Pendahuluan

Indonesia, with its diverse natural beauty, has become a paradise for adventure tourism, and mountain climbing is one of the nature tourism activities that has experienced a significant increase in popularity in recent years [1]. This rapid growth has also been accompanied by an increase in climbing-related accidents. Between 2015 and 2019, there were 130 reported cases of missing climbers, resulting in 26 fatalities, with hypothermia or illness (47%) and accidents (24%) identified as the main causes. Based on the identified gap and theoretical foundation, this research aims to develop and evaluate an Android-based markerless augmented reality application to enhance pre-climbing safety induction for beginner climbers. The developed application presents interactive three-dimensional AR models to deliver safety induction information and is developed using Blender and Unity, equipped with zoom and audio features to support multimodal learning. Practically, markerless AR improves accessibility and usability, as it can be used anytime and anywhere without additional physical markers, making it suitable for outdoor safety education. the Augmented Reality Safety Induction Mountain Climbing application developed for beginner climbers obtained a feasibility score of 87%. Compared to conventional safety induction methods such as direct briefings, reading materials, and educational videos, AR-based media shows advantages in increasing user engagement and providing a more immersive learning experience.

Metode

This study employed a development-oriented research approach in the form of applied system development, focusing on the design and implementation of an Android-based markerless augmented reality (AR) application for mountain climbing safety induction. The Multimedia Development Life Cycle (MDLC) method was selected because it is specifically designed for multimedia-based applications that integrate visual, audio, and interactive components, making it more suitable than general instructional models such as ADDIE, which primarily emphasize pedagogical planning rather than technical multimedia implementation. MDLC consists of six structured stages: concept, design, material collection, assembly, testing, and distribution. Work Breakdown Structure (WBS) is a hierarchical diagram arranged from top to bottom in order to divide the work process into more detailed parts. This approach helps in management and control during the implementation of research [24]. After the WBS is compiled, the next step is to discuss each stage of the research that has been carried out in accordance with the objectives and research methods.

Hasil

The questionnaire results obtained from beginner climbers, there were 20 respondents with a score of 5, totaling 95; a score of 4, totaling 57; a score of 3, totaling 25; a score of 2, totaling 2; and a score of 1, totaling 1 respondent. The formula for assessing respondents' responses to the augmented reality safety induction application for beginner climbers on a Likert scale. The highest score is marked with an X, and the highest score is in the "optimal performance" category with a score of 5. The score obtained is the number of questions multiplied by the questionnaire submitted, namely X = 5 x 9 = 45. The expected score is represented by Y, then calculated by multiplying that value by the number of respondents determined, Y = 45 x 20 (number of respondents) = 900.

- f = Total frequency value for each question   P = Feasibility presentation

- T = Total respondents   Y = Expected score

- Pn = Likert score

- Therefore, the user satisfaction calculation results are:
  - f = T x Pn   (1)
  - f = (95 x 5) + (57x4) + (25x3) + (2x2) + (1x1)
  - f = 475 + 228 + 75 + 4 + 1 = 783
  - p = f/y x 100% = P%   (2)
  - p = 783/900 x 100% = 87%

Based on the analysis results, the Augmented Reality Safety Induction Mountain Climbing application developed for beginner climbers obtained a feasibility score of 87%. Compared to conventional safety induction methods such as direct briefings, reading materials, and educational videos, AR-based media shows advantages in increasing user engagement and providing a more immersive learning experience. These results are in line with scientific studies on safety training, which state that the use of AR is generally more effective than traditional methods, especially in increasing engagement and learning retention, although the difference in knowledge acquisition is not always statistically significant. A meta-analysis of various studies also shows that AR is superior in delivering complex material. Therefore, the developed AR application can be considered highly effective and suitable for use as an educational medium for mountain climbing safety induction for beginner climbers [27].

