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Exploring the effectiveness of an augmented reality-based program in improving writing skills among students with learning disabilities from a Jordanian context

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Abstract

This study investigated the effectiveness of an augmented reality (AR) program in improving Arabic writing skills among students with learning disabilities. Using a quasi-experimental design, the research aimed to evaluate how AR-based instruction impacts writing performance in this student group. A specially designed writing test targeted key writing challenges such as producing visually and phonetically similar letters, long vowels (Al-Madd), nunation (Al-Tanween), geminated letters (Al-Shaddah), differentiating between Taa Marbutah and Taa Maftouhah, identifying solar and lunar letters, and sentence construction.Thirty-two students were divided equally into an experimental group, which received AR-based instruction, and a control group, which was taught using traditional methods. The study found a statistically significant improvement in the writing performance of the experimental group compared to the control group. These results confirm that AR technology can effectively enhance Arabic writing skills in elementary students with learning difficulties.The study concludes that AR programs offer promising tools for educational development in special education contexts. It recommends future research focus on scientifically grounded educational strategies, customize AR interventions for students with cognitive and developmental challenges, and employ more precise assessment tools for measuring writing skills. This approach would maximize educational benefits and provide reliable evidence for adopting AR in teaching writing to students with learning disabilities.

Keywords: Augmented Reality, Writing Skills, Learning Disabilities.

Introduction

Handwriting is considered one of the essential foundational skills that school-aged children need, given its vital role in self-expression as an effective form of communication. It enables students to articulate their thoughts and document visual experiences and acquired knowledge. Therefore, writing must be accurate and free of errors—whether in spelling, structure, or in the organization and presentation of ideas (Meisarah et al., 2023; Tosto et al., 2021). Mastery of writing also demands the integration of visual, motor, and conceptual skills. Among students, writing difficulties are among the most common challenges. According to Yuniari (2024), the development of reading skills depends on the early and effective acquisition of writing skills, including handwriting. Writing skills are crucial in the academic context, as students need to be able to articulate their ideas on paper—whether to explain concepts or revise existing ones through new information (Onintra et al., 2023). Furthermore, students who struggle with writing often face broader academic challenges. Some teachers mistakenly assume their students are lazy when, in reality, they may be dealing with learning difficulties (Sihwi et al., 2019). Learning disabilities represent a significant challenge for many affected students (Khodabandeh,et al 2025), Learners spend more than half of their classroom time engaged in handwriting-related tasks such as spelling and copying. Studies estimate that approximately 10–30% of children face handwriting difficulties during their academic journey (Amini et al., 2023).

The majority of these issues are prevalent among students with learning disabilities who struggle in multiple academic domains—especially reading (Khodabandeh et al 2025), arithmetic, and writing. Writing difficulties are among the most impactful barriers to academic achievement. They hinder students' success across subjects, limit their social integration within the classroom and school, and extend their effects to the broader community. Such difficulties are persistent in students with dysgraphia (Khan et al., 2017).

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According to the American Psychiatric Association, writing difficulties are defined as a condition in which individuals struggle to express their thoughts in writing and often fail to recall letter or symbol patterns. Dysgraphia is not limited to poor handwriting—it also includes significantly reduced writing abilities that are inconsistent with a person's intellectual level, age, and educational experience. Hussain et al. (2023) emphasize that children with dysgraphia frequently encounter challenges in meeting academic demands due to the high cognitive load involved in writing. This often results in fatigue, cognitive overload, negative self-comparison, and heightened performance anxiety. (Bualtoot & Saadawi, 2023, Khodabandeh,et al2025)

From a researcher's perspective, writing difficulties should not be perceived merely as academic obstacles. Rather, they represent a broader pedagogical challenge that calls for comprehensive, individualized instructional responses (Bualtoot & Saadawi, 2023). Effective interventions must address students' unique learning profiles and foster supportive environments that empower them to build their skills and overcome psychological barriers. Consequently, there is a growing need for innovative educational strategies that not only support students with learning difficulties but also actively engage and motivate them.

In light of the rapid advancements in digital technologies, incorporating technology into education has become indispensable—especially for students with special needs. Educational experiences have evolved significantly through the integration of digital tools alongside traditional resources. As Cipresso et al. (2018) argue, digital technology has become a deeply embedded component of both the educational landscape and broader societal functions, transforming how teaching and learning take place.

