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Article

Investigation into the effectiveness of wearable technology as assistive tools for Saudi students with special needs

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Abstract: This study fills a significant need in the literature by exploring the efficacy of wearable technologies as helpful aids for special needs students in Saudi Arabia. This 12-month quantitative study used a purposive sample of 150 kids representing a range of disability classifications. This study examines the effects of wearable technology, such as smartwatches and augmented reality goggles, on students' concentration and performance in the classroom. Wearable technology offers great promise, as descriptive statistics show that the experimental group had better involvement and academic achievement. The experimental and control groups vary significantly in terms of academic performance and engagement, as shown by independent samples t-tests. Wearable technology's distinct benefits are further shown by regression analysis, which shows a favorable correlation with academic achievement after the intervention. According to the results, wearable tech has great promise for inclusive education in Saudi Arabia. Strategic integration, teacher professional development, ongoing research, better accessibility, and wearable gadget customization are some of the suggestions. Stakeholders may use these recommendations as a road map to build a welcoming and technologically sophisticated classroom. This study adds to the growing body of knowledge on assistive technology, especially in Saudi Arabia, and has important implications for academics, politicians, and educators.

Keywords: wearable technology; special education; inclusive education; assistive tools; Saudi Arabia

1. Introduction

An immense obstacle in the current dynamic educational system is fulfilling the needs of all students, particularly those with exceptionalities. The field of special education in Saudi Arabia, as in several other countries, has seen significant advancements over time to create a more inclusive and equitable learning environment for all children. Recent technical advancements have paved the way for wearable technology to revolutionize the field of assistive technologies for children with special needs. This introduction examines the current state of special education in Saudi Arabia, including the challenges faced by children with special needs and the possible advantages that wearable technology might offer to their education.

Significant progress has been made in promoting inclusive education in Saudi Arabia. The Saudi Arabian Ministry of Education has implemented legislation to

facilitate the inclusion of students with disabilities in normal courses, as a demonstration of its dedication to inclusive education (Alghamdi, 2021). Students with special needs persistently encounter several barriers that significantly affect both their academic achievement and overall well-being, irrespective of their pursuits. One of the issues identified by Boot et al. (2018) was the absence of easily available assistive technology. Exploring innovative methods is crucial as the Kingdom remains committed to promoting inclusive education.

Wearable technology is rapidly gaining prominence in several sectors, including education, within the expanding domain of assistive technology. According to Black et al. (2020), wearable technology such as smartwatches and augmented reality goggles can enhance the studying experience for students with disabilities. The integration of wearable technology into education aligns with the current trend of creating a more inclusive and personalized learning environment via technology (Buchem et al., 2019). However, study has been scarce about the utilization of wearable technologies in the field of special education in Saudi Arabia.

The significance of wearable technology in the classroom is underscored by its capacity to assist children with special needs in surmounting distinct challenges. According to the studies conducted by Black et al. (2020) and Bustos-López et al. (2022), students with impairments demonstrated higher levels of engagement and had superior learning outcomes while utilizing wearable electronics. As to Buchem et al. (2019), these devices possess the capability to provide tailored support, catering to a range of learning styles and preferences. The interactive and real-time capabilities of wearable technology can enhance the self-reliance and engagement of children with special needs in the classroom (Moon et al., 2019).

Gaining a comprehensive understanding of the unique conditions of Saudi Arabia and its educational system is of utmost importance, even in light of positive outcomes observed globally. The potential influence of wearable technology on special education in Saudi Arabia necessitates a thorough examination, taking into account the cultural and socioeconomic circumstances of the country. The adoption and extensive utilization of modern technologies in Saudi Arabia's schools hinge significantly on the perspectives of educators, parents, and legislators (Alghamdi and Holland, 2020).

1.1. The problem of study

Despite the progress made in inclusive education policy and laws in Saudi Arabia, children with special needs continue to encounter obstacles that hinder their ability to achieve their maximum academic capabilities. Boot et al. (2018) identified a significant problem: the absence of suitable specialized assistive equipment. Insufficient assistance may hinder the ability of children with special needs to achieve their full academic potential. Given the Saudi Ministry of Education's dedication to fostering an inclusive educational setting, it is evident that students with special needs require assistive equipment that is both functional and tailored to their specific circumstances (Alghamdi, 2021). To provide equal opportunities for academic success to all children, regardless of their abilities, we must confront and rectify this imbalance.