Pembahasan

The results of this study indicate that the developed augmented reality–based mountain climbing safety induction application is feasible and well accepted by beginner climbers. The feasibility score of 87% obtained from the Likert scale questionnaire reflects positive user perceptions in terms of usability, visual clarity, interactivity, and perceived usefulness. These findings are in line with recent literature which reports that AR technology can significantly enhance safety training and immersive learning experiences by increasing engagement and active participation compared to traditional methods. One of the key contributions of this study lies in the implementation of markerless AR technology for outdoor safety education. Unlike marker-based AR, which relies on printed markers, markerless AR allows users to interact with three-dimensional safety equipment models in flexible settings without additional physical tools. This characteristic supports experiential and situated learning principles, particularly in dynamic real-world environments such as mountain climbing, and aligns with findings that AR and extended reality technologies enrich safety training by creating realistic, interactive learning environments. Specifically, comparative studies show that AR-based safety training is more effective in short-term knowledge acquisition and long-term retention than traditional slide-based methods, as observed in metro construction safety case studies [29]. These findings are consistent with experiential learning theory, emphasizing the importance of active engagement with real content in developing practical competencies and preparedness for risk situations.

Manfaat Penelitian

Based on the results of this study, it can be concluded that the Mountain Climbing Safety Induction Application for Beginner Climbers contributes to the development of interactive safety education media by integrating markerless augmented reality technology into outdoor safety training. This research demonstrates how AR-based visualization can be effectively applied to present climbing equipment usage and emergency handling procedures in a more engaging and immersive manner compared to conventional safety induction methods. The use of markerless AR allows users to access three-dimensional learning content flexibly without the need for physical markers or actual equipment, thereby enhancing practicality and supporting visual and experiential learning for beginner climbers.

Referensi

- R. Nursyanti, Budiman, and A. Widianto, "Pemanfaatan Augmented Reality untuk Eksplorasi Gunung Berapi di Jawa Barat," *Journal of Informatic Engineering (JOUTICA)*, vol. 9, pp. 149–161, 2024, doi:10.30736/informatika.v9i2.1289.

- [2]   S. Wahyuni and R. Doni, "Penerapan Augmented Reality Sebagai Metode Jenis-Jenis Gunung di Sumatera Utara Menggunakan Metode Marker Based Tracking Berbasis Android," *JID (Jurnal Info Digit)*, vol. 2, no. 2, pp. 459–471, 2024.

- [3]   R. Setiawan, S. Rahayu, and I. Komalasari, "Pengembangan Aplikasi Augmented Reality untuk Edukasi Keselamatan Kebakaran: Metode Prototyping dan Usability," *J. Appl. Comput. Sci. Technol.*, vol. 6, no. 1, pp. 1–8, 2025, doi: 10.52158/jacost.v6i1.1028.

- [4]   M. Fachruddin, R. Dijaya, and M. A. Rosid, "Replication of the Climbing Post on Mount Arjuno Using Augmented Reality (AR) with the Open Asset Import Library Method," *Procedia of Engineering and Life Science*, vol. 4, Jun. 2023, doi:10.21070/pels.v4i0.1428.

- [5]   A. U. Syarif and C. C. Astuti, "Pengembangan Media Pembelajaran Augmented Reality (AR) pada Pembelajaran Perangkat Keras Komputer di SMK Al-Aziziyah Candi," *J. Ilm. Edutic: Pendidikan dan Informatika*, vol. 10, no. 1, pp. 24–35, Nov. 2023, doi:10.21107/edutic.v10i1.22082.

- [6]   D. Alifah, R. Megawaty, D. A. Najib, and M. Satria, "Pemanfaatan Augmented Reality untuk Koleksi Kain Tapis (Studi Kasus: UPTD Museum Negeri Provinsi Lampung)," *J. Teknol. dan Sist. Inf.*, vol. 2, no. 2, pp. 1–7, 2021.