One particularly promising technological innovation is augmented reality (AR), which has shown potential in supporting students with learning difficulties, especially those with dysgraphia (Şimşek, 2024). Cipresso et al. (2018) define AR as an emerging technology that overlays virtual elements onto the real world in real time. A robust AR system should meet three core criteria: (1) seamlessly blend real and virtual content in a physical environment; (2) function interactively and in real-time; and (3) align virtual content spatially and logically with the real world. As technology progresses, interaction modalities have also shifted—from traditional mouse and keyboard interfaces to full-body and gesture-based controls.

AR-based applications offer rich and exploratory learning environments by combining digital multimedia elements such as animations, sounds, images, and videos with real-world contexts (Rahman et al., 2020). These engaging formats can significantly enhance the learning process—particularly for students with dysgraphia, who often find writing tasks monotonous and discouraging (Tosto et al., 2021).

Moreover, AR enables educators to present abstract content in concrete and visual forms, helping learners observe and interact with learning materials more directly and meaningfully. A wide range of AR applications have already been developed to support education (Khan et al., 2017; Boonbrahm et al., 2015; Tosto et al., 2021), and studies have shown that AR can reduce anxiety and stress in educational settings (Al-Obaidan, 2022).

Despite the growing body of international literature on AR's effectiveness in supporting students with dysgraphia and other learning disabilities, research in Arab contexts remains limited. Therefore, this study seeks to investigate the impact of an augmented reality-based educational program on the writing performance of students with learning difficulties, specifically within the Jordanian educational context It sought to answer the following research questions:

Is there an absence of statistically significant differences (at $\alpha = 0.05$) between the average post-test writing scores of the experimental and control groups, which could be attributed to the type of instruction method (traditional teaching versus augmented reality-based approach)?

Is there an absence of statistically significant differences (at $\alpha = 0.05$) between the average post-test writing scores and follow-up test of the experimental and control groups, which could be attributed to the type of instruction (traditional teaching versus augmented reality-based approach)?

Study significance:

The importance of the current study lies in its potential to contribute to the development of innovative teaching methods tailored to students with learning difficulties, thereby enhancing the effectiveness of the educational process. It will also provide valuable data to special education teachers, helping them adopt smart technologies to improve the quality of specialized education.

Literature Review:

Previous research on the use of AR in educational environments has shown that AR systems enhance learner motivation, engagement, and retention of educational content—providing a plausible explanation for its gradual impact on academic achievement (Hussain et al., 2023; Tosto et al. (2021) successfully implemented an augmented reality (AR)-based solution as part of a digital literacy program that integrated advanced technologies to support interactive educational content.

Experiments by Boonbrahm and colleagues on primary school students demonstrated increased motivation and learning engagement. Studies also revealed the effectiveness of AR in teaching English grammar (Belda-Medina & Gomez, 2024).

In the field of special education, Al-Obaidan (2022) found that AR improved specific reading skills among girls with mild intellectual disabilities, while Daajam (2020) showed AR's effectiveness in enhancing math achievement in students with learning difficulties. Meisarah et al. (2023) utilized the Assemblr app, which had a significant impact on students' writing abilities. The ARLexic game notably increased enjoyment, attention, and motivation for students with dyslexia (Hussain et al., 2023). Onintra et al. (2023) developed a reading assistant app using QR code scanning embedded in flashcards to teach word spelling, showing improved spelling and learning motivation. Khan et al. (2017) proposed the AR-DAWE model, an AR-based writing environment for students with dysgraphia, featuring 3D spelling assistance and real-time speech-to-text conversion via cloud services. Sihwi et al. (2019) developed an Android app with handwriting recognition to collect data from primary school students with and without dysgraphia.

Methodology:

To achieve the study's objective, a quasi-experimental design was used to examine the effectiveness of the AR program in enhancing the writing performance of students with learning difficulties. Two groups were formed: experimental and control. The study included the following variables:

Independent variables: Teaching strategy (AR-based vs. traditional),

Dependent variables: Writing skill performance.

Participants:

The study included 32 male and female students diagnosed with writing difficulties from Irbid Governorate, Jordan. They were randomly divided into two groups, each consisting of 16 students: one experimental and one control.

