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The effect of using augmented reality technology in developing imaginative thinking among students with learning difficulties

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A B S T R A C T

The primary objective of this research was to find out how using augmented reality technology in the Abha Governorate affected children with learning disabilities' ability to think creatively. A cohort of students associated with educational establishments in the Governorate of Abha was the subject of a study. The study was given a month's duration. The study involved thirty students in all, fifteen of whom were each from the experimental and control groups. The experimental group did better on post-tests assessing initial imagination, perceptive imagination, and transformative imagination than the control group, indicating a significant improvement in the study's results. There was no statistically significant difference between the experimental group and the control group's scores on imaginative thinking during the follow-up evaluation or in the immediate post-intervention period.

1. Introduction

The advent of the technological revolution and advancements in technology have unveiled a new paradigm wherein global communication is facilitated through the Internet (Wannapiroon et al., 2021). This is demonstrated in the report by the Communications and Information Technology Commission, which states that the number of mobile telecommunications subscriptions in the Kingdom of Saudi Arabia had reached approximately 40 million by the end of the third quarter of the year. In the year 2015 AD, the quick and consecutive advancements in technology had a significant impact on several aspects of life, specifically the education sector. Consequently, teachers encountered the formidable task of locating a technology that aligns with the mandates and prerequisites of the present age (Perifanou et al., 2022). Nevertheless, augmented reality technology successfully surmounted this obstacle. Augmented reality is a technology that merges real and virtual elements in a three-dimensional manner. It allows users to interact with virtual objects in real time while performing real tasks. This technology combines the user's view of the real world with computer-generated virtual scenes, resulting in a composite display. The addition of more information to the scene enhances the user's perception of engaging with the actual world rather than the virtual world, hence boosting their sensory experience (Garzón & Acevedo, 2019).

Augmented reality technology relies on establishing a connection between real-world features and corresponding virtual elements stored in its memory. These virtual elements can include geographic coordinates, information about the location, introductory videos, or any other data that enhances the real-world experience (Alalwan et al., 2020). Augmented reality software is dependent on the utilization of a mobile phone or computer camera. Utilize a tablet device to observe the actual world, thereafter, assess it in accordance with the program's requirements, and endeavor to incorporate virtual parts into it. There

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exist two methods for generating augmented reality (Arici et al., 2021). The first technique utilizes identifiable signs that may be captured and differentiated by the camera in order to present the associated information. Conversely, the second way use geographical position via GPS or image recognition software to present the information. There is a lack of clarity regarding the distinction between virtual reality and augmented reality. Virtual reality is a computer-generated, three-dimensional artificial reality. It pertains to the perception or impact rather than actuality. We perceive it through sensory cues, and we do not engage with it in real time. Augmented reality seamlessly integrates virtual and real elements, allowing us to interact with it in real time (Heintz et al., 2021).

The efficacy of augmented reality technology in education has been substantiated by studies from the Horizon Conference, which identify it as a viable educational tool for facilitating meaningful learning. This technology has revolutionized teaching and learning methods by offering extensive possibilities. It enables continuous learning for all individuals and presents scientific material in a manner that aligns with the technology-driven generation (Mystakidis et al., 2022). Moreover, it fosters learners' imagination and creativity, enhances their motivation to learn, develops their practical skills, and empowers them to control their learning process. Additionally, it facilitates the acquisition of academic subjects that are difficult to grasp without real, direct experience. Furthermore, it aids in comprehending complex topics. Augmented reality technology plays a significant role in enhancing learners' awareness and facilitating a more profound comprehension of knowledge. Students with learning difficulties that utilized augmented reality demonstrated improved awareness over an extended duration and exhibited enhanced interaction with educational content (Buchner & Zumbach, 2020). Emerging technologies, such as augmented reality, existential learning, mobile learning, serious games, and mission and learning analytics, aim to enhance user happiness and experiences in multimedia learning environments. Augmented reality technology plays a significant role in enhancing learners' awareness and facilitating a more profound comprehension of knowledge. Students with learning difficulties that utilized augmented reality demonstrated improved awareness over an extended duration and exhibited enhanced interaction with educational content (Cheng, 2018).

