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Augmented Reality in Pre-University Education (A Methodological Study)

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ABSTRACT

This systematic review explores the adoption of augmented reality (AR) technology and its impact on pre-university education. By conducting a comprehensive analysis of (61) studies from the Dar Almandumah and Shamaa databases, the study aims to highlight the methodological and applied trends in scientific research on AR technology in pre-university education. It also examines the research variables derived from these studies. The findings revealed a significant increase in the number of published studies since 2019, reaching a peak in 2022. Furthermore, it was found that secondary education represents the most frequently targeted stage for implementing AR applications. Science was identified as the subject where AR's effectiveness was most commonly assessed. The study also indicated that thinking skills were the most frequently studied research variables related to AR technology in pre-university education. The study recommended the development of a comprehensive training guide for pre-university teachers to effectively integrate AR technology into educational practices.

Keywords: Augmented Reality, Pre-University Education, Kindergarten, Elementary Education, Middle School, High School.

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1. Introduction

Augmented reality (AR) technologies have witnessed significant development in recent years, evolving from laboratory research to becoming available on devices that people use daily. Since their emergence in the 1960s, the hardware supporting this technology has become more advanced and user-friendly; image quality and device size have been noticeably improved, which has helped spread the use of augmented reality in various fields, including education.

AR technology combines reality and the virtual world using hardware and software to display three-dimensional images, graphics, and texts that are overlaid onto the physical world. This technology can be utilized through a variety of devices such as computers, smartphones, tablets, and wearable devices (Chatwattana, Kanyawimon & Jaipaitoon, 2022).

Augmented reality allows learners to interact with the real world using their various senses—sight, hearing, and touch—and contributes to enhancing education by offering interactive and innovative experiences that increase responsiveness and engagement, thereby raising learning efficiency by combining technology with traditional methods. It also contributes to increasing learners' interest in academic content and deepening their comprehension by providing an interactive and engaging learning environment (Watkraw & Sangsawang, 2023).

AR enhances learners' ability to engage in self-directed learning, increases their interest in educational materials, and develops their desire to use modern technical capabilities and interactive technologies. It can also replace textbooks and laboratory equipment with multimedia computer models, improving the quality of education particularly in the context of distance learning (Gurevych et al., 2021).

AR technology allows the integration of real objects with virtual information that can be overlaid on them, enhancing learners' interaction with the physical environment and facilitating their learning process (Ke & Hsu, 2015). AR benefits learners in visualizing complex relationships, providing experiences that are difficult or impossible to achieve in real life, embodying abstract concepts, and making learning more enjoyable while effectively increasing student participation (Yılmaz & Goktas, 2018).

AR applications also contribute to processes such as attention, motivation, knowledge acquisition, collaboration, and information-based feedback. They allow the development of new skills through specialized training that includes repeating the same task in an environment containing advanced verbal and visual cues for learners (Cascales-Martínez et al., 2017; Çakır & Korkmaz, 2019).

AR is distinguished by its entertainment aspect, which helps increase learners' interest in learning by making it a real and engaging experience. It engages all five senses of learners, contains characteristics similar to traditional learning media, and is considered useful for interactive and realistic learning that learners can use directly (Cahyono et al., 2020; Yip et al., 2019). It also provides interaction that helps learners see the real situation directly and imagine the outcomes of the learning process presented by teachers (Pujiastuti & Haryadi, 2020).

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AR has received significant attention in education due to its potential to influence not only learning outcomes but also student behavior in classrooms. A study by Qiu & Luo (2022) found that AR use led to improved student behavior through increased motivation and a more interactive learning environment. Goo et al. (2020) found AR changed learner behavior, with learners showing greater preference for exploratory and collaborative learning. Tatarinova et al. (2022) also found a significant effect of AR on the development of creative thinking.