Study instrument

First: the writing skills test

The Arabic writing test is the main tool used to measure the writing skill level of the study sample. The test was constructed to align with the educational objectives and the students' proficiency level, while considering the psychological and linguistic characteristics of the target group. The writing skills test consists of seven sub-skills to measure the writing proficiency of the study participants before and after the experiment, and once again in a follow-up assessment. The total score for the test is 50 points, distributed as follows:

Difficulty producing letters similar in shape and sound: 5 points

Elongated letters (al-madd): 5 points

Nunation (Al-Tanween): 5 points

Geminated letters (al-shaddah): 5 points

Taa marbutah and taa maftouhah: 5 points

Lunar and solar letters (al-qamariyyah and al-shamsiyyah): 5 points

Sentence formation and arrangement: 20 points (four sub-sections)

Item difficulty and discrimination indices (writing skill test)

The responses of a group of 15 participants from outside the study sample were analyzed using SPSS to calculate item difficulty and discrimination indices for the writing skill test items. Item difficulty was computed as the percentage of students who answered the item incorrectly, while the discrimination index was calculated as the item-total correlation. The following table presents number (1) these indices for each test item.

Table 1. Item difficulty and discrimination indices

Item No.	Difficulty Index	Discrimination Index
1	0.40	0.60*
2	0.67	0.75**
3	0.47	0.72**
4	0.53	0.61*
5	0.60	0.66**
6	0.60	0.70**
7	0.67	0.61*
8	0.40	0.61*
9	0.67	0.64**
10	0.53	0.72**
11	0.47	0.58*
12	0.47	0.69**
13	0.60	0.71**
14	0.33	0.71**
15	0.67	0.68**
16	0.60	0.65**
17	0.40	0.60*
18	0.47	0.55*
19	0.40	0.61*
20	0.40	0.60*
21	0.53	0.61*
22	0.53	0.61*
23	0.53	0.57*
24	0.47	0.61*
25	0.20	0.60*
26	0.47	0.55*
27	0.20	0.60*

Item No.	Difficulty Index	Discrimination Index
28	0.33	0.55*
29	0.60	0.60*
30	0.27	0.65**
31	0.33	0.62*
32	0.53	0.61*
33	0.60	0.57*
34	0.53	0.55*
35	0.27	0.59*
36	0.53	0.54*
37	0.47	0.62*
38	0.47	0.66**
39	0.67	0.74**
40	0.53	0.54*
41	0.73	0.72**
42	0.67	0.65**
43	0.47	0.73**
44	0.60	0.81**
45	0.60	0.56*
46	0.60	0.69**
47	0.67	0.65**
48	0.60	0.69**
49	0.53	0.67**
50	0.73	0.55*

* Statistically significant at the 0.05 level
** Statistically significant at the 0.01 level

As shown in the table, item difficulty ranged between 0.20 and 0.73, and discrimination indices ranged from 0.55 to 0.81. According to Odeh (2010), acceptable item difficulty values range from 0.20 to 0.80. An item is considered good if its discrimination index is above 0.39, acceptable but improvable if between 0.20 and 0.39, weak and recommended for deletion if between 0 and 0.19, and unacceptable if negative. Based on these criteria, no items were deleted.

Reliability of the writing skill test

To ensure test reliability, the test-retest method was applied by administering the test twice, with a two-week interval, to a group of 15 participants from outside the study sample. Pearson's correlation coefficient between the two test administrations was 0.91 for the overall test. Internal consistency Reliability was also calculated using the Kuder-

Richardson Formula 20 (KR-20), yielding a value of 0.86 for the entire test. These reliability coefficients are deemed adequate for the purposes of this study.

Group equivalence: writing skill test (pre-test)

To verify the equivalence of the experimental and control groups, the Mann-Whitney U test was used to assess significant differences in writing skill pre-test scores between the two groups. Results are shown below.

Table 2. Mann-whitney u test results for writing skill pre-test

Group	N	Mean Rank	Sum of Ranks	U	W	Z	p-value
Experimental	16	19.63	314.00	78.000	214.000	-1.891	0.059
Control	16	13.38	214.00				

The results indicate no statistically significant differences ($\alpha = 0.05$) between the two groups, confirming their equivalence at the pre-test stage.