- [7]   [7] R. Wahyuddin, A. Sucipto, and T. Susanto, "Pemanfaatan Teknologi Augmented Reality dengan Metode Multiple Marker pada Pengenalan Komponen Komputer," J. Informatika dan Rekayasa Perangkat Lunak (JATIKA), vol. 3, no. 3, pp. 278–285, 2022.

- [8]   N. Sugihartini and I. G. A. M. Swisnandy, "Augmented reality in computer systems integrated with project-based learning in vocational schools," Indonesian Journal of Educational Development (IJED), vol. 6, no. 2, pp. 465–478, 2025, doi:10.59672/ijed.v6i2.5093.

- [9]   S. Ding, T. Lu, X. Lv, Y. Zhang, R. Deng, and X. Huang, "Augmented Reality for Enhancing Educational Experience in Laboratory Safety Training," Journal of Loss Prevention in the Process Industries, vol. 100, p. 105848, 2025, doi:10.1016/j.jlp.2025.105848.

- [10]   S. D. Prasetya and Y. Anistyasari, "Studi Literatur Pengaruh Media Pembelajaran Berbasis Augmented Reality Markerless terhadap Motivasi Belajar Siswa," IT-Edu: Jurnal Information Technology and Education, vol. 5, no. 3, pp. 468–479, 2020.

Referensi

- M. Agil and S. L. M. Sitio, "Implementasi Metode Markerless Augmented Reality Untuk Edukasi Nama Buah-Buahan Berbasis Android," *J. Din. Inform.*, vol. 14, no. 2, pp. 105–115, 2022, doi: 10.35315/informatika.v14i2.9199.

- [12] A. W. Arisandi, R. Agustina, and Y. S. Dwanoko, "Implementasi Augmented Reality Markerless User Defined Target Pada Enhance Learning Pengenalan Komponen Internet of Things (IoT)," *J. Terap. Sains Teknol.*, vol. 4, no. 3, pp. 198–207, 2022.

- [13] I. D. Barus, A. Usman, and D. Dharmawati, "Implementasi Augmented Reality Sebagai Media Edukasi dan Promosi Aceh Tenggara Menggunakan Metode Markerless," *J. Ilmu Komput. dan Sist. Komput. Terap.*, vol. 7, no. 1, pp. 19–32, 2025, doi: 10.35447/jikstra.v7i1.1146.

- [14] [14] R. Dijaya, W. S. Bintara, and A. S. Fitrani, "Wisata Alam Digital di Kota Kediri Menggunakan Augmented Reality," JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika), vol. 6, no. 2, pp. 293–304, 2021, doi:10.29100/jipi.v6i2.2001.

- [15] A. Yudiernawati, T. D. Wahyuni, and P. Suryani, "Learning innovation using augmented reality for interactive learning experiences," *J. Konseling dan Pendidik.*, vol. 13, no. 1, pp. 305–315, 2025, doi: 10.29210/1142300.

- [16] E. Ahdhianto, Y. K. Barus, and M. A. Thohir, "Augmented reality as a game changer in experiential learning: Exploring its role cultural education for elementary schools," *J. Pedagog. Res.*, vol. 9, no. 1, pp. 296–313, 2025, doi: 10.33902/JPR.202533573.

- [17] A. A. L. Putri and A. Lestari, "Analisis Kualitas Video Pembelajaran Berdasarkan Teori Multimedia Mayer," *Sinergi J. Ilm. Multidisiplin*, vol. 1, no. 2, pp. 1555–1573, 2025.

- [18] H. T. Crogman, V. D. Cano, E. Pacheco, R. B. Sonawane, and R. Boroon, "Virtual Reality, Augmented Reality, and Mixed Reality in Experiential Learning: Transforming Educational Paradigms," *Educ. Sci.*, vol. 15, no. 3, pp. 1–23, 2025, doi: 10.3390/educsci15030303.

- [19] F. K. Nst, I. Faisal, and K. Chiuloto, "Media Pengenalan Makanan Khas Daerah Sumatera Menggunakan Teknologi Augmented Reality Berbasis Android," Jurnal Teknologi Pangan, vol. 6341, no. Apr., pp. 60–67, 2022.

