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RESEARCH ARTICLE

Augmented Reality as Catalyst for Digital Literacy Enhancement: Investigating University Students' Readiness in the Era of Disruptive Educational Technologies

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Abstrak

Penelitian ini mengkaji sejauh mana kesiapan mahasiswa dalam menggunakan Augmented Reality (AR) dapat meningkatkan literasi digital di lingkungan pembelajaran berbasis teknologi. Dengan menggunakan desain survei kuantitatif, data dikumpulkan dari 356 mahasiswa Teknologi Pendidikan di sebuah universitas terbuka. Penelitian ini mengukur lima dimensi literasi digital dan empat indikator kesiapan AR. Hasil menunjukkan tingkat literasi digital mahasiswa berada pada kategori sedang hingga tinggi, dengan korelasi positif yang signifikan antara seluruh indikator kesiapan AR dan domain literasi digital. Analisis regresi mengungkapkan bahwa persepsi kegunaan dan kepercayaan diri dalam menggunakan AR menjadi prediktor terkuat terhadap kompetensi digital. Temuan ini menegaskan peran AR sebagai media transformatif dalam pengembangan keterampilan abad ke-21, khususnya jika kesiapan mahasiswa ditingkatkan melalui intervensi pedagogis yang tepat. Studi ini memberikan wawasan empiris untuk mendukung perancangan kurikulum yang mengintegrasikan teknologi imersif guna mendorong kecakapan digital yang lebih mendalam.

Kata kunci: Augmented Reality; Literasi Digital; Teknologi Pendidikan; Kesiapan Mahasiswa; Keterampilan Abad 21; Integrasi Teknologi; Pendidikan Tinggi.

Abstract

This study investigates the extent to which university students' readiness for Augmented Reality (AR) can enhance digital literacy in technology-integrated learning environments. Using a quantitative survey design, data were collected from 356 Educational Technology students at an open university. The study measured five dimensions of digital literacy and four indicators of AR readiness. Results revealed moderate to high digital literacy levels, with significant positive correlations between all AR readiness indicators and digital literacy domains. Multiple regression analysis showed that perceived usefulness and confidence in using AR were the strongest predictors of digital competence. These findings underscore AR's role as a transformative medium for fostering 21st-century skills, especially when student readiness is addressed through targeted pedagogical interventions. The study offers empirical insights to inform curriculum design, emphasizing the integration of immersive technologies not only to support content delivery but to actively cultivate digital fluency.

Keywords: Augmented Reality; Digital Literacy; Educational Technology; Student Readiness; 21st-Century Skills; Technology Integration; Higher Education.

1. INTRODUCTION

The rapid advancement of digital technology has reshaped the landscape of higher education, demanding a fundamental shift in how learning is designed and delivered. One such innovation is Augmented Reality (AR), a tool that blends digital content with the physical world, offering immersive and interactive learning experiences. In the context of Education 4.0 and the increasing push toward technology-integrated pedagogies, AR has gained traction for its potential to enhance student engagement, motivation, and conceptual understanding (Çetin & Türkan, 2023). However, the role of AR extends beyond instructional enrichment—it also holds promise as a catalyst for fostering digital literacy, a critical competence in the 21st century learning ecosystem (Al-Khalifah et al., 2021).

Digital literacy, encompassing skills such as information evaluation, online collaboration, content creation, and ethical use of digital platforms, has become a foundational requirement for students in navigating the complexities of digital society (Ng et al., 2020). In parallel, universities face increasing pressure to produce graduates who are not only content-competent but also digitally fluent. Despite this urgency, studies indicate that students often possess fragmented digital skills, especially in areas such as critical thinking and information ethics (Fisher et al., 2021). As such, there is a growing call to embed digital literacy across disciplines and integrate technologies like AR to support this objective (Zarraonandia et al., 2022).