Study implementation procedures

To achieve the study's objectives, the following procedures were implemented:

Phase one:

After identifying the educational content from the elementary Arabic curriculum that would serve the augmented reality program, the preliminary version of the study instrument (the writing skills test) was constructed. The test was then presented to a number of specialized reviewers, their observations were considered, and the suggested modifications were made. The final version of the writing skills test was then prepared. The study sample groups (experimental and control) were selected purposefully.The instruments were applied to a pilot sample from the study population but outside the main sample to verify the validity, reliability, and appropriateness of the proposed time for implementation.Finally, the writing skills test was administered as a pre-test to both groups (experimental and control) to ensure their equivalence and to control for their initial performance.

Phase two: the intervention

The specific technology, an augmented reality system named "Al-Tahajee Club," was developed. A number of ready-made platforms and software were used to build this system, including Assemblr EDU, CoSpaces Edu, and the Qutouf platform.The system was then shown to a number of specialists in computer science and Arabic language for their feedback. Before the actual implementation, the system was tested on a sample from outside the study participants, and after the system was evaluated, it was implemented. The system included a series of windows, starting with the easiest skills and progressively increasing in difficulty. Before applying the system, a set of videos was shown to the students to explain how to operate it.

The system included the following:

For the first skill: Difficulty producing letters similar in shape and sound. A video was displayed on a mobile phone linked to an interactive whiteboard. This video featured the similar letters that students struggle with. The student then used commands on an iPad to display the following similar letters in Arabic: **(ك/ل), (ف/ق), (جـ/ حــ/ خــ), بـ/ تــ/ ثــ**. The task was to match the correct letter to the appropriate word, which was linked to images. The images were of a house (بيت), a camel (جمل), a book (كتاب), a key (مفتاح), and a garden (حديقة). A letter was left blank in each word, and the student was asked to place the correct letter.

For the second skill: Elongated letters (Al-Madd). The word was linked to electronic images within the system. The images were of a car (سيارة), beauty (جمال), water (ماء), and an airplane (طائرة). The word was displayed away from the image with a missing elongated letter, for example, "س...ارة". The student was asked to place the appropriate letter.

For the third skill: Nunation (Al-Tanween). Animated images were displayed for words containing different types of nunation (dammah,

fathah, kasrah) and words containing the letter noon (ن) to distinguish between them, along with pictures of these words.

For the fourth skill: Geminated letters (Al-Shaddah). The word was linked to electronic images in the system. Colored image cards were displayed showing a tree (الشـــــــجرة), a shadow (الظـــــــل), and a teacher (المعلـــــــم), with the correct spelling of the word linked to them.

For the fifth skill: Taa Marbutah and Taa Maftouhah. A three-minute video was shown on a mobile phone linked to an interactive whiteboard, featuring these letters. Additionally, electronic letter cards were used, with a musical sound providing reinforcement for a correct answer.

For the sixth skill: Lunar and Solar letters (Al-Qamariyyah and Al-Shamsiyyah). The system screen was divided into two windows: one for words with lunar letters and one for words with solar letters. The student was then asked to classify the words.

The program's implementation began on March 11, 2025, and continued until April 7, 2025, consisting of 35 training sessions, each lasting 15-30 minutes. The writing skills test was then administered as a post-test to both groups (experimental and control). To ensure continuity, follow-up, and to assess retention, the test was re-administered three weeks after the system's application.

Results

To answer the first research question: Is there an absence of statistically significant differences (at α = 0.05) between the average post-test writing scores of the experimental and control groups, which could be attributed to the type of instruction method (traditional teaching versus augmented reality-based approach)?

To answer this question, the Mann-Whitney U test was conducted on the post-test writing scores. Results are presented below.

Table 3. Mann-whitney u test results for writing skill post-test

Group	N	Mean Rank	Sum of Ranks	Mean	U	W	Z	p-value
Augmented Reality	16	24.25	388.00	43.19	4.000	140.000	-4.688	0.000
Traditional	16	8.75	140.00	32.31				

The table results indicate statistically significant differences in favor of the experimental group that used the augmented reality-based instructional program, with a p-value of 0.000, which is below the significance level (α ≤ 0.05). The effect size (r) was calculated to be 0.83, which is considered a large effect according to Cohen's criteria. This suggests a strong impact of the program in improving the writing skills of students with learning disabilities compared to traditional instruction.