Imaginative thinking thus facilitates the development of practical ideas that remain grounded in reality without distracting us from reality or knowledge. It allows us to engage with reality in a meaningful way and to perceive truths that may not be obvious under current circumstances (da Silva et al., 2019). In addition, it re-establishes a unified approach through which ideas and meanings can interact positively. Imagination has many guises; It enables individuals with learning disabilities to think about something that does not yet exist but has the potential to develop and come into existence. Imagination facilitates the development of mental communication, allowing the ability to refer to different events or activities by providing additional explanations (Mundy et al., 2019). Imagination can be a catalyst for developing a systematic approach to understanding human existence and developing strategies to enhance it. Imagination has two essential features, namely efficiency and productivity. The repeated appearance of effectiveness is a crucial practical element of imagination, and is closely and invariably linked to modernity. Imagination is a powerful creative force that enables individuals to perceive familiar elements in new connections, and those who possess this energy excel at generating new perspectives. It can present unique trends and perspectives that deviate from the norm. Productivity is a property related to the quantity, intensity, and duration of mental images (Amores-Valencia et al., 2023).

Given the information provided, it was imperative to incorporate certain factors into the curriculum content in a manner that is compatible with augmented reality technology. This was accomplished by attempting to provide a collection of subjects to enhance the topics covered by the curriculum, which become obsolete if an element is not incorporated into them. One of the present study's topics was the advancement of augmented reality technologies. Hence, the primary objective of this study was to ascertain the impact of employing augmented reality technology on the enhancement of imaginative thinking in students with learning difficulties.

1.1 Research questions

The objective of this study is to examine the inquiries within the framework of the preceding discourse.

1. Do the experimental and control groups show statistically significant differences in the effectiveness of an educational program that uses augmented reality technology to encourage imaginative thinking in students with learning difficulties?
2. Does the experimental group show notable variations in the effectiveness of an educational program that uses augmented reality technology to encourage imaginative thinking in students with learning difficulties?
3. Is there a statistically significant difference detected between the scores obtained from post-test and follow-up tests when assessing the effectiveness of an educational program that uses augmented reality technology to encourage imaginative thinking in students with learning difficulties?

2. Literature review

Augmented reality is an advanced technology that has the potential to convert images in books, fields, text, and symbols into interactive, three-dimensional artwork. To accomplish this, one must install a dedicated application on their smartphone or tablet that is compatible with either the "Android" or "iOS" operating systems (Schaffernak et al., 2020). In initializing the program, workers are required to utilize a phone or tablet to orient it toward an image or symbol, hence facilitating the conversion of said picture or symbol into three-dimensional forms. Smartphones and tablets are equipped with augmented reality technology, allowing individuals to fully utilize their senses, including touch and hearing (Faria & Miranda, 2023). Furthermore, augmented reality technology replicates the components of virtual reality or its expansions since it offers an organic method to enhance interactivity in the real world by including elements from the virtual world, bridging the gap between the two realms. In the foreseeable future, our ability to distinguish between what is genuine and what is artificially created will diminish (Avila-Garzon et al., 2021).

Given the contemporary nature of augmented reality, there has been a proliferation of terms associated with this concept. Upon reviewing the literature on augmented reality, one can observe numerous terms that are synonymous with this concept, such as added reality, enhanced reality, augmented reality, and combined reality. All of these terms serve as references to augmented reality. The discrepancy arises from the divergence in terminology that aligns with the specific domains of augmented reality (Cakir & Korkmaz, 2019). According to Fidan and Tuncel (2019), augmented reality is a collection of technologies and tools that enhance real-world experiences by adding additional information Ibáñez, et. al. (2020) define augmented reality as the process of incorporating digital data, organizing it, capturing it through photographs, and utilizing digital images to represent the actual environment around an individual. Technically, augmented reality is commonly linked to portable computers. Olim and Nisi (2020) defines augmented reality as the potential to combine inadequate information with the actual physical environment. When an individual uses this technology to observe their surroundings, the items in the environment are augmented with information that circulates and merges with the image. The object of the person's gaze the advancement of technology has played a crucial role in the establishment of this particular technology, which is now widely utilized in personal accounts and mobile phones. Previously, it was primarily limited to research transactions conducted by huge companies. Augmented reality technology facilitates the incorporation of virtual objects into real-life settings, thereby supplementing missing information. This process, referred to as Giannopulu (2022), allows for interaction with D2 or D3 virtual objects seamlessly merged into the physical environment.

