Volume 10, Issue 5, May – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

Trends in Augmented Reality for Programming Education: A Scopus-Based Bibliometric Study

Anuprabha V[1]

[1]Department of Computer Applications Don Bosco College Mampetta

Publication Date: 2025/05/16

Abstract: This study presents a bibliometric analysis of research conducted in Augmented reality for programming education. Using the Scopus database, this study aims to identify trends and themes in this emerging field. This study analyzed a dataset of publications from 2010 to 2025 using the bibilometrix R package via the bibiloshiny interface. This study includes scientific productions, most relevant authors, most relevant sources, and keyword occurrences.

Keywords: *Augmented Reality (AR), Mixed Reality, Virtual Reality, Programming, Coding, Software Development, Computer Science, Bibliometric Analysis.*

How to Cite: Anuprabha V (2025). Trends in Augmented Reality for Programming Education: A Scopus-Based Bibliometric Study. *International Journal of Innovative Science and Research Technology*, 10(5), 228-234.
https://doi.org/10.38124/ijisrt/25may467

I. INTRODUCTION

Programming Education is a challenge many students face, especially computer science students. Many students found it difficult to understand concepts such as algorithms, data structures, memory management, and object-oriented design. To improve students' computational thinking, it is necessary to provide them with good programming education. However, most of the time the traditional approaches of teaching make it difficult. In order to address these problems, we must incorporate augmented reality into programming education.

Augmented Reality (AR) technologies enhance users' perceptions of reality by mixing the physical environment of the real world with a computer-generated virtual object. To view this virtual object, users can use smart gadgets.

The integration of AR into programming education has grown significantly over the past decade. In this model, students actively engage with content through hands-on, technology-enhanced experiences.

The number of students enrolled in programming education increases year by year a comprehensive overview of the integration of AR into programming education development strategy is presented. In addition, major publications, key contributors, and trends in this research theme are presented. This study conducted a bibliometricanalysis of integration of AR into programming education. Bibilometric analysis enables the quantification of scholarly outputs, identification of influential publications, and visualization of thematic trends, offering valuable insights into how this research area has evolved over time (Aria & Cuccurullo, 2017).

By analyzing publications indexed in the Scopus database from 2010 to 2025, this study aims to:

- Identifying trends in scientific production.
- Highlight the most contributed authors.
- Explore keyword co-occurrence and thematic evolution.

This bibliometric analysis provides a data-driven overview of its current state, supporting educators, researchers, and policymakers in understanding the development and trajectory of AR applications in programming pedagogy.

II. LITERATURE REVIEW

Immersive technologies such as AR and MR technologies, are being used more frequently in programming education to improve learning experiences. Research indicates that these technologies enhance students' understanding of intricate ideas, encourage teamwork, and increase student involvement. They provide useful tools for visualizing code execution, troubleshooting processes, and grasping system-level ideas.

Particular Instances and Uses: Team-Based Programming: Radu et al. (2021) discovered that augmented reality-enhanced collaborative programming settings, especially in the context of robot programming, have a beneficial effect on learning results and social engagement among peers.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

Imagining Abstract Ideas: Kim et al. (2019) illustrated how MR can help visualize code execution and control flow, greatly enhancing comprehension, particularly for beginner programmers.

AR Tools for Debugging: Martins et al. (2023) presented LCSMAR, an AR application that enables students to visualize and engage with programs sequentially, assisting them in understanding intricate logic and debugging methods.

System-Level Insight: Mahamad et al. (2024) employed AR to educate on internal computer architectures and demonstrated that visualizing interactions between the CPU and memory enhances the retention and accuracy of mental models.

Enhanced Engagement: Drljević et al. (2022) and Lampropoulos et al. (2023) demonstrated that AR can boost student engagement and enhance motivation, persistence, and conceptual understanding, particularly when integrated with gamification and serious games.

Change in Educational Models: Crogman et al. (2025) advocated for a comprehensive shift in education via immersive technologies, highlighting the importance of reevaluating curriculum development, evaluation methods, and educator preparation.