Recent studies have examined the use of AR in education, predominantly within STEM fields, highlighting improvements in spatial visualization, learner motivation, and content mastery (Ibáñez & Delgado-Kloos, 2021; Akçayır & Akçayır, 2019). For instance, Safar et al. (2022) demonstrated that AR-based chemistry labs significantly enhanced conceptual understanding and retention. Similarly, Huang et al. (2020) found that AR applications in biology classes increased student motivation and active learning. In language learning, AR has been linked to improvements in vocabulary acquisition and learner autonomy (Wang et al., 2021). Moreover, in teacher training programs, AR tools have helped pre-service teachers simulate classroom environments and develop reflective practices (Faridi & Subekti, 2023).

Nevertheless, few studies have explored the direct correlation between AR usage and digital literacy development. While Saad et al. (2021) investigated AR's role in interactive learning, its impact on digital literacy domains such as online ethics or information management remained unaddressed. Similarly, research by Lin & Chen (2020) acknowledged AR's cognitive benefits but did not connect them to broader digital competencies. This lack of integration between technology adoption and digital literacy outcomes constitutes a significant research gap, particularly within non-STEM disciplines like educational technology, where AR is often underutilized despite its relevance.

Moreover, existing studies tend to generalize findings across educational levels or disciplines, without delving into the readiness and contextual challenges faced by university students in specific academic settings (Ferri et al., 2020). Readiness, which encompasses both technological access and digital competence, is a key determinant of whether AR can truly act as an enabler of digital literacy. Yet, the literature remains limited in examining student readiness for AR integration in open and distance learning environments, where digital tools are increasingly central but not always equitably accessible (Hussein et al., 2021).

Given these gaps, this study aims to investigate the extent to which Augmented Reality can enhance digital literacy among university students, focusing specifically on student readiness to engage with AR-based learning tools. By situating the research within a digital education context and targeting students of educational technology, the study offers nuanced insights into how emerging technologies intersect with foundational digital competencies. The findings are expected to inform future pedagogical strategies and curricular frameworks that leverage AR not only as a content

delivery tool, but as a transformative medium for cultivating critical digital skills.

2. LITERATURE REVIEW

2.1. Augmented Reality in Higher Education

Augmented Reality (AR) has emerged as a transformative educational tool in the context of higher education, offering immersive learning experiences that overlay digital elements onto real-world environments. Numerous studies have demonstrated AR's capacity to enhance student engagement, spatial understanding, and conceptual clarity, particularly in science, technology, engineering, and mathematics (STEM) domains (Ibáñez & Delgado-Kloos, 2021; Safar et al., 2022). For instance, Safar et al. (2022) observed that chemistry students using AR applications developed stronger spatial reasoning and were more motivated to engage with experimental content compared to traditional methods.

Similarly, Çetin and Türkan (2023) found that AR-integrated instruction significantly increased learning motivation and performance among university engineering students. In biology education, Huang et al. (2020) showed that AR-based simulations contributed to deeper learning by enabling students to visualize abstract biological processes. These findings underscore AR's potential to make invisible or complex concepts tangible and accessible.

However, while the pedagogical benefits of AR have been well-documented in STEM contexts, its implementation in broader domains—such as social sciences, humanities, or teacher education—remains limited (Faridi & Subekti, 2023). Moreover, many studies primarily focus on usability, user experience, or knowledge retention, rather than exploring how AR contributes to the development of higher-order competencies, including digital literacy, critical thinking, and digital ethics (Zarraonandia et al., 2022).

Furthermore, current literature lacks a unified framework connecting AR's pedagogical use with students' readiness to adopt such technology. Readiness is not merely technical proficiency but also encompasses affective, cognitive, and motivational aspects that determine the effectiveness of AR integration in learning environments (Ferri et al., 2020). In this regard, more research is needed to understand how students in diverse academic disciplines engage with AR tools and whether such engagement leads to measurable growth in core digital competencies.