2. Statement of the Problem

Saudi Arabia has shown distinguished efforts by institutions and companies seeking to change the educational system under the slogan 'Smart Learning Using Modern Technology.' However, the activation of AR technology in the educational field remains limited to a local scope in a few cities, and the vast majority remains in the category of late adopters according to Rogers' innovation adoption curve. Saudi Arabia is leading educational development efforts through Vision 2030, which includes strong initiatives and plans aimed at promoting the use of technologies in the educational field—including augmented reality—to achieve results that contribute to transforming the Kingdom into an emerging and advanced nation globally in the educational domain (Al-Mubarak, 2018).

Many studies have confirmed the effectiveness of AR technology in education: it increases motivation and achievement (Estapa & Nadolny, 2015; Solak & Cakır, 2015), develops scientific concepts (Yena, Tsaib & Wua, 2013), develops achievement and attitudes (Abdulhadi, 2018), supports learner engagement (Han, Jo, Hyun & So, 2015), and helps with perseverance, focus, and creativity (Kotzageorgiou et al., 2018). It also increases learning motivation (Cheng & Tsai, 2016). Bacca et al. (2014) reviewed (32) research papers on AR between 2003–2013 and revealed consensus on the effectiveness of AR in education.

There is increasing interest in using AR applications in the educational system, which necessitates a systematic review to analyze Arabic studies published in recent years. Additionally, no Arabic studies have presented a systematic review on AR in pre-university education up to the year 2023.

3. Research Questions

1. What are the methodological and applied trends in scientific studies conducted on AR technology in pre-university education?
   - How were studies distributed according to publication years?
   - How were studies distributed according to academic subjects?
   - How were studies distributed according to educational stage?
2. What are the research variables obtained from scientific studies conducted on AR technology in pre-university education?

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4. Study Objectives

The current study seeks to achieve the following objectives:

- Reveal the methodological and applied trends in scientific studies conducted on AR technology in pre-university education, in terms of: (a) distribution by publication years, (b) distribution by academic subjects, (c) distribution by educational stage.
- Identify the research variables obtained from scientific studies conducted on AR technology in pre-university education.

5. Significance of the Study

5.1 Theoretical Significance

- The study may contribute to strengthening the role of AR in pre-university education.
- It may constitute an addition to the educational literature on the use of AR technology in education.

5.2 Practical Significance

- The study may assist teachers by providing a comprehensive overview of the most important AR applications in education.
- The study may open new horizons for researchers on AR and its connection to school curricula.
- The study may assist educational supervisors in guiding teachers to use AR applications in education.

6. Limitations of the Study

The study is limited to surveying and analyzing the content of published Arabic research and studies that addressed the field of AR in pre-university education during the period from January 2019 to December 2023, available in the Mandumah and Shamaa databases.

7. Terminology

7.1 Augmented Reality

Augmented reality is defined as: a real-time direct view of the physical environment that is enhanced by adding virtual information generated by a computer (Goff, Hartstone-Rose, Irvin & Mulvey, 2020).

The researcher defines it operationally as: the technology that allows enhancement of the real world by merging three-dimensional objects created in computer

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environments with the real environment, helping learners perceive and understand their surroundings better.

8. Methodology and Procedures

This study aims to review scientific studies that addressed the use of AR technology in pre-university education. The systematic review methodology was used. Systematic review is a comprehensive means of examining studies by evaluating them and synthesizing findings on a specific topic (Uman, 2011). It is a valuable method for generating research findings and presenting conclusions that add value to discussions in educational research (Bennett, Lubben, Hogarth, & Campbell, 2005). Systematic reviews enhance the research process using transparent and replicable procedures (Tranfield, Denyer, & Smart, 2003). Systematic review involves three main phases: planning, execution, and reporting (Kitchenham, 2004):

- Phase One – Planning the Review: Establishing a review protocol that defines objectives, search terms, inclusion/exclusion criteria, and the data to be analyzed.
- Phase Two – Executing the Review: Searching and screening studies, applying criteria filters, designing data extraction forms, and summarizing findings.
- Phase Three – Preparing the Report: Formulating the final report presenting systematic review findings in a clear and methodical manner.