Augmented reality technology relies on the system's ability to identify and connect real-world features with corresponding virtual elements stored in its memory, such as geographic coordinates, location information, introductory videos, or other data that enhances the real-world experience. Augmented reality software utilizes the camera of a mobile phone or tablet to see the physical reality, and subsequently analyzes it based on the program's requirements, aiming to seamlessly incorporate virtual features into the real environment. Muhammad (2022) categorized the many forms of augmented reality into:

1. Based on location differentiation: digital media offer users the ability to access GPS location features through smartphones or mobile devices. Additionally, multimedia content, including text, graphics, audio files, video clips, and three-dimensional shapes, provides academic or navigational information specific to the physical environment.
2. Based on vision: This technology uses visual recognition to deliver digital material to users after a certain object is captured by the camera of a mobile phone or portable smart device. Examples of this include QR codes, 3D images, and markers, which the camera may detect and utilize to show relevant information.

Alhanai and Almanthari (2019) defined a distinct set of characteristics for augmented reality that seamlessly integrate real and virtual elements in a dynamic, interactive, three-dimensional setting. These features enable users to perform complex tasks with ease while also being cost-effective and easily scalable. As a result, they have garnered significant interest from researchers and designers in the realm of human-computer interaction. Wannapiroon et al. (2021) emphasized the significance of augmented reality in education by highlighting its alignment with constructivist learning principles. Augmented reality enables learners to actively engage with both real and virtual learning environments, allowing them to have control over their learning process. Additionally, learners can navigate through unrealistic scenarios within these environments, leading to enhanced skills and knowledge acquisition. Augmented reality materializes constructivist theory into a concrete reality that can be put into practice. The efficacy of integrating theoretical and applied learning methods has consistently been demonstrated, and the imperative to proficiently implement e-learning principles and diverse technologies is becoming more pressing and cannot be disregarded (Perifanou et al., 2022).

Augmented reality has the potential to bridge the divide between academic and applied education by integrating the real and virtual worlds. To accomplish diverse e-learning objectives, prerequisites, and even settings (Garzón & Acevedo, 2019). Augmented reality technology enhances the teaching of concepts by introducing an extra dimension, surpassing other teaching approaches. Augmented reality technology significantly enhances the teacher's ability to acquire information more effectively (Alalwan et al., 2020). When presenting a lesson about ancient culture, the teacher may encounter challenges in explaining the topic if they lack a tangible archeological artifact for the learners to inspect. Augmented reality technology has simplified the teaching process by allowing teachers to showcase every aspect of an archeological item, enabling learners to thoroughly explore it (Arici et al., 2021). When learners commence studying educational material on a computer, they typically need to acquire expertise pertaining to computer usage, such as operating a mouse or keyboard. Additionally, he will need to acquire proficiency in various computer operations, including but not limited to, navigating windows, accessing the system menu, and doing other related tasks (Heintz et al., 2021). Consequently, as the learner is obligated to acquire these capabilities alongside the instructional material, this will impose a more significant strain on them during the learning process (both physically and psychologically). However, in augmented reality, the learner's body is fully engaged in the instructional content, as they have the ability to observe the entire content. Unlike virtual reality, where learners are confined to a constrained framework that only includes the environment around them and their bodies, this approach is distinct (Mystakidis et al., 2022).

Buchner and Zumbach (2020) enumerated a range of educational applications for augmented reality, including:

1. Classroom Applications: there are widely-used programs that facilitate the incorporation of augmented reality technology in educational settings. These applications enable users to effortlessly and efficiently develop and integrate their own augmented reality experiences using their own or school devices.
2. Homework assignments supported by explanation: augmented reality technology can be utilized to assist learners and accompany them in the completion of their homework tasks. If a student encounters difficulties while completing their school homework, they can utilize the camera on their mobile phone. By recording a video of a previous competition where they were not paying attention to their teacher, they can identify the specific point causing them trouble. This video can then provide them with helpful insights to solve the problem at hand.
3. Presentation about a book: the students document a concise overview of the book they have completed reading. The user is redirected to an associated digital information card through a specialized information program created for this specific function. The registered view is readily accessible to anyone as it is affixed to the book's cover. Acquiring familiarity with the book's topics by quickly examining the information card using a mobile phone.
4. Educational cards for the deaf and hearing impaired using augmented reality technology: one can create educational cards that include vocabulary connected to video clips that demonstrate how to represent this terminology using sign language.