Teacher Preparedness and Infrastructure: Vashisht (2024) underscored the significance of teacher preparedness and infrastructure, stressing that effective AR implementation necessitates not only access to technology but also congruence in pedagogy and digital skills among teachers.

➢ *Main Advantages:*

- Improved Understanding: AR and MR can transform abstract ideas into more concrete and comprehensible forms.
- Enhanced Engagement: Immersive experiences can boost student motivation and enthusiasm for learning.
- Improved Retention: Augmented Reality (AR) and Mixed Reality (MR) can help create mental visuals and enhance concentration, resulting in improved knowledge retention.
- Experiential Learning: These technologies facilitate experiential learning theories and enable students to actively participate in learning materials.

In summary, the incorporation of AR and MR into programming education has significant potential to revolutionize learning experiences, rendering them more interactive, captivating, and efficient.

III. METHODOLOGY

➢ *Database and Search*

The study utilized the Scopus database, a widely recognized source for peer-reviewed scientific literature. A comprehensive search string was constructed using keywords related to the research topics: augmented reality (AR), mixed reality (MR), virtual reality (VR), programming, coding, software development, computer science, education, learning, instruction, training, engagement, motivation, interaction, experience, visualization, simulation, tools, and applications. This search string was designed to capture a wide range of research focusing on the intersection of these concepts.

➢ *Filtering and Refinement*

The initial search results of 1,463 records were refined through several filtering steps. This included focusing on document type (articles), language (English), and subject area (Computer Science) to ensure the analysis was limited to relevant and scholarly publications. This process narrowed the scope to 175 articles.

➢ *Data Export and Analysis*

The filtered articles were exported in RIS format, a common format for bibliographic databases. These data were then analyzed using the Bibliometrix R package, a tool specifically designed for quantitative analysis of research literature, according to the website.

➢ *Preprocessing and Final Sample:*

The analysis began with the initial 175 articles, but a preprocessing step was conducted to ensure data quality and consistency. This likely involved tasks such as cleaning text, correcting errors, and standardizing formats. The final analysis included 173 articles after preprocessing, representing the core data set for the research.

IV. RESULTS

A. Dataset Characteristics

A total of 173 articles related to augmented reality in programming education from 2010 to 2025 were analyzed. The documents were sourced from 108 different publication outlets, reflecting a moderately diverse range of journals, conference proceedings, and academic venues. The annual publication growth rate is 15.78%, indicating a steady increase in scholarly interest over time. This trend is further underscored by the average document age of 4.27 years, which suggests that most research in this area is relatively recent.

The dataset includes 691 unique authors, with only 9 authors contributing single-authored papers and 10 single-authored documents. This highlights a strong tendency toward collaborative research in the field. On average, each document included 4.32 co-authors, which aligns with common authorship patterns in interdisciplinary and technology-focused research domains. Notably, 23.12% of the documents involve international co-authorship, indicating a substantial level of global collaboration.

In terms of content, the dataset contains 1,567 Keywords Plus and 678 Author Keywords, offering a rich semantic base for thematic and co-word analysis. The average citation count per document was 15.42, suggesting that many included studies had gained moderate to high academic attention.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

The dataset predominantly comprises journal articles (n = 172), with one document labeled ambiguously as an article article, likely due to a metadata duplication error during import or indexing.