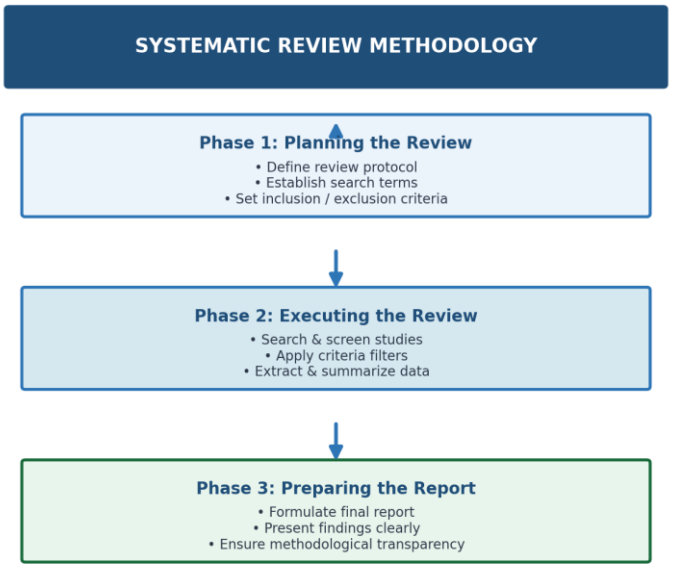

Figure (1): Basic Phases of Systematic Review Studies

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8.1 Planning the Review

In this review, a comprehensive search for scientific studies was conducted primarily in the Dar Almandumah and Shamaa databases. Results were filtered using keywords in the paper title and keyword list. The following criteria were taken into account when selecting studies for inclusion:

- Research must evaluate the effects or effectiveness of using AR in pre-university education.
- Articles must be published during the period between 2019 and 2023.
- Full access to the full text of the study must be available.
- The study must be accessible using keywords: "AR and Kindergarten Children", "AR and Primary Stage", "AR and Middle Stage", "AR and Secondary Stage".

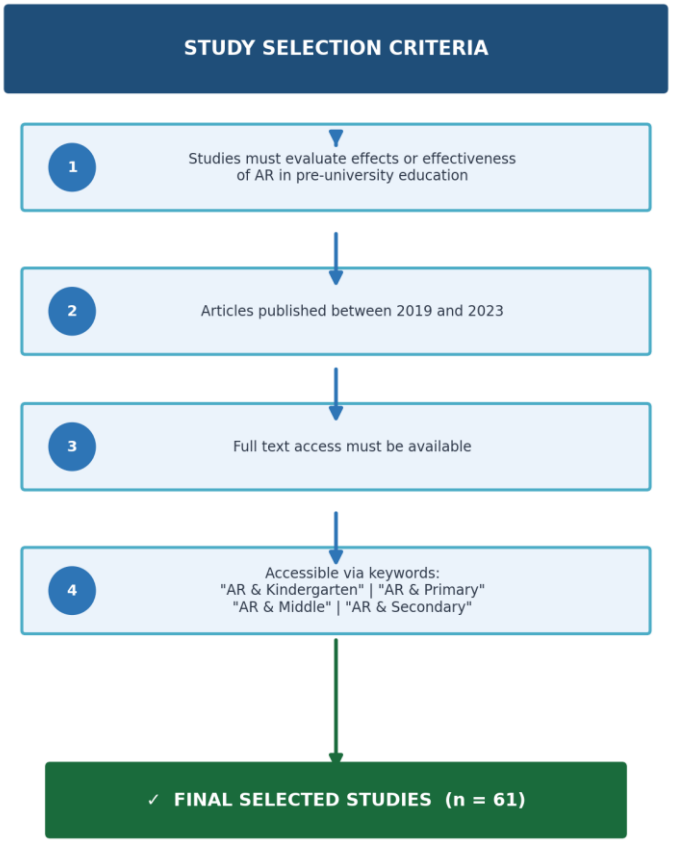

Figure (2): Criteria for Selecting Studies for Inclusion

Figure (2): Criteria for Selecting Studies for Inclusion in the Study

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Table (1): Keywords Used in the Search

Search Strategy	Search Terms (Title)	Dar Almandumah	Dar Shamaa
1	"AR" and "Kindergarten Children"	12	5
2	"AR" and "Primary Stage"	28	13
3	"AR" and "Middle Stage"	22	12
4	"AR" and "Secondary Stage"	40	15
	Total	102	45

Grand Total: 147 studies

Table (1) shows that (147) studies were initially selected to be included in Phase Two.