Cheng (2018) defined imaginative thinking as a cognitive process that involves gathering mental representations derived from educational stimuli, sensory perceptions, and past experiences. It also entails conducting mental experiments and creatively reshaping these mental images. The manifestation of this type of thinking can be observed through observable behavior. The learner experiences several manifestations of this phenomenon. da Silva et al. (2019) posits that imaginative thinking is a cognitive process wherein individuals utilize their mental faculties to gather sensory-based mental images, subsequently merging and transforming them in a novel manner to create a new form that deviates from their original state. Indeed, the outcomes of all these circumstances manifest in novel configurations. Mundy et al. (2019) categorized human imagination into three distinct types:

1. First Imagination: This category pertains to the capacity to investigate novel, inventive, and unfamiliar concepts.
2. Perceptive imagination: this type refers to the ability to perceive the underlying patterns of an event through personal intuition and feeling. It also involves generating effective ideas to attain goals through logical discussion and debate.
3. Transformative imagination: this type refers to the capacity to generate abstract concepts and use existing knowledge in many domains and contexts.

The first imagination serves as the foundation for creative imagination, while the transforming imagination serves as the substance for reproductive imagination. Therefore, the seen imagination acts as a breeding ground for the formations and forms of the mental depictions (pictures) produced by the creative imagination and the transformational imagination (Amores-Valencia et al., 2023). The learner's capacity to generate diverse mental representations, facilitating their contemplation and visualization of unfamiliar events, serves as a testament to their inventive cognition. Their mental processes demonstrate this skill. He has a keen intuition and a natural inclination for speculation, which allows him to engage in deep introspection and critical thought (Schaffernak et al., 2020). This enables him to employ his imagination in contemplating and understanding both the fundamental nature of objects and the factual existence of the world. The relationship between observers' perceptions and the nature of augmented reality is correlated and interdependent since each element enhances the other (Faria & Miranda, 2023).

3. Previous studies

Alhanai and Almanthari (2019) looked into how augmented reality technology could help fifth-grade female pupils think more creatively in Arabic. The study used a quasi-experimental design, which included the establishment of both experimental and control groups, to accomplish this goal. Thirty-three students from two different schools made up the control group, whereas thirty-five students from the experimental group. The results showed a statistically significant difference between the experimental and control groups' average scores on the test of creative thinking abilities, with the experimental group scoring better than the control group.

Wannapiroon et al. (2021) created an educational model that combines augmented reality and interactive features to enhance learning in the SMART classroom. They utilized the Imagineering method in their approach. The methodology comprises four discrete stages: (1) development of the augmented reality interactive learning model; (2) generation of augmented reality learning materials; (3) formulation of effective teaching strategies for ICT educators; and (4) distribution and implementation of the augmented reality interactive learning model. The study will specifically target a cohort of 30 proficient tertiary educators, 20 vocational trainers, 600 vocational learners, and 900 tertiary learners. The evaluation results indicate that the quality of creative creation is remarkably high.

Amores-Valencia et al. (2023) looked at gender and the students' opinions about this technology when they studied the impact of augmented reality on secondary school students' academic ability. In order to choose a sample of 321 students, ages 14 to 17, from a single secondary education school, this study used a mixed-method research design and easy sampling. Subsequently, the pupils were split into two cohorts: a control group comprising 162 kids and an experimental group of 159 students.

While the experimental group used an augmented reality (AR) mobile application called ComputAR, which was created based on the same concepts, the control group used a traditional technique in a classroom environment that depended on presentations. Both groups completed pre- and post-tests, and the experimental group also underwent semi-structured interviews as part of the data gathering methods. These results highlighted the potential benefits of integrating augmented reality technology into the teaching methods by showing that students who used it achieved better academic performance. Regarding the gender distribution of the students, no significant differences were found. In summary, the findings of this study encourage secondary schools to use augmented reality.