B. Publication Analysis

➤ *Publication Trend*

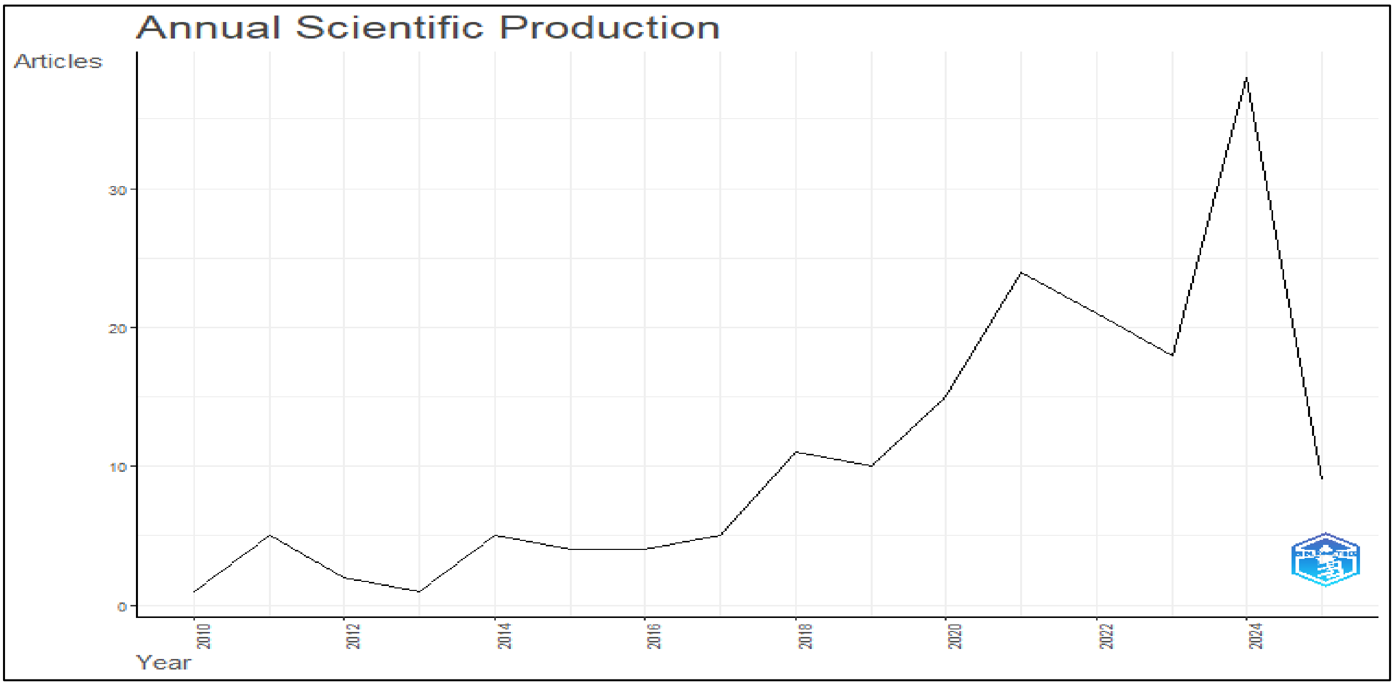

Fig 1 Publication Trend

The number of publications shows a consistent upward trend during these years, indicating growing interest in this topic. The initial years of research in this field saw limited activity, with only a few publications per year until around 2017. From 2018 onwards, the number of publications grew steadily, culminating in a significant surge in 2024, where the highest output of 38 articles was achieved. This increase is likely due to improvements in AR technology, wider adoption in education, and increased scholarly interest in immersive learning methods. While 2025 has fewer publications currently, the year is still ongoing, and continued growth is expected as more research is published and indexed.