8.2 Executing the Review

The output of the previous phase, totaling (147) studies, was subjected to an additional screening process in accordance with PRISMA 2020 guidelines (Page et al., 2021) in order to assemble studies relevant to the current study. In light of this, data extraction was carried out in full accordance with the study objectives.

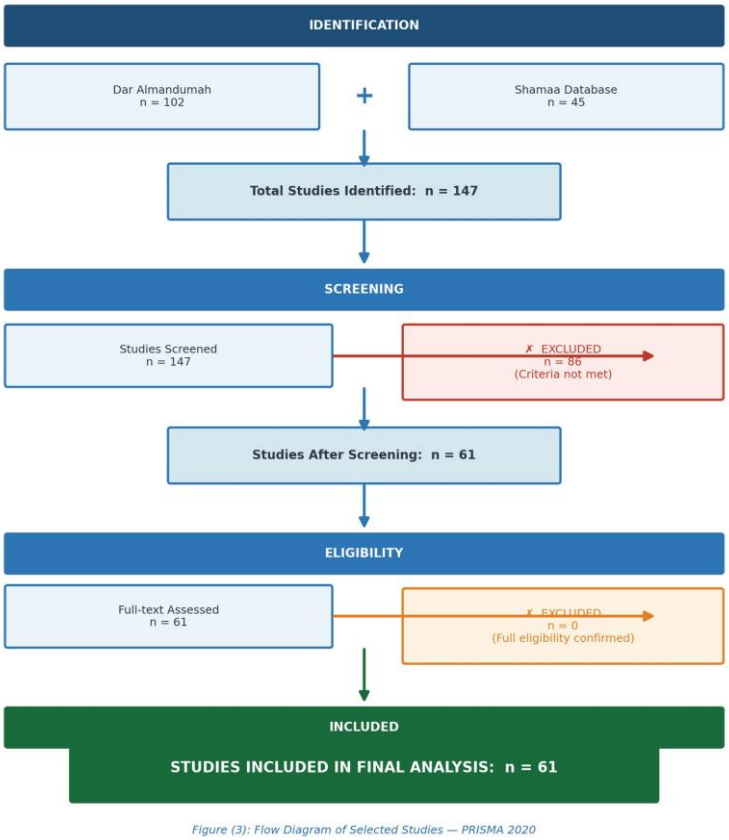

Figure (3): Flow Diagram of Selected Studies — PRISMA 2020

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8.3 Preparing the Report

In light of the research questions and the findings of the selection process, the researcher arrived at (61) studies that suit the objectives and nature of the current study. In light of this, findings were derived that will be presented in accordance with the research questions.

9. Study Results

Studies related to the use of AR technology in pre-university education were analyzed and the extracted results were presented under two main headings: trends in studies and main findings.

9.1 Answer to the First Research Question

What are the methodological and applied trends in scientific studies conducted on AR technology in pre-university education?

9.1.1 Distribution of Studies by Publication Years

Previous studies were analyzed by publication years. The following table and figure show the results:

Table (2): Distribution of Studies by Publication Years

Publication Year	Number of Studies	Percentage
2019	13	21.3%
2020	10	16.4%
2021	11	18.0%
2022	14	23.0%
2023	13	21.3%
Total	61	100%

Table (2) shows that the number of studies by publication years: 2019 (13 studies, 21.3%), 2020 (10 studies, 16.4%), 2021 (11 studies, 18.0%), 2022 (14 studies, 23.0%), and 2023 (13 studies, 21.3%).