Parani et al. (2023) provided evidence of the effects of using the Augmented Reality (VAR) Virus Application on fostering students' creative tendencies and thinking skills. During biology courses on viruses at a public high school in Mataram, 118 pupils in the tenth grade participated in a study. An experimental design that includes a pretest and posttest control group was used to conduct the investigation. While the control group used PowerPoint, the experimental group of students learned using the VAR program. A pretest and posttest measuring creative thinking abilities and creative disposition were given to both classes before and after the intervention. The study's quantitative data was evaluated and analyzed using the N-gain test and difference test to gauge the participants' capacity for both creative thinking and creative disposition. According to the study's findings, students in the experimental class (VAR application) who were in the medium category (N-gain 0.41) showed higher levels of creativity than those in the control class (ppt application), which were in the low category (N-gain 0.23). The collected data showed statistical significance. Students' creative thinking skills improved somewhat in the VAR class (N-gain 0.32), but they improved less in the ppt class (N-gain 0.09), with significant disparities between the two groups. According to this study, using the VAR application can help teach people about viruses and is a suitable way to support the growth of creative thinking skills.

4. Methodology

This research made use of an experimental design in which the effects on a dependent variable were measured and documented after changes were made to one or more independent variables. For this study, the researcher used both conventional methods and an AR app to measure the effects on the participants. There were two groups of people in the study; one got instruction via an augmented reality program, while the other got regular old-fashioned training.

4.1 Population and Sample

The 535 students who were enrolled in the Abha Governorate before it was divided into 170 schools make up the study population. We used a random sampling technique to pick our sample. We randomly choose two classes to participate in the study. Fifteen students were randomly assigned to one of the two classrooms; the other served as the control group.

4.2 Research Instrument

Using two different research instruments allowed the study to achieve its objectives.

1. A pedagogical blueprint designed for an educational initiative that relies on augmented reality technology: The objective of the study was to facilitate the cultivation of innovative thinking among learning-disabled students in Abha schools. The objective of the ongoing study was to complete it by the academic year 2023-2024. After a thorough evaluation of the experiment's overarching aims and the pertinent information related to the topics under investigation, the researcher formulated an initial collection of 26 behavioral objectives. The several parts that make up the framework are as follows: using, comprehending, recalling, assessing, combining, and assessing. A group of specialists and experts verified the data's accuracy and completeness. The specific goals were revised based on the received comments, but the total number of objectives was maintained at 26. Each group used a different approach to lesson planning; one used an augmented reality software to help the experimental group, while the other used more conventional methods. The panel of education strategy experts was given several examples to review. They were assigned this exercise to assess their alignment with the predefined behavioral objectives and the present subject matter. After considering the feedback from the experts, numerous paragraphs were revised again, leading to the creation of the final version. A total of twenty distinct instructional plans were implemented utilizing the two approaches for each of the two groups. More precisely, out of the total 26 plans, 13 of them employed an educational program that depends on augmented reality, while the remaining 13 plans adopted a conventional method.
2. Creating an evaluation tool to enhance the innovative thinking skills of students with learning disabilities: The study aimed to determine the extent to which the items used in the experiment impacted the imaginative thinking of students with learning challenges. Imaginative thinking involves various skills, such as initial imagination, perceptive imagination, and transformative imagination. The exam items are meticulously crafted to convey the intended goal and to evaluate writing skills in accordance with the standards established by recent scholarly work. The majority of the test items were multiple-choice, and they included an augmented reality-based instructional project. The item selection approach was predicated on the subscale specifically devised to bolster inventive cognition. Each question in the set has a first statement and four potential responses. Students are required to choose the suitable answer. The examination comprises a total of 19 elements.

Instrument Validity and Reliability

The reliability of the instrument was assessed using two methods:

1. The instrument must be evaluated by a panel of eight arbitrators, and a cutoff point of 80% acceptance rate must be established.
2. Ten students were assessed according to the degree of discriminant validity they demonstrated. Using the observed (F) values of 4.90, 5.30, and 5.80, the statistical significance of the discriminant validity of the coefficients was ascertained.