➤ *Most Relevant Authors*

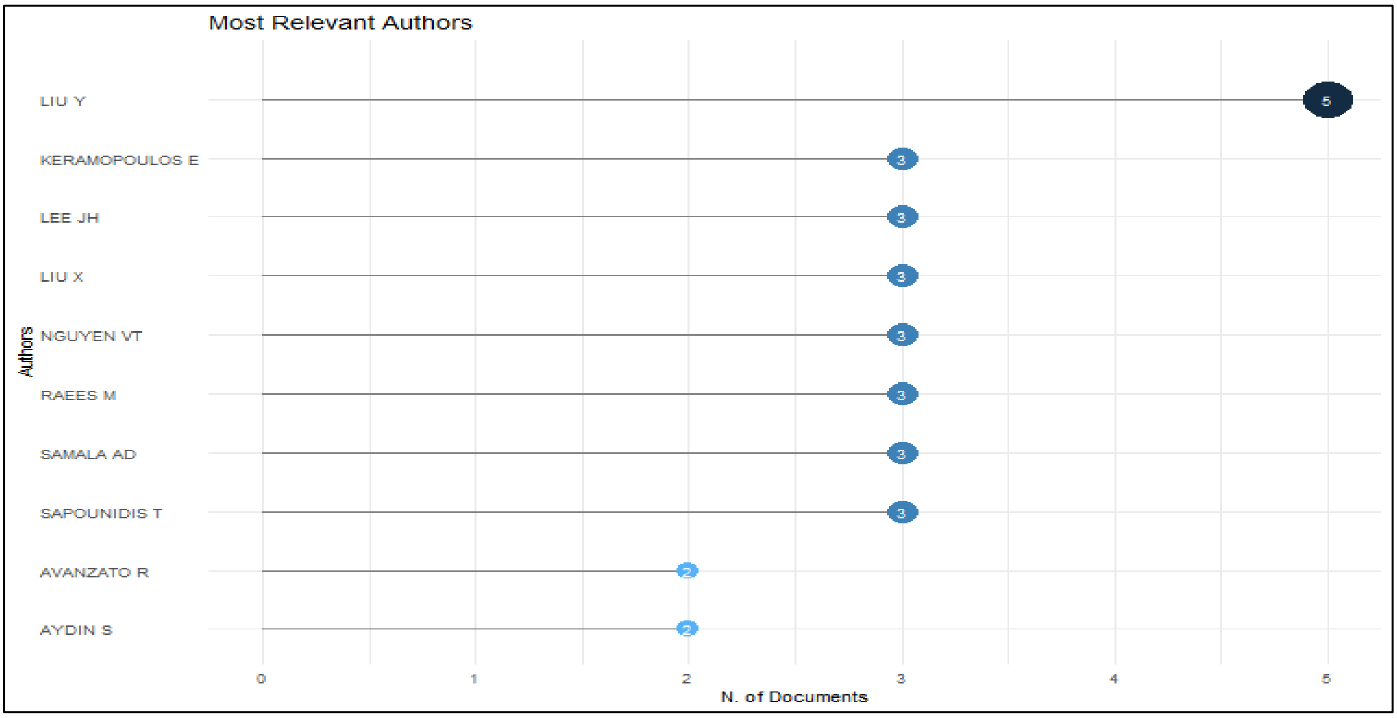

Fig 2 Most Relevant Authors

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

Author productivity is measured by the number of publications and the most recent publication frequency of the authors. This section presents an overview of the author productivity of the research field in augmented reality in programming education. At the top of the figure is the prestigious LIU Y, whose five-publication frequency indicates strong commitment to the topic in its early stages. The next most prolific authors of publications are several other members of the field: LEE JH, LIU X, NGUYEN VT, RAEES M, SAMALA AD, and SAPOUNIDIS T (these authors each have three publications and correspondingly contribute substantially to the literature). Among authors with two publications, such as AVANZATO R, CLARKE PM and GUERRERO-ARIAS A, these authors contributed substantively. Authors with only one publication form the long tail of researchers with emerging or occasional involvement in the field. The distributions illustrate Lotka's Law (11): the high prevalence of small numbers of authors accounts for a large proportion of the output of any scientific discipline. The list contains many familiar surnames (such as Liu, Wang, or Zhang), which suggests the potential for author ambiguity, especially in East Asian contexts.I stress the importance of author disambiguation in author data interpretation. Additionally, the high diversity of authors indicates that all disciplines covered the topic. More work on co-authorship networks and citation impact will help us better understand author productivity and influence in the research community.