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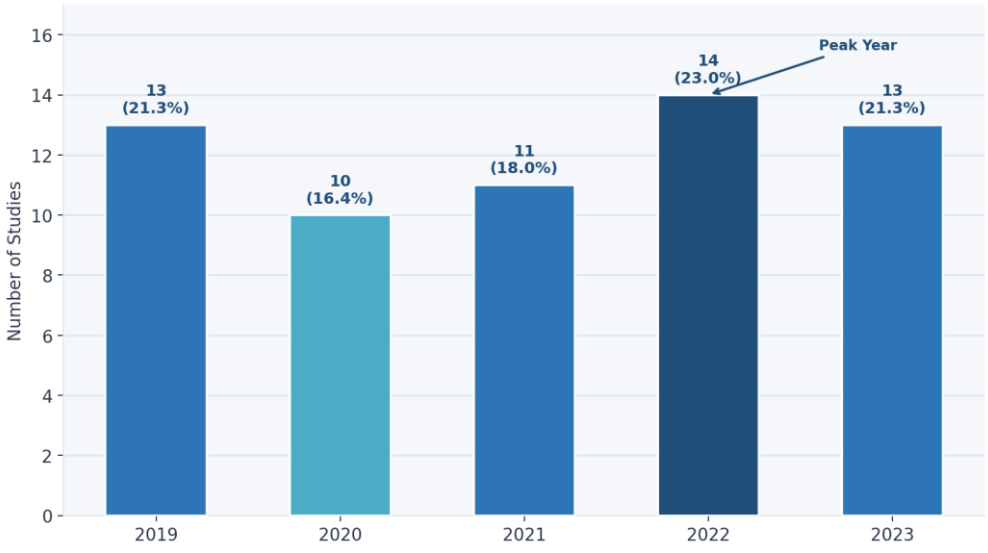

Figure (4): Distribution of Studies by Publication Years

Figure (4): Distribution of Studies by Publication Years

9.1.2 Distribution of Studies by Academic Subjects

Previous studies were analyzed by academic subject. The following table and figure show the results:

Table (3): Distribution of Studies by Academic Subjects

Academic Subject	No. of Studies	Percentage
Arabic Language	6	9.8%
English Language	2	3.3%
Science	18	29.5%
Social Studies	6	9.8%
Mathematics	7	11.5%
Chemistry	3	4.9%
Biology	5	8.1%
Computer Science	7	11.5%
Islamic Education	2	3.3%
Library & Research	1	1.6%
Art Education	2	3.3%
Psychology	1	1.6%
Music	1	1.6%
Total	61	100%

Table (3) shows the distribution of studies by academic subject. Science had the highest number of studies (18, 29.5%), followed by Mathematics and Computer

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Science (7 each, 11.5%), Arabic Language and Social Studies (6 each, 9.8%), Biology (5, 8.1%), Chemistry (3, 4.9%), and the remaining subjects with 1–2 studies each.

