers can advocate for and implement policies that promote inclusive education practices, ensuring that educational institutions have the resources and support needed to integrate autistic students effectively, leveraging smart technology as a tool for inclusion.

VII. CONCLUSION

In conclusion, the Smart Heuristic Kit has demonstrated promising potential in augmenting key learning domains for students with Autistic Spectrum Disorder in the UAE, particularly in areas like vocal awareness, reading basics, word recognition, and speaking fluency. However, comprehension, a vital cornerstone of holistic learning, exhibited limited enhancement through the kit, urging educators and developers to delve deeper into strategies that might bridge this gap.

As we move forward, there are several pertinentdirections for future research. For instance, we recommend broadening the demographic. While this study focused on children aged 6-12 in the UAE, future research could extendthe application of the kit to different age groups and diverse cultural or regional settings to determine its versatility and adaptability. In addition, we suggest researchers consider a longitudinal study to observe the long-term effects and benefits of the Smart Heuristic Kit over multiple academic years, which could provide deeper insights into its sustained impact on students' learning trajectories. Moreover, integration the kit with other learning tools to explore how the SHK interacts or complements other educational tools andmethodologies, can also paint a clearer picture of its place ina multifaceted educational landscape. Furthermore, future research could delve into real-time feedback mechanisms within the kit, allowing educators to dynamically adapt and modify teaching strategies based on instantaneous student responses.

By heeding these directions, we can continue to refine and optimize tools like the Smart Heuristic Kit, ensuring that they cater to the holistic needs of every student, especially those with unique learning challenges.

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