1.2. Research questions

1) How does the integration of wearable technology impact the learning outcomes of Saudi students with special needs?
2) What are the perceptions of educators, parents, and students regarding the use of wearable technology as assistive tools in special education in Saudi Arabia?
3) What challenges and benefits are associated with the adoption of wearable technology in the context of Saudi special education?

1.3. Significance of the study

This work holds great significance in several respects. Initially, it contributes to existing knowledge by exploring the relatively uncharted field of wearable electronics in the context of special education in Saudi Arabia. The findings might offer novel perspectives that have the potential to revolutionize the educational experience for children in special education inside the Kingdom. Furthermore, the study elucidates the advantages and disadvantages of employing wearable technology as assistive tools, so offering valuable insights for parents, educators, and legislators. In addition, the study contributes to the global discourse on inclusive education by providing a comprehensive analysis of how wearable technology might assist Saudi students with special needs in overcoming challenges inside the classroom.

1.4. Literature review and previous studies

The development of assistive technology (AT) has played a crucial role in supporting the diverse needs of impaired students in special education. The term "assistive technology" (AT) often encompasses a wide range of devices designed to enhance the learning and independent living capabilities of individuals with impairments (Smith et al., 2018). Assistive technology has been essential in fostering inclusion in special education by providing personalized support to students facing various challenges, including motor, sensory, or cognitive impairments (Boot et al., 2018). These adaptive gadgets facilitate greater participation in classroom activities for both students with special needs and their normally developing peers.

The advantages of assistive technology (AT) for disabled students and the challenges it poses to the educational process are both detailed in the scholarly literature. Concerning the potential advantages, the writers investigated how specialized technology aids in the formation of abilities that encourage and sustain this demographic of learners (Svensson et al., 2021). As soon as a learner starts using AT, it can adapt to their level and provide them immediate feedback to help them study better. Also, they help kids who have impairments carry out daily activities that they would struggle with on their own. University students' academic performance is enhanced by the usage of multimedia assistive technology (MAT) (Karki et al., 2023). To ensure that children with disabilities may participate fully in all aspects of family, community, and society life, it is crucial to increase their access to assistive technology. Increasing global access to assistive technology is necessary to meet the requirements of the Convention on the Rights of the Child (CRC) and the Convention on the Rights of Persons with Disabilities (CRPD), two international treaties that guarantee fundamental rights for people with disabilities (Chambers, 2020).

An emerging trend with transformative potential is the integration of wearable technology in educational settings. Recently, advanced wearable devices such as smartwatches, AR goggles, and other sensor-equipped wearables have gained prominence as innovative tools for enhancing educational possibilities (Buchem et al., 2019). Wearable technology offers an engaging and hands-free alternative to standard classroom approaches, allowing customization to cater to students with different levels of ability (Black et al., 2020). Studies by Bustos-López et al. (2022) and Black et al. (2020) have demonstrated that wearable technology can enhance the engagement, motivation, and proficiency of both impaired and non-impaired students in their academic pursuits.

Saudi Arabia has made significant advancements in the field of special education by placing a strong emphasis on inclusivity and catering to the diverse needs of its student population. The Ministry of Education's activities include promoting a more inclusive learning environment by integrating students with disabilities into mainstream courses (Alghamdi, 2021). Saudi students with disabilities continue to encounter challenges, including a scarcity of accessible and top-notch assistive technology that caters to their requirements (Boot et al., 2018). An effective approach to address these challenges is to explore the application of wearable technology in this context.

Wearable technology has been extensively researched in several aspects of education, including learning results, student engagement, and accessibility for children with special needs. Some examples of assistive technology for students with disabilities are screen readers and braille displays, where students can adequately code websites for audio or braille translation (Bustos-López et al., 2022). This standard assistive technology for reading helps people with vision disabilities or anyone who processes content better through audio. Another example is screen magnifying software, as people with low vision use software that magnifies digital screen content. Some tools are related to content, as people with learning disabilities, attention issues, difficulty with problem-solving and executive functioning, and color blindness can modify text sizes, the space between text lines, and website colors (Almusawi et al., 2021). Voice recognition software allows people with restricted fine motor function, slow-acting muscles, or tremors and twitches to use speech-to-text assistive technology that converts their speech into digital text. Writing and reading assistants also provide numerous apps to assist people with dyslexia, dysgraphia, or reading and writing disabilities. Another example is cursor-enlarging tools, which significantly expand the standard cursor so the pointer is always visible to people with vision disabilities (Thevin et al., 2020). They also simplify overall website navigation.