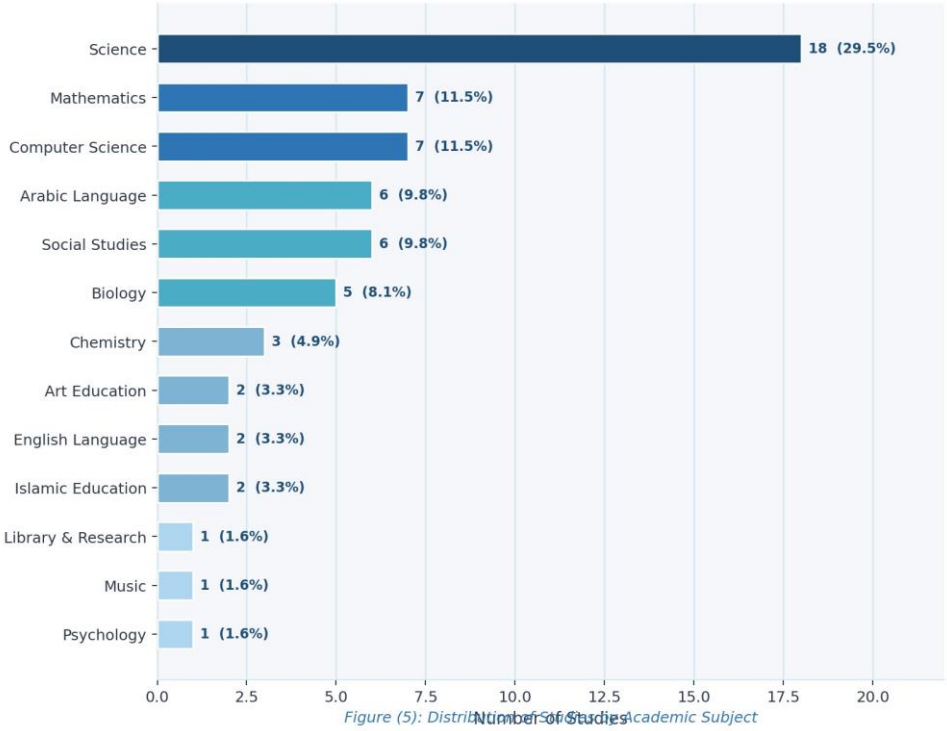

Figure (5): Distribution of Studies by Academic Subject

9.1.3 Distribution of Studies by Educational Stage

Previous studies were analyzed by educational stage. The following table and figure show the results:

Table (4): Distribution of Studies by Educational Stage

Educational Stage	No. of Studies	Percentage
Kindergarten	13	21.3%
Primary Stage	15	24.6%
Middle Stage	14	23.0%
Secondary Stage	19	31.1%
Total	61	100%

Table (4) shows the distribution of studies by educational stage: Kindergarten (13, 21.3%), Primary Stage (15, 24.6%), Middle Stage (14, 23.0%), and Secondary Stage (19, 31.1%) — the highest.

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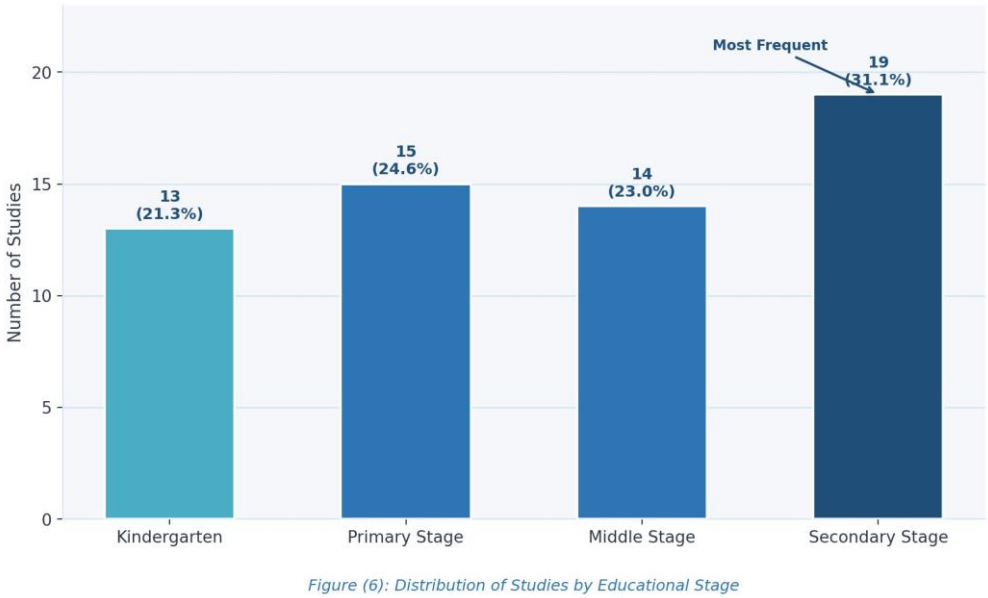

Figure (6): Distribution of Studies by Educational Stage

Figure (6): Distribution of Studies by Educational Stage

9.2 Answer to the Second Research Question

What are the research variables obtained from scientific studies conducted on AR technology in pre-university education?