➤ *Most Relevant Sources*

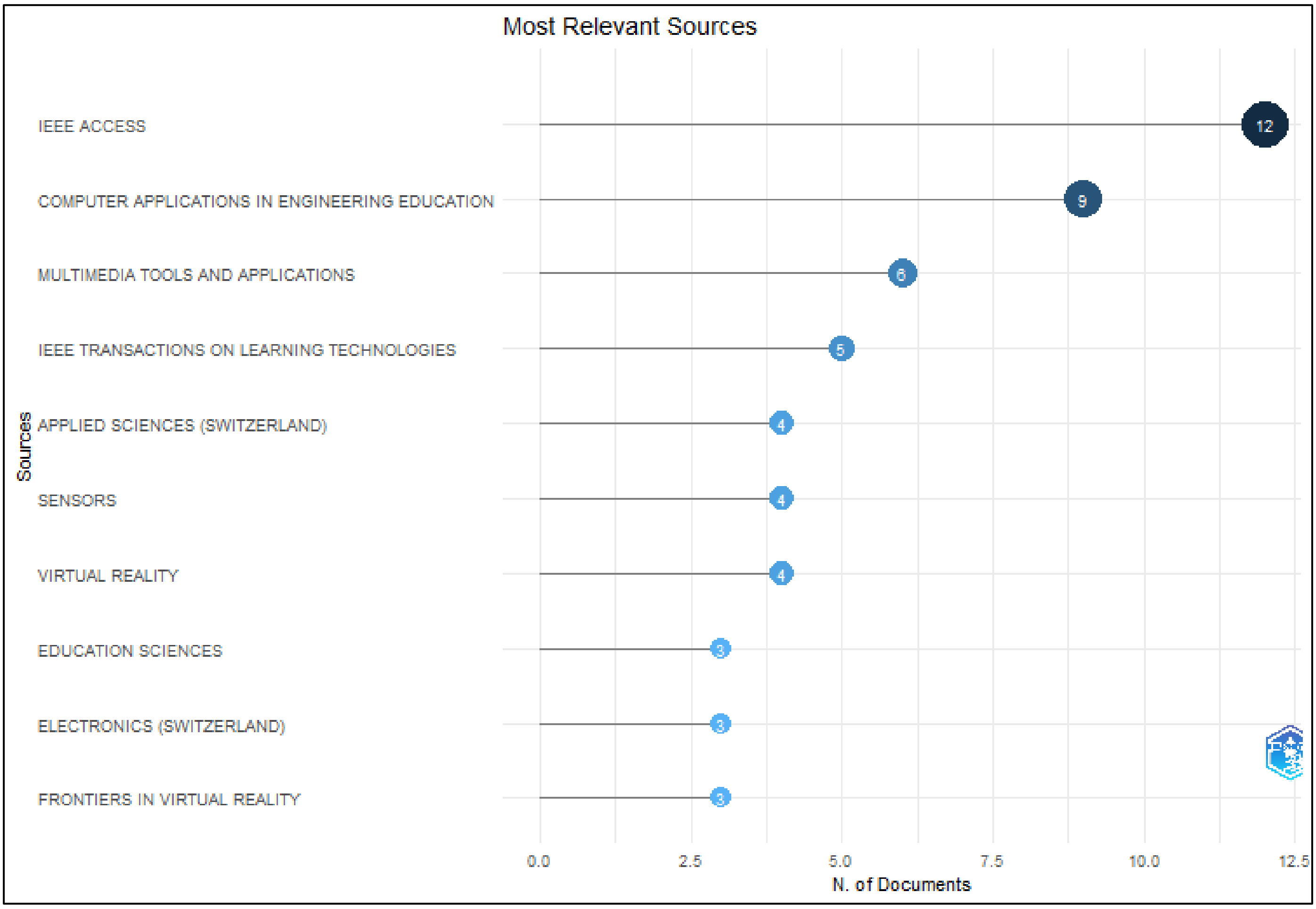

Fig 3 Most Relevant Sources

IEEE Access is notably the top source, with 12 publications, highlighting its significant impact on the field. Next is Computer Applications in Engineering Education, which features 9 documents that highlight the journal's emphasis on innovative teaching methods in technical and engineering education, rendering it highly pertinent for AR-integrated programming instruction.

Multimedia Tools and Applications (6 articles) and IEEE Transactions on Learning Technologies (5 articles) demonstrate considerable involvement. These journals are recognized for their focus on educational technologies, multimedia systems, and teaching applications of digital tools, which corresponds with the interdisciplinary aspect of AR research. Their presence suggests that AR in programming education is not only a subject in conventional education journals, but is also being investigated within wider multimedia and learning technology research areas.