2.2. Digital Literacy and 21st Century Skills

In the evolving landscape of higher education, digital literacy has become a cornerstone of 21st-century skill development. Defined as the ability to access, evaluate, create, and communicate information through digital platforms, digital literacy comprises multiple dimensions: technological proficiency, critical information literacy, online communication, digital content creation, and responsible digital citizenship (Ng et al., 2020; Al-Khalifah et al., 2021). These skills are critical not only for academic success but also for students' employability and civic participation in an increasingly digitized world.

Recent studies have drawn attention to the discrepancy between students' familiarity with digital tools and their actual competence in using them for academic or professional purposes. For instance, Fisher

et al. (2021) found that while students frequently use digital platforms, they often lack the ability to critically assess the credibility of information, manage digital identities, or practice ethical online behavior. This aligns with Hussein et al. (2021), who reported significant gaps in students' ability to create meaningful digital content or collaborate effectively in virtual environments.

Efforts to enhance digital literacy in higher education have included embedding information literacy into curricula, offering digital skills workshops, and promoting collaborative learning via online platforms. Yet, many of these initiatives remain fragmented and disconnected from emerging educational technologies such as AR (Zarraonandia et al., 2022). Integrating AR into digital literacy instruction may provide opportunities for students to engage with digital content in more interactive and reflective ways, enabling the development of deeper digital competencies.

Additionally, as universities transition toward blended and hybrid models of learning, the demand for adaptive digital literacy frameworks becomes more pressing (Wang et al., 2021). AR, by virtue of its interactive and multimodal nature, presents an opportunity not only to teach digital skills but also to contextualize them in authentic problem-solving scenarios—potentially bridging the gap between theory and practice in digital literacy education.

3. METHOD

3.1. Research Design

This study employed a quantitative survey research design to investigate the readiness of university students in engaging with Augmented Reality (AR) as a medium to enhance digital literacy. Survey research is considered effective in capturing students' perceptions, attitudes, and competencies across large populations (Creswell & Creswell, 2018). Given the exploratory nature of the study, this design enabled the collection of standardized data on key variables such as digital literacy dimensions and AR readiness.

3.2. Participants

Participants in this study were undergraduate students majoring in Educational Technology at a state-run open university in Indonesia. The population was selected purposively, based on their exposure to educational technologies in their coursework and potential relevance to AR-based learning environments. A total of 356 students voluntarily completed the online survey. Inclusion criteria required participants to be actively enrolled in at least one course that utilized digital or blended learning models. The sampling method applied was purposive non-probability sampling, which is commonly used when targeting respondents with specific characteristics relevant to the research objectives (Etikan, Musa, & Alkassim, 2016).

3.3. Research Instruments

Data in this study were collected using a structured questionnaire designed to measure students' readiness for digital literacy in the context of Augmented Reality (AR)-based learning. The instrument was

developed based on the European Commission's Digital Competence Framework (DigComp 2.1) and adapted from previously validated instruments (Vuorikari et al., 2016; Ng et al., 2020). The questionnaire comprised 30 closed-ended items, categorized into two main sections.

The first section measured students' digital literacy competencies, covering five core domains: (1) information and data literacy, (2) communication and collaboration, (3) digital content creation, (4) safety and digital ethics, and (5) problem-solving using digital tools. The second section focused on students' readiness for AR-based learning, which included four dimensions: (1) attitude toward technology adoption, (2) familiarity with AR concepts, (3) confidence in using mobile or AR applications for educational purposes, and (4) perceived usefulness of AR in supporting digital competence development.

Each item was rated using a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), allowing for the measurement of varying degrees of agreement toward each statement. Prior to the main data collection, a pilot test was conducted with 30 students who were not part of the final sample to assess the clarity, reliability, and internal consistency of the instrument. The results of the pilot test showed that the instrument had a Cronbach's Alpha coefficient of 0.87, indicating a high level of internal reliability and consistency across the questionnaire items.