Table (5) shows the results of analyzing previous studies in terms of research variables:

Table (5): Research Variables of AR Technology in Pre-University Education

#	Variable	Studies	Example Study
1	Achievement	14	Khalaf & Hariri (2019)
2	Thinking Skills	15	Al-Zahrani (2021)
3	Motivation	6	Al-Hujaili (2019)
4	Attitudes	2	Al-Ghamdi & Qutb (2020)
5	Computer Skills	3	Mujarshi & Al-Zahrani (2019)
6	Sustainable Development	2	Abd Al-Basit, Salam & Mohammed (2023)
7	Reading Skills	3	Mohammed, Yousef, Shehata & Morsi (2023)
8	Concepts	8	Al-Otaibi & Al-Malki (2022)
9	Programming Skills	2	Al-Juhani & Al-Rahili (2022)
10	Learning Difficulties	1	Ahmed (2020)
11	Inclination / Tendency	1	Mohammed (2020)
12	Learning Engagement	2	Oraibi (2023)
13	Science Processes	1	Mutawalli (2019)
14	Cognitive Load	1	Al-Ma'dawi (2019)
15	Scientific Curiosity	1	Al-Ma'dawi (2019)
16	Letter-Sound Linking Skills	1	Al-Zahiri & Al-Hassani (2021)
17	21st Century Skills	1	Shalabi et al. (2023)

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#	Variable	Studies	Example Study
18	Cognitive Operations	1	Rashwan & Amin (2022)
19	Learning Perceptions	1	Rashwan & Amin (2022)
20	Number Addition	1	Al-Mutawwa & Al-Dosari (2023)
21	Reading Comprehension Skills	1	Buqlawa & Abd Al-Haq (2021)
22	Improving Learning Outcomes	1	Buqlawa & Abd Al-Haq (2021)
23	Conceptual Comprehension	2	Mohammed (2019)
24	Intellectual Curiosity	1	Mohammed (2019)
25	Mathematical Proficiency	1	Al-Ghamdi (2020)
26	Science Experiment Skills	1	Al-Ajmi (2021)
27	Information Searching Skills	1	Mansour (2021)
28	Spatial Visualization	1	Al-Dukhni & Darwish (2020)
29	Learning Retention	1	Qahuf & Abd Al-Rahman (2019)
30	Artistic Skills	1	Wahish (2022)
31	Spatial Sense	1	Mua'wad et al. (2022)
32	Reading Readiness Skills	1	Mohammed, Habd & Al-Shawa (2022)
33	Awareness	2	Othman & Ali (2023)
34	Enjoyment of Learning	1	Abd Al-Sayyid (2023)
35	Cognitive Processes	1	Mohammed (2023)
36	Rhythmic and Melodic Sense	1	Ali (2020)
37	Auditory Discrimination	1	Mohammed (2021)