Second: results of the second research question

To answer the second research question, Is there an absence of statistically significant differences (at α = 0.05) between the average post-test writing scores and follow-up test of the experimental and control groups, which could be attributed to the type of instruction method (traditional teaching versus augmented reality-based approach)?

To answer this question, the Wilcoxon Signed Ranks Test was used to assess differences in writing skill scores between the post-test and follow-up for the experimental group.

Table 4. Wilcoxon signed ranks test results (post-test vs. follow-up)

Comparison	N	Mean Rank	Sum of Ranks	Z	p-value
Negative Ranks	2	3.50	7.00	-0.135	0.893
Positive Ranks	3	2.67	8.00		
Ties	11				
Total	16				

The results reveal no statistically significant differences between the post-test and follow-up assessments, indicating stability in writing skill performance over time.

The Wilcoxon Signed Ranks Test indicated no statistically significant differences between the post-test and follow-up writing skill scores for the experimental group ($Z = -0.135$, $p = 0.893$), suggesting that the effect of the augmented reality-based program was maintained over time.

This means that the augmented reality-based program had a significant and substantial effect on the study sample's retention of mastery in Arabic writing skills.

Discussion

The findings of this research demonstrated a notable improvement in the writing abilities of students with learning disabilities and dysgraphia, as evidenced by their post-test results. This progress is largely attributed to the implementation of an augmented reality (AR)-based intervention. Participants were able to overcome previous difficulties encountered in the targeted writing skills assessed during the study.

Moreover, the experimental group outperformed the control group significantly, underscoring the efficacy of the AR program in enhancing writing competencies. Students exposed to this innovative approach achieved superior outcomes compared to their peers who received traditional instruction. These results provide strong support for the adoption of such technology-driven methods in teaching writing skills and suggest promising potential for broader application in similar educational settings, surpassing conventional teaching techniques.

These findings are consistent with several previous studies, such as those by Khan et al. (2017), Onintra et al. (2023), and Da'jam (2020). They also align with the results of Meisarah et al. (2023), which showed the significant impact of AR features on improving students' writing skills, as evidenced by the higher average post-test scores of the experimental group compared to the control group. This impact is attributed to the nature of augmented reality, which utilizes colorful animated videos and images accompanied by sound effects that help stimulate students' learning. The study's results also revealed a clear positive improvement in the retention of writing skills among students with learning disabilities and dysgraphia, as observed in the follow-up test. The findings indicated that this retention was due to the use of the AR program. There was an observable difference in the mean performance of the experimental and control groups on the follow-up writing test. These results are in line with the findings of Marzouk et al. (2023), Sihwi et al. (2019), and Hussain et al. (2023), which confirmed the effectiveness of augmented reality in delivering interactive exercises, activities, and multimedia content specifically designed to address the challenges faced by individuals with dysgraphia.

Conclusion

As is well known, technology can bring about a huge leap in the effectiveness of education for regular students in general and for students with learning disabilities, especially in early and elementary stages. We have witnessed a significant increase in the use of augmented reality in education, which highlights the immense benefits for both teachers and students. What is noteworthy is the research and studies' focus on students with reading and arithmetic learning disabilities while neglecting those who suffer from writing difficulties in the Arabic language.

Therefore, the current study recommends that research should focus on AR programs for Arabic writing skills that were not included in this study due to time constraints. The study also highlights the need to implement educational strategies based on scientific research and to explore the effectiveness of AR programs tailored for students who face cognitive and developmental challenges.

Declarations

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The author acknowledges using Grammarly (**https://app.grammarly.com/**) for proofreading. " also was used to generate citations in Chicago style. The prompt provided to ChatGPT was specifically "Chicago Citation" to ensure the proper format for

Author contributions. The sole author, Dr. Monjed Muhammad Najadat, conducted all stages of the research and study, including study design, data collection, data analysis, and writing of the final report. There were no other contributors involved in this research work.

Conflicts of interest. The author declares that they have no conflict of interest.

Ethical approval. The study was conducted in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Board. The Ethical Committee of Ajloun National University, Jordan, granted approval for this study on 12 March 2025 (Ref No. 211/1/125 .11/K,A,T/2025).

Data availability statement. The data that support the findings of this study are not publicly available reasons participant confidentiality but are available from the corresponding author upon reasonable request.

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