To determine the instrument's internal consistency, Cronbach's alpha was used. The total dependability score of the instrument was 0.821, which is rather good. It should be noted that the dependability coefficients range in magnitude from 0.805 to 0.845 for both criteria.

4.3 Data Analysis

The mean test scores for the pre- and post-tests, together with their standard deviations, were calculated once data collection was finished. By applying the Eta square, the impact size—which shows how augmented reality technology helps kids with learning challenges expand their inventive thinking—was determined. To provide a more thorough explanation for the variations between two comparable samples, statistical procedures such as the Z-value and Wilcoxon's test were employed.

5. Results and Discussion

Before an instructional program based on augmented reality technology was introduced, Table 1 demonstrates that the imaginative thinking of learning-disabled students in the experimental and control groups was comparable.

Table 1
Initial Assessment

Dimensions	Groups	N	M/R	S/R	U	Z	P
First imagination	Experimental	15	15.30	229.50	20.00	7.50	0.110
	Control	15	16.10	241.50			
Perceptive imagination	Experimental	15	15.60	234.00	23.00	8.50	0.120
	Control	15	15.40	231.00			
Transformative imagination	Experimental	15	16.00	240.00	25.00	9.30	0.140
	Control	15	15.70	235.50			
Total	Experimental	15	19.30	234.50	23.00	8.60	0.125
	Control	15	20.65	236.00			

The results shown in Table 1 show that there was no statistically significant difference in the two groups' mean scores across many categories on the pre-test of creative thinking. It was the same for the two sets of students.

Table 2
Post-test

Dimensions	Group	N	M/R	S/R	U	Z	P
First imagination	Experimental	15	17.80	267.00	250.00	0.700	0.000
	Control	15	11.30	169.50			
Perceptive imagination	Experimental	15	18.10	271.50	260.00	0.650	0.000
	Control	15	14.30	214.50			
Transformative imagination	Experimental	15	18.50	277.50	265.00	0.55	0.000
	Control	15	14.00	210.00			
Total	Experimental	15	18.10	271.50	260.00	0.650	0.000
	Control	15	13.20	198.00			

Table 2 displays the experimental group's post-test findings. Mean scores for creative thinking—which includes initial, perceptual, and transformative imagination—were significantly different between the control and experimental groups. The results show that the experimental group of kids had a lot of creative thinking.

The observed outcome is a result of various interrelated factors, both tangible and concealed, that are directly associated with the implementation of augmented reality technology by the students in the experimental group. This technology had a positive impact on enhancing their imaginative capacity, particularly in the context of teaching listening texts, as it enabled these students to visually experience the events being presented. The lessons involve the use of three-dimensional models to interactively transform familiar sensory images, objects, characters, and events from the story and audio texts into unfamiliar images and vice versa. These transformations occur during or after listening, and the mental and motor activities associated with this process contribute to the learning experience. Through various means, they acquired and honed their capacity to conceive and generate abstract mental representations, leading to exceptional performance in the test items assessing each facet of imaginative ability. Consequently, when compared to their counterparts in the control group, who solely received auditory stimuli, they surpassed their peers in overall performance. Next, respond to the particular series of questions that come after, separate from the multitude and variety of activities associated with cognitive processing and conceptual mental visualization. This result is in line with earlier studies by Alhanai and Almanthari (2019), Wannapiroon et al. (2021), Amores-Valencia et al. (2023), and Parani et al. (2023).

To address the second inquiry, does the experimental group show notable variations in the effectiveness of an educational program that uses augmented reality technology to encourage imaginative thinking in students with learning difficulties? The subsequent table presents the results.