Various other journals, including Applied Sciences (Switzerland), Sensors, and Virtual Reality, each provides 4 publications. Their inclusion showcases the technology- and application-focused aspects of AR, especially regarding hardware, sensory integration, and immersive settings. The

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

existence of journals centered on education such as Education Sciences, Electronics (Switzerland), and Frontiers in Virtual Reality (each featuring 3 documents) indicates that the research covers both technical applications and educational theory or practice.

In general, the data showcases a varied collection of publication venues across engineering, computer science, educational technology, and applied sciences. This cross-disciplinary reach underscores the intricacy of AR in programming education, necessitating contributions from various fields to tackle both technical advancement and teaching efficacy. The chart highlights prominent publication venues while also showcasing the diverse characteristics of the field, indicating that researchers use and add to a wide array of disciplinary viewpoints.

➢ *Keyword Analysis*

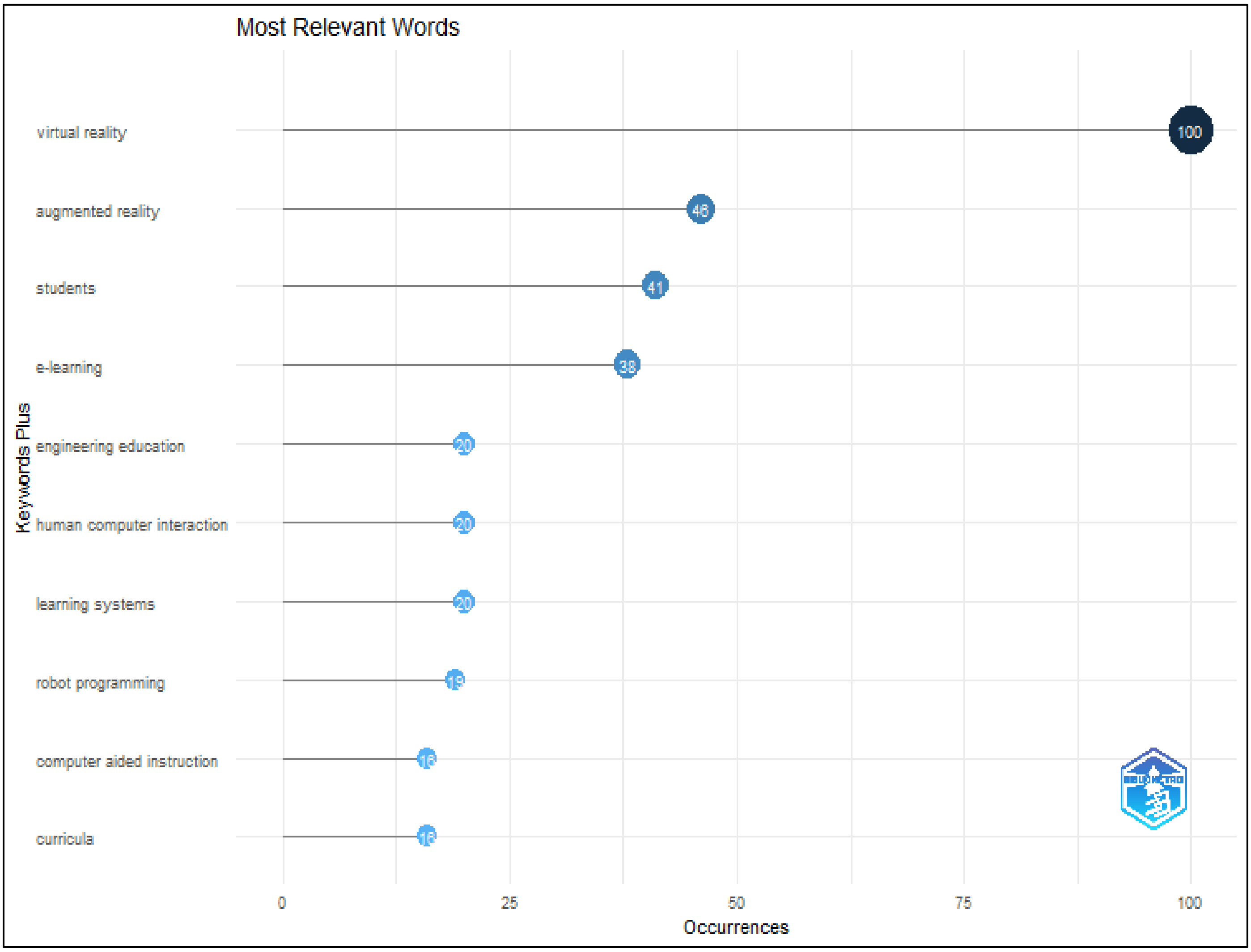

Fig 4 Keyword Analysis

The leading term is "virtual reality," found in 100 documents, suggesting that although there is a specific emphasis on augmented reality, numerous studies also address or compare it to virtual reality (VR). This may be due to technological convergence and the common objective of improving immersive learning experiences. The notable occurrence of this term indicates that VR continues to be an important contextual or comparative technology in the field of immersive learning research.

Next is "augmented reality" itself, appearing 48 times. This illustrates the main emphasis of the examined literature and validates its position as a primary research topic. The repeated occurrence of the word "education" (41 times) closely matches the thematic range of the dataset, highlighting the instructional use of AR and associated technologies.

"E-learning" (38 instances) surfaces as another significant notion, highlighting the transition to digital and remote educational platforms where AR can be especially effective. This is reinforced by the existence of phrases like "learning systems," "computer-based instruction," and "web-based programming," all emphasizing the methodological incorporation of AR in educational design and software distribution.

Numerous technical and discipline-specific terms are also presented. For example, "engineering education" (20 instances) and "human-computer interaction" (20) indicate

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may467