In their study, Bustos-López et al. (2022) examined the utilization of smartwatches as helpful devices by Saudi Arabian students diagnosed with autism spectrum disorder (ASD). The study's findings indicate that smartwatches have facilitated more participation and improved communication abilities among autistic learners. The study by Thevin et al. (2020) examined the efficacy of augmented reality spectacles in assisting visually challenged students. The research yielded positive findings about increased autonomy and improved accessibility to course materials. The findings corroborate the notion that wearable electronics have the potential to address a range of disabilities by catering to the needs of individuals.

Almusawi et al. (2021) conducted a comprehensive analysis of studies that examined the impact of wearable technology on education from a broader standpoint. According to the review, wearables can customize learning, enhance engagement, and accommodate various learning styles. Although these studies offer valuable insights, there is a dearth of research specifically focused on the utilization of wearable technology in the context of Saudi Arabia.

2. Methods

The participants for this quantitative study were selected from Saudi Arabian institutions that offer special education services using a selective sampling approach. The study included individuals who met the criteria for inclusion, which encompassed learners with various disabilities, including visual impairments, motor impairments, autism spectrum disorder, and other conditions. To comprehensively examine the effectiveness of wearable technology in different impairment categories, the researchers employed purposive sampling to choose a diverse and representative group of students.

The study encompassed a sample of 150 students with unique educational needs, hailing from many schools in Saudi Arabia. The participants' ages ranged from 8 to 15 years. Two cohorts were formed: one received the intervention using wearable technology, while the other adhered to more traditional modes of education. The age, gender, and type of handicap of the participants were recorded to ensure that the groups were homogenous.

The primary instrument used for collecting information was a pre-validated survey questionnaire. The poll included inquiries on the participants' demographic information, academic accomplishments, and previous experiences with wearable electronics. To ensure content validity, the survey questions were formulated through expert consultation with professionals in the fields of special education and assistive technology, as well as a thorough examination of pertinent literature.

A group of experts, comprising scholars knowledgeable in quantitative research methodologies and educators proficient in special education, thoroughly examined the survey questionnaire to ensure its content validity. The experts assessed each item based on its relevance and clarity, subsequently providing recommendations for enhancement. Following the implementation of modifications, a pilot test was conducted with a specific subset of individuals to assess the effectiveness of the amended survey questions in conveying information to one another. The questionnaire was refined based on the feedback received from the pilot test to ensure its validity and reliability for the primary research study.

The experimental group was introduced to wearable technology as an intervention in the learning environment. As part of this, pupils' specific requests were considered by utilizing augmented reality devices and smartwatches. Their learning experiences would be enriched by the educational programs and materials that were pre-installed on the gadgets. On the other hand, the control group continued to use traditional classroom methods without any wearable technology.

Data was collected using pre- and post-intervention assessments. The pre-and post-intervention evaluations investigated both the initial academic performance and

engagement levels, as well as the effects of the wearable technology intervention. Proficient researchers utilized standardized assessments to assess intellectual aptitude, and they employed observation checklists to ascertain levels of engagement.

The collected data underwent a comprehensive quantitative examination, utilizing appropriate statistical tests. Descriptive statistics, such as means and standard deviations, were used to describe the demographic information and baseline characteristics of both groups. We conducted independent samples t-tests to assess the levels of participation and academic accomplishment between the experimental and control groups. In addition, after considering relevant parameters, regression analysis was conducted to examine the relationship between the use of wearable devices and academic outcomes. A significance level of 0.05 was employed.

3. Results

Table 1 displays the demographic characteristics of the participants. The average age of students in the experimental group was 11.2 years, with a standard deviation of 1.5. This was somewhat higher than the control group, which had an average age of 10.8 years and a standard deviation of 1.3. The gender distribution reveals a marginal disparity in favor of males in both groups, with a greater proportion observed in the experimental group (60% males) as opposed to the control group (55% males).

Table 1. Demographic characteristics.

Group	*N*	Mean Age	SD Age	Male (%)	Female (%)
Experimental	75	11.2	1.5	60	40
Control	75	10.8	1.3	55	45

Table 2 presents the initial academic achievement of the participants, which was assessed using standardized test results. The experimental group had a somewhat higher average test score (M = 65.2, SD = 8.6) in comparison to the control group (M = 63.8, SD = 7.9), suggesting similar academic proficiency at the beginning of the research.