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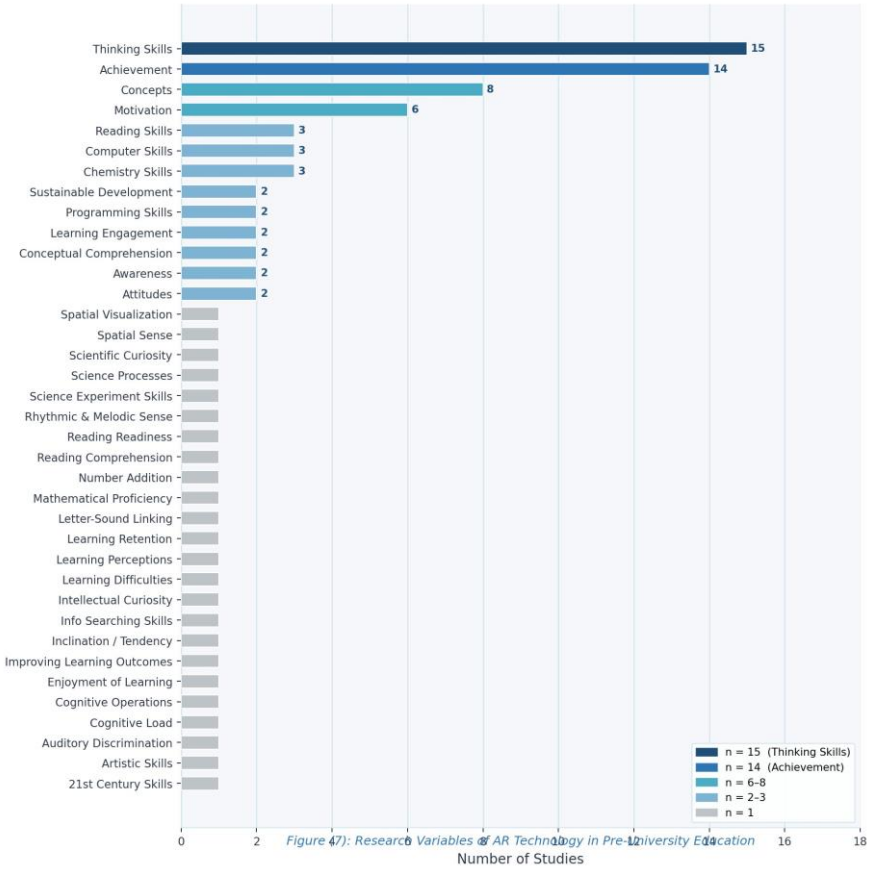

Figure (7): Research Variables of AR Technology in Pre-University Education

10. Discussion and Interpretation of Results

In this study, studies obtained from the Dar Almandumah and Shamaa databases were analyzed in terms of research trends and main findings. The results showed a rise in the number of published studies since 2019, reaching a peak in 2022. This is attributed to the emergence of COVID-19, which led to a faster search for technological media that could be employed in e-learning. AR applications were among the most prominent applications used during the pandemic, and Risdianto (2021) indicates that AR applications contributed positively to visual communication between students and teachers during COVID-19.

The study found that Science is the subject where AR's effectiveness was most commonly measured. AR increases students' interest and motivation toward learning scientific concepts by providing interactive learning experiences and three-dimensional views. It allows students to understand complex concepts more clearly, enhances student participation and enthusiasm, and contributes to enhanced cooperation between students and teachers (Yildirim, 2021).

The Secondary Stage was the most frequent stage for AR applications. This is attributed to adolescence, where students tend toward freedom in learning decisions

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and incline toward modern technology. AR applications give secondary students great freedom to explore educational content interactively. They stimulate multiple senses, enable learning through direct experience, and provide flexibility between collective and individual learning. This technology also contributes to teaching topics requiring visual representation, such as dangerous situations, abstract concepts, or complex topics (Bursali & Yilmaz, 2019).

The most studied research variable was thinking skills. This is attributed to 21st century students' need for technology that encourages thinking (Burke & Fedorek, 2017). Integrating AR in education supports the development of thinking skills by creating a strong link between learners and educational content. Previous studies indicate that AR's most important advantage lies in creating an immersive experience that helps students interact deeply with educational content, contributing to the development of thinking skills (Rodríguez-García et al., 2019; Yip et al., 2019).

11. Study Recommendations

In light of what the current study found, the researcher recommends the following:

- Conduct extensive studies on the impact of AR technology on students with learning difficulties, given that the reviewed studies commonly used experimental methods with mostly secondary-level samples.
- Employ AR technology in teaching various academic subjects in pre-university education.
- Prepare a comprehensive training guide for pre-university teachers to employ AR technology in education.
- Conduct meta-analysis studies to quantitatively determine the effects of using AR technology in pre-university education.

12. Future Studies

In light of the results of the current study, the following future studies are recommended:

- The effectiveness of AR in developing higher-order thinking skills for pre-university students.
- Pre-university students' attitudes toward using AR technology in education.
- The effectiveness of an adaptive training program in developing skills for producing AR applications among pre-university teachers.
- A meta-analysis of AR studies in pre-university education in the period between (2020–2025).

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