that numerous studies have been conducted at the crossroads of technical training and user experience design. This aligns with the objectives of AR, which frequently depends on intuitive, interactive interfaces to promote effective learning.

Additional terms like "simulation" (16) further demonstrate the hands-on, frequently experiential aspect of AR applications in education. Simulations serve as a primary application of AR, especially in programming settings where abstract ideas can be visualized and handled more tangibly through augmented layers.

The spread of keywords indicates a changing educational model in which AR transcends novelty and becomes a crucial instrument in teaching innovation.

V. CONCLUSION

This bibliometric study provides a detailed summary of the changing terrain of augmented reality in programming education. The findings indicate a consistent increase in academic interest, which is highlighted by a significant number of publications in prestigious journals like IEEE Access and Computers and Education, highlighting both technological depth and educational significance. The keyword analysis underscores “virtual reality,” “augmented reality,” and “education” as key themes, demonstrating a significant convergence between immersive technologies and teaching methods. The occurrence of phrases such as “e-learning,” “engineering education,” and “human-computer interaction” highlights the interdisciplinary characteristics of this research field. Even with the expanding literature, the field continues to evolve, presenting chances for more in-depth investigation into programming-focused AR interventions, instructional design, and practical classroom implementation. Together, the results provide important insights into publication patterns, thematic areas, and possible research gaps, establishing a strong basis for future studies in this developing field.

REFERENCES

[1]. Radu, I., Hv, V., & Schneider, B. (2021). Unequal impacts of augmented reality on learning and collaboration during robot programming with peers. Proceedings of the ACM on Human-Computer Interaction, 5(CSCW2), Article 400. https://doi.org/10.1145/3479589

[2]. Mahamad, S., Sulaiman, S., & Faizul, A. N. I. (2024). Enhancing the learning of computer internal systems through augmented reality. In 2024 8th International Conference on Computing, Communication, Control and Automation (ICCUBEA) (pp. xx–xx). IEEE. https://doi.org/10.1109/ICCUBEA.2024.xxxxxx

[3]. Martins, L. C., Lima, L. V., & Henriques, P. R. (2023). LCSMAR, an AR based tool to inspect imperative programs. OpenAccess Series in Informatics, 110, 1–15. https://doi.org/10.4230/OASIcs.xxx

[4]. Kim, J., Agarwal, S., Marotta, K., & Chau, D. H. (2019). Mixed reality for learning programming. In Proceedings of the 18th ACM International Conference on Interaction Design and Children (IDC '19) (pp. xx–xx). ACM. https://doi.org/10.1145/3311927.3323134