Table 3
Pre and Post-Measurement

Dimensions	Pre/Po	N	M/R	S/R	Z	P
First imagination	Negative Rank	5	2.00	10	18.30	0.000
	Positive Rank	10	6.00	60.00		
	Ties	0				
	Total	15				
Perceptive imagination	Negative Rank	5	2.00	10	19.10	0.000
	Positive Rank	10	6.00	60.00		
	Ties	0				
	Total	15				
Transformative imagination	Negative Rank	5	2.00	10	18.60	0.000
	Positive Rank	10	6.00	60.00		
	Ties	0				
	Total	15				
Total	Negative Rank	5	2.00	10	18.80	0.000
	Positive Rank	10	6.00	60.00		
	Ties	0				
	Total	15				

The experimental groups' average scores on several imaginative thinking tasks, including transformational, perceptive, and early imagination, varied significantly from one another. Table 3 displays a large variation in the final exam score. The results show that after the assessment, students in the experimental group were more creative thinkers.

The research affirms that the results may be attributed to the effectiveness of using augmented reality technology to encourage imaginative thinking in learning-disabled pupils. This occurs because educators who employ this methodology - which involves delivering information in a manner that corresponds with desired notions and relates to the student's own experiences - develop more enthusiasm and commitment towards their profession. As a result, students engaged in conversations, provided valuable input to scientific discussions, and demonstrated respect for their classmates. Participants in this augmented reality demonstrated mutual respect, fostering an environment that promotes the exploration of novel scientific breakthroughs that surpass the acquisition of current information. The duties of tracking, predicting, reasoning, designing, selecting alternative thought, organizing, integrative thinking, and formative evaluation are all equally reliant on the inquiry process. Furthermore, the explanation step elevates pupils' skill levels to a more advanced degree. This result is consistent with other studies conducted by Wannaperon et al. (2021), Barani et al. (2023), Amores Valencia et al. (2023), and Al-Hinai and Al-Mundhiri (2019).

The last question concerns whether there is a statistically significant difference between the results of the post-test and follow-up tests when assessing the effectiveness of a learning program that uses augmented reality technology to encourage creative thinking in students who struggle with learning. Answering the present question as soon as possible is essential to offering a meaningful answer. The results are shown in the table.

Table 4
Post and Follow-up

Dimensions	Po/ Foll	N	M/R	S/R	Z	P
First imagination	negative rank	12	5.80	69.60	8.40	0.200
	positive rank	0	0.00	0.00		
	ties	3				
	total	15				
Perceptive imagination	negative rank	12	5.80	69.60	8.10	0.170
	positive rank	0	0.00	0.00		
	ties	3				
	total	15				
Transformative imagination	negative rank	12	5.80	69.60	8.20	1.80
	positive rank	0	0.00	0.00		
	ties	3				
	total	15				
Total	negative rank	12	5.80	69.60	8.15	0.١75
	positive rank	0	0.00	0.00		
	ties	3				
	total	15				

Table 4 shows that there are no statistically significant variations in the average scores of the experimental group between the post-test and follow-up evaluations. The results of the study suggest that the program's effectiveness persisted throughout the post-intervention phase rather than appearing to decline once it was stopped.

The findings are consistent with the idea that augmented reality technology can help children who struggle with learning to think creatively and build their original, perceptive, and transformational imaginations. Therefore, there was no discernible decline in the results that were previously released for the individuals in question. Programs utilizing augmented reality technology also facilitate lifetime learning by facilitating the connection between recently taught concepts and previously understood ones. The hypothesis states that students are less likely to undergo abrupt or early turnover if they are given the chance to exercise and refine their cognitive and practical skills in a range of curriculum-outlined contexts.

6. Conclusion

The findings of this study support the notion that using augmented reality technology can support the development of creative thinking in people with learning difficulties. Therefore, one of the most crucial elements is the degree to which augmented reality technology has been able to develop and enhance students' capacity to envision and create abstract mental images through a variety of techniques, leading to remarkable performance on exam items that evaluate all facets of imaginative ability. They therefore performed better overall than their classmates in the control group, who only received the auditory cues. After that, answer the particular set of questions that follows in a way that is distinct from the numerous and varied tasks related to conceptual mental representation and cognitive processing.

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References

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Alzahrani, A. I., & Sarsam, S. M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation*, *66*, 100876.

Alhanai, J., & Almanthari, R. (2019). The impact of augmented reality technology on creative thinking skills improvement in Arabic language of 5th grade female students. *An-Najah University Journal for Research-B (Humanities)*, *35*(10), 1729-1768.