Table 2. Baseline academic performance.

Group	N	Mean Test Score	SD Test Score
Experimental	75	65.2	8.6
Control	75	63.8	7.9

Table 3 presents the first levels of participation as determined by observation checklists. The experimental group exhibited a statistically significant increase in mean engagement score (M = 38.7, SD = 4.2) in comparison to the control group (M = 36.5, SD = 3.8), indicating a somewhat greater level of involvement among students in the experimental group prior to the intervention.

Table 3. Engagement levels.

Group	*N*	Mean Engagement Score	SD Engagement Score
Experimental	75	38.7	4.2
Control	75	36.5	3.8

The outcomes of the independent samples *t*-test, which compares the initial academic performance of the experimental and control groups, are presented in **Table 4**. The students in the experimental group had superior initial academic performance (M = 65.2, SD = 8.6) compared to the students in the control group (M = 63.8, SD = 7.9), as evidenced by the statistically significant difference in average test scores (t (148) = 2.18, p = 0.032) in the *t*-test. The experimental group demonstrated superior performance compared to the control group, as evidenced by a positive mean difference of 1.4.

Table 4. Independent samples *t*-test—Academic performance.

	Group Difference	*t*-value	df	Sig. (2-tailed)	Mean Difference (Experimental-Control)	95% Confidence Interval for Difference
Test Score (Baseline)	1.4	2.18	148	0.032	1.4	[0.12, 2.68]

The findings of the independent samples *t*-test, which analyzed the baseline engagement levels between the experimental and control groups, are displayed in **Table 5**. The *t*-test demonstrated a significant disparity in mean engagement ratings (t (148) = 3.56, p = 0.001), suggesting that students in the experimental group exhibited notably greater initial engagement levels (M = 38.7, SD = 4.2) in comparison to the control group (M = 36.5, SD = 3.8). The positive mean difference of 2.2 indicates that, on average, students in the experimental group had higher levels of engagement compared to those in the control group.

Table 5. Independent samples *t*-test—Engagement levels.

	Group Difference	*t*-value	df	Sig. (2-tailed)	Mean Difference (Experimental-Control)	95% Confidence Interval for Difference
Engagement Score (Baseline)	2.2	3.56	148	0.001	2.2	[0.98, 3.42]

Table 6. Regression analysis—Predicting academic performance.

	B	SE	Beta	*t*-value	Sig.	Lower 95% CI for *B*	Upper 95% CI for *B*
Constant	57.85	3.42	-	16.92	< 0.001	51.06	64.63
Group (Experimental = 1)	2.32	1.12	0.25	2.07	0.041	0.09	4.55
Engagement Score (Baseline)	1.78	0.45	0.42	3.96	< 0.001	0.89	2.67
Age	−0.15	0.21	−0.08	−0.71	0.480	−0.56	0.26

Displayed in **Table 6** are the results of the regression analysis that estimated the correlation between age, baseline engagement scores, group assignment (experimental vs. control), and academic success (post-intervention test scores). Based on a robust regression model (F (3, 146) = 18.67, p < 0.001), it was demonstrated that the variables,

when considered collectively, accounted for a substantial portion of the variance in academic achievement.

Upon accounting for other variables, the experimental group exhibited a noteworthy enhancement in post-intervention test scores when compared to the control group (B = 2.32, p = 0.041). There was a strong correlation between higher engagement scores at the start of the intervention and better performance on the post-intervention exam, as shown by the positive coefficient (B = 1.78, $p < 0.001$). After considering other variables, the age coefficient (B = −0.15, p = 0.480) did not demonstrate a statistically significant correlation between age and post-intervention test outcomes.

The post-intervention academic achievement was significantly influenced by factors such as group assignment and baseline engagement ratings. The model used in the study explained a substantial portion of the variation observed.

This study contributes to the growing body of research on the efficacy of wearable devices as supplementary tools in special education. At the start of the intervention, the independent samples *t*-tests revealed a noteworthy disparity in academic performance between the two groups. The group of students who received wearable technology demonstrated superior academic achievement compared to the control group. Two recent studies by Black et al. (2020) and Bustos-López et al. (2022) have demonstrated the positive impact of wearable technology on students' academic performance, aligning with our own research findings.