[5]. Crogman, H. T., Cano, V. D., Pacheco, E., & Boroon, R. (2025). Virtual reality, augmented reality, and mixed reality in experiential learning: Transforming educational paradigms. Education Sciences, 15(1), Article xx. https://doi.org/10.xxxx/educsci1501xxxx

[6]. Vashisht, S. (2024). Enhancing learning experiences through augmented reality and virtual reality in classrooms. In Proceedings of the 2nd IEEE International Conference on Recent Advances in Information Technology for Sustainable Development (ICRAIS) (pp. xx–xx). IEEE. https://doi.org/10.1109/ICRAIS.2024.xxxxxx

[7]. Drljević, N., Botički, I., & Wong, L.-H. (2022). Investigating the different facets of student engagement during augmented reality use in primary school. British Journal of Educational Technology, 53(1), 88–108. https://doi.org/10.1111/bjet.13100

[8]. Lampropoulos, G., Keramopoulos, E., Diamantaras, K., & Evangelidis, G. (2023). Integrating augmented reality, gamification, and serious games in computer science education. Education Sciences, 13(4), 400. https://doi.org/10.3390/educsci13040400

[9]. Utami, N., Setiawan, A., & Hamidah, I. (2023). A bibliometric analysis of augmented reality in higher education. Journal of Engineering Science and Technology, 18(3), 1817–1833.

[10]. Abad-Segura, E., González-Zamar, M.-D., Luque-de la Rosa, A., & Cevallos, M. B. M. (2020). Sustainability of educational technologies: An approach to augmented reality research. Sustainability, 12(10), 409. https://doi.org/10.3390/su12104091

[11]. Theodoropoulos, A., & Lepouras, G. (2021). Augmented reality and programming education: A systematic review. International Journal of Child-Computer Interaction, 30, 100306. https://doi.org/10.1016/j.ijcci.2021.100306

[12]. Wulansari, R. E., Sakti, R. H., Saputra, H., & Tun, H. M. (2024). Multimodal analysis of augmented reality in basic programming course: Innovation learning in modern classes. Journal of Applied Engineering and Technological Science, 5(1), 134–142. https://doi.org/10.37385/jaets.v5i1.1278

[13]. Larson, K., & Chambers, R. (2020). AR in the computer programming classroom: A review of the literature. In Proceedings of the 2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) (pp. 671–678). IEEE. https://doi.org/10.1109/TALE48869.2020.9368427

[14]. Kao, G. Y.-M., & Ruan, C.-A. (2014). The effects of AR-based instruction on students' learning performance, motivation and self-efficacy in programming learning. In Workshop Proceedings of the 22nd International Conference on Computers in Education (ICCE 2014) (pp. 123–128). Asia-Pacific Society for Computers in Education.

[15]. Radu, I., Hv, V., & Schneider, B. (2021). Unequal impacts of augmented reality on learning and collaboration during robot programming with peers. Proceedings of the ACM on Human-Computer Interaction, 5(CSCW2), Article 400. https://doi.org/10.1145/3479589
[16]. Chung, C.-Y., & Hsiao, I.-H. (2021). Exploring the effect of augmented reality on verbal communication and code-editing in a collaborative programming task. In Proceedings of the IEEE 21st International Conference on Advanced Learning Technologies (ICALT) (pp. 134–138). IEEE. https://doi.org/10.1109/ICALT52272.2021.00044
[17]. Alhebaishi, S., & Stone, R. (2024). Augmented reality in education: Revolutionizing teaching and learning practices – State-of-the-art. International Journal of Advanced Computer Science and Applications, 15(1), 102–110. https://doi.org/10.14569/IJACSA.2024.0150114
[18]. Vinueza-Morales, M., Rodas-Silva, J., & Vidal-Silva, C. (2025). Teaching programming in higher education: Analyzing trends, technologies, and pedagogical approaches through a bibliometric lens. International Journal of Advanced Computer Science and Applications, 16(2), 85–94. https://doi.org/10.14569/IJACSA.2025.0160211