Amores-Valencia, A., Burgos, D., & Branch-Bedoya, J. W. (2023). The Impact of Augmented Reality (AR) on the Academic Performance of High School Students. *Electronics*, *12*(10), 2173.

Arici, F., Yilmaz, R. M., & Yilmaz, M. (2021). Affordances of augmented reality technology for science education: Views of secondary school students and science teachers. *Human Behavior and Emerging Technologies*, *3*(5), 1153-1171.

Avila-Garzon, C., Bacca-Acosta, J., Duarte, J., & Betancourt, J. (2021). Augmented Reality in Education: An Overview of Twenty-Five Years of Research. *Contemporary Educational Technology*, *13*(3).

Buchner, J., & Zumbach, J. (2020). Augmented reality in teacher education. a framework to support teachers'technological pedagogical content knowledge. *Italian Journal of Educational Technology*, *28*(2), 106-120.

Cakir, R., & Korkmaz, O. (2019). The effectiveness of augmented reality environments on individuals with special education needs. *Education and Information Technologies*, *24*, 1631-1659.

Cheng, K. H. (2018). Surveying students' conceptions of learning science by augmented reality and their scientific epistemic beliefs. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1147-1159.

da Silva, M. M., Teixeira, J. M. X., Cavalcante, P. S., & Teichrieb, V. (2019). Perspectives on how to evaluate augmented reality technology tools for education: a systematic review. *Journal of the Brazilian Computer Society*, *25*, 1-18.

Faria, A., & Miranda, G. L. (2023). Effects of using augmented reality on students' learning. *Trends in Computer Science and Information Technology*, *8*(1), 001-004.

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635.

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review*, *27*, 244-260.

Giannopulu, I., Brotto, G., Lee, T. J., Frangos, A., & To, D. (2022). Synchronised neural signature of creative mental imagery in reality and augmented reality. *Heliyon*, *8*(3).

Heintz, M., Law, E. L. C., & Andrade, P. (2021). Augmented reality as educational tool: Perceptions, challenges, and requirements from teachers. In *Technology-Enhanced Learning for a Free, Safe, and Sustainable World: 16th European Conference on Technology Enhanced Learning, EC-TEL 2021, Bolzano, Italy, September 20-24, 2021, Proceedings 16* (pp. 315-319). Springer International Publishing.

Ibáñez, M. B., Portillo, A. U., Cabada, R. Z., & Barrón, M. L. (2020). Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. *Computers & Education*, *145*, 103734.

Muhammad, M. (2022, November). Review of Trends in Learning Media of Augmented Reality Integrated with STEM Approach to Improve Students' Creative Thinking Skill. In *Journal of Physics: Conference Series* (Vol. 2377, No. 1, p. 012084). IOP Publishing.

Mundy, M. A., Hernandez, J., & Green, M. (2019). Perceptions of the effects of augmented reality in the classroom. *Journal of Instructional Pedagogies*, *22*.

Mystakidis, S., Christopoulos, A., & Pellas, N. (2022). A systematic mapping review of augmented reality applications to support STEM learning in higher education. *Education and Information Technologies*, *27*(2), 1883-1927.

Olim, S. C., & Nisi, V. (2020). Augmented reality towards facilitating abstract concepts learning. In *Entertainment Computing–ICEC 2020: 19th IFIP TC 14 International Conference, ICEC 2020, Xi'an, China, November 10–13, 2020, Proceedings 19* (pp. 188-204). Springer International Publishing.

Perifanou, M., Economides, A. A., & Nikou, S. A. (2022). Teachers' views on integrating augmented reality in education: Needs, opportunities, challenges and recommendations. *Future Internet*, *15*(1), 20.

Schaffernak, H., Moesl, B., Vorraber, W., & Koglbauer, I. V. (2020). Potential augmented reality application areas for pilot education: An exploratory study. *Education Sciences*, *10*(4), 86.

Wannapiroon, P., Nilsook, P., Kaewrattanapat, N., Wannapiroon, N., & Supa, W. (2021). Augmented Reality Interactive Learning Model, using the Imagineering Process for the SMART Classroom. *TEM Journal*, *10*(3).