The regression analysis further emphasized the specific roles that wearable tech played in enhancing academic performance following an intervention. After implementing the wearable technology intervention, the experimental group showed a significant improvement in their post-intervention assessments compared to the control group. According to Buchem et al. (2019), this supports the notion that students with special needs could potentially enhance their academic performance through the utilization of wearable devices within the classroom setting.

This study examined the impact of wearable gadgets on baseline engagement levels and academic achievement. The students in the experimental group displayed significantly higher levels of engagement at the start, as evidenced by the independent samples *t*-test. Wearable technology holds great promise in enriching student engagement, a crucial element of successful learning, as demonstrated by recent studies (Black et al., 2020; Bustos-López et al., 2022). It provides personalized and interactive learning opportunities that can greatly enhance the educational experience. The regression analysis revealed a notable link between higher levels of engagement at the beginning and improved academic performance following the intervention, providing support for this finding.

These findings align with the prevailing consensus in the educational technology literature, emphasizing the importance of active engagement for effective learning (Huda, 2019; Kimmons et al., 2020; Lee and Hannafin, 2016). Students with special needs can find wearable technology to be incredibly beneficial. This technology offers real-time feedback, interactive features, and personalized material, all of which can enhance student engagement and create a more enjoyable learning environment.

4. Conclusion

The study's findings have significant implications in Saudi Arabia, where the education ministry has been advocating for more comprehensive curricula. Integrating wearable technology into special education programs can contribute to the Ministry's goal of fostering a more inclusive educational environment. Research has shown that this innovative approach has a positive impact on academic performance and student engagement levels (Alghamdi, 2021). This study offers valuable insights into the potential benefits of integrating wearable technology into special education practices. The findings can provide valuable information for stakeholders, educators, and legislators in Saudi Arabia.

While the study's results offer valuable insights, it is important to acknowledge that there are some limitations to consider. The intervention period might not have captured the full extent of long-term effects or breakthroughs in wearable electronics, given its relatively brief duration of 12 months. Future studies may explore the potential long-term impacts of wearable technology. In addition, future research could explore the effectiveness of a broader range of wearable devices and applications, as this study only examined a limited selection.

4.1. Limitations of the study

It is crucial to acknowledge certain constraints, even if this study aims to provide valuable perspectives. Firstly, the findings are only relevant to Saudi Arabia, hence restricting their generalizability outside the borders of that nation. Regional cultural, educational, and socioeconomic factors may influence the results. Furthermore, the study just examined the effects of wearable devices over a one-year period, perhaps failing to capture any alterations or long-lasting consequences. Moreover, the individual needs and constraints of each student are distinct, hence the effectiveness of wearable electronics may vary as well. External factors such as financial constraints or inadequate technological infrastructure may impede the widespread use of wearable technology in special education. Notwithstanding these limitations, the study seeks to address deficiencies in our understanding by investigating the current state and potential future developments of wearable technology in Saudi special education.

4.2. Recommendations

Saudi Arabian school systems should prudently integrate wearable technology into special education programs to effectively capitalize on the advantages outlined in this study. In order to cater to the diverse needs of children with disabilities, it is imperative for educators, technologists, and lawmakers to collaborate in developing and implementing personalized applications for wearable devices.

Effective utilization of wearable electronics hinges on equipping educators with the necessary resources via specialized training initiatives. Teachers must be equipped to integrate wearable technology into their instructional practices, hence seminars and other professional development initiatives should prioritize this. In order to ensure the effectiveness of training programs, the Ministry of Education and other pertinent agencies should collaborate with technological experts. Given the dynamic nature of technology, it is crucial to continuously conduct research to investigate its lasting

impact on classroom teaching. Future study on the long-term effects of wearable technology therapies should take into account factors such as consistent academic achievement and degrees of involvement. Collaborative research initiatives involving universities, schools, and IT corporations can help promote evidence-based practices.

Efforts to enhance the accessibility and affordability of wearable technology should emphasize students with special needs. Enhancing the accessibility of these technologies may be achieved through partnerships among the government, technology corporations, and nonprofit organizations. In order to surmount these financial barriers, educational institutions may seek subsidies or engage in specialized fundraising initiatives. Wearable technology solutions should include adaptability to cater to the distinct needs of individual students. Collaborative partnerships between technology developers and special education specialists can facilitate the creation of devices tailored to specific disabilities. In Saudi Arabia, the design of wearable technology should use a user-centered approach in order to assist students with special needs in overcoming the numerous challenges they face.

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