- [20] J. Apriliano, S. Boediono, M. Rizqi, and F. Iqbal, "ScienceDirect ScienceDirect Markerless Augmented Reality Application for Indonesian Traditional House Education," *Procedia Comput. Sci.*, vol. 227, pp. 718–725, 2023, doi: 10.1016/j.procs.2023.10.576.

Referensi

- O. Okta Rita and G. Guspatni, "Teknologi Augmented Reality dalam Pembelajaran Kimia: Tinjauan Pustaka," J. Pendidikan Tambusai, vol. 8, no. 2, pp. 18552–18562, 2024, doi:10.31004/jptam.v8i2.15094.

- [22]   R. M. A. Trikotama, M. N. Nurrohman, and D. K. Hutajulu, "Application of Augmented Reality in Education," Hipkin J. Educ. Res., vol. 1, no. 3, pp. 263–274, Dec. 2024, doi:10.64014/hipkin-jer.v1i3.26.

- [23]   D. Rhomadiniyah, R. Dijaya, and Y. Rahmawati, "The Digital City Tour Guide Using Augmented Reality on the Pasupati Bridge: City Tour Guide Digital Menggunakan Augmented Reality Pada Jembatan Pasupati," Procedia of Engineering and Life Science, vol. 4, Jun. 2023, doi:10.21070/pels.v4i0.1431.

- [24]   I. Insyiroh, C. Taurusta, and S. Suprianto, "Perancangan aplikasi pengenalan ikon wisata Kota Surabaya berbasis augmented reality," Jurnal Pendidikan Informatika dan Sains, vol. 12, no. 1, pp. 123–135, 2023, doi:10.31571/saintek.v12i1.5825.

- [25]   R. Silva, A. Putri, Y. Rahmawati, S. Busono, and A. Eviyanti, "Aplikasi Go Tour Sekitar Tugu Yogyakarta Berbasis Augmented Reality," J. Teknol. dan Manaj. Inf., vol. 9, no. 2, pp. 99–109, 2023.

- [26]   A. F. Makarim, "Aplikasi Edukasi Jenis Narkoba Berbasis Augmented Reality Sebagai Media Pembelajaran Bagi Generasi Muda," J. Pendidikan dan Teknologi Informasi, vol. 15, no. 1, pp. 70–80, 2025.

- [27]   M. C. Howard and M. M. Davis, "A Meta-analysis of augmented reality programs for education and training," *Virtual Real.*, vol. 27, no. 4, pp. 2871–2894, 2023, doi: 10.1007/s10055-023-00844-6.

- [28]   P. Gong, Y. Lu, R. Lovreglio, X. Lv, and Z. Chi, "Applications and effectiveness of augmented reality in safety training: A systematic literature review and meta-analysis," *Saf. Sci.*, vol. 178, p. 106624, 2024, doi: https://doi.org/10.1016/j.ssci.2024.106624.

- [29]   P. Gong, Y. Lu, R. Lovreglio, X. Yang, and Y. Deng, "Comparing the effectiveness of AR training and slide-based training: The case study of metro construction safety," *Saf. Sci.*, vol. 176, p. 106561, 2024, doi: https://doi.org/10.1016/j.ssci.2024.106561.

- [30]   G. Lampropoulos, P. Fernández-Arias, Á. Antón Sancho, and D. Vergara, "Examining the Role of Augmented Reality and Virtual Reality in Safety Training," Electronics, vol. 13, no. 19, p. 3952, 2024, doi:10.3390/electronics13193952.

- [31]   S. Li, Q.-C. Wang, H.-H. Wei, and J.-H. Chen, "Extended Reality (XR) Training in the Construction Industry: A Content Review," Buildings, vol. 14, no. 2, p. 414, 2024, doi:10.3390/buildings14020414.