3.4. Data Collection Procedure

The survey was distributed online using Google Forms and remained open for a two-week period. Participants were informed of the study's objectives, anonymity, and voluntary nature through a consent form embedded in the questionnaire. Only those who agreed to participate were granted access to the main survey. Ethical clearance was obtained from the institutional ethics committee, and the study adhered to ethical principles of confidentiality and informed consent in line with the Declaration of Helsinki.

3.5. Data Analysis

he collected data were analyzed using IBM SPSS Statistics version 26 to ensure a rigorous quantitative examination of the research objectives. The analysis began with descriptive statistics, including means, standard deviations, and frequency distributions, to provide an overview of students' digital literacy levels and their readiness to adopt Augmented Reality (AR) in learning contexts. Subsequently, inferential statistical tests were employed to explore deeper relationships within the data. Specifically, Pearson correlation analysis was conducted to examine the strength and direction of associations between students' AR readiness and the various domains of digital literacy. Additionally, independent-samples t-tests were used to investigate potential differences based on demographic variables such as gender and age.

Where appropriate, regression analysis was also applied to assess the extent to which AR readiness could predict digital literacy levels. This step was crucial in identifying whether readiness factors—such as confidence in using AR tools or perceived usefulness—significantly contributed to students' broader digital competencies. The combination of correlational and predictive analyses aimed not only to describe general patterns in the data but also to uncover underlying dynamics that may inform future pedagogical and

technological interventions. This approach follows the analytical recommendations outlined by Hair et al. (2019) in conducting multivariate statistical evaluations for educational research.

4. RESULT AND DISCUSSION

The findings are organized into three subsections: descriptive statistics, correlational analysis, and predictive modeling using regression.

4.1. Descriptive Statistics of Digital Literacy and AR Readiness

To gain an overview of students' self-perceived competencies and preparedness toward the use of Augmented Reality (AR) in educational settings, descriptive statistical analysis was conducted on nine key variables. These include five domains of digital literacy, derived from the European DigComp 2.1 framework, and four dimensions representing AR readiness, as developed in the research instrument. By analyzing the means and standard deviations of each variable, the study aimed to identify which competencies were strongest and where potential gaps or challenges existed in the student population.

Table 1. Descriptive statistics for digital literacy and ar readiness (n = 356)

Variable	Mean (M)	Standard Deviation (SD)
Information and Data Literacy	3.92	0.67
Communication and Collaboration	3.87	0.71
Digital Content Creation	3.75	0.74
Safety and Digital Ethics	3.49	0.83
Problem-Solving Using Digital Tools	3.68	0.69
Attitude Toward Technology Adoption	4.15	0.61
Familiarity with AR Concepts	3.42	0.88
Confidence in Using AR for Learning	3.33	0.91
Perceived Usefulness of AR	3.85	0.70

The data indicate that students generally exhibit moderate to high levels of digital literacy, with the highest mean observed in Information and Data Literacy (M = 3.92), suggesting a strong ability to search for, evaluate, and manage digital information. This may reflect students' frequent engagement with online academic resources and exposure to digital platforms in their coursework. Communication and Collaboration also received a relatively high score (M = 3.87), indicating students' familiarity with digital interaction tools such as learning management systems, discussion forums, and messaging applications.

On the other hand, Safety and Digital Ethics received the lowest score (M = 3.49), highlighting a potential gap in students' understanding of digital privacy, cybersecurity, and responsible behavior online. This finding is consistent with prior research that found students often undervalue or lack formal instruction in digital ethics and identity management (Fisher et al., 2021).

Regarding AR readiness, students showed a high level of openness to technology adoption, as indicated by the highest mean score for Attitude Toward Technology Adoption (M = 4.15). This positive

orientation suggests that students are conceptually receptive to new tools like AR in learning environments. However, the dimension Confidence in Using AR for Learning received the lowest mean (M = 3.33), indicating some uncertainty or inexperience in utilizing AR tools effectively for academic purposes. Likewise, Familiarity with AR Concepts also yielded a moderate mean (M = 3.42), reinforcing the notion that while students are open to innovation, they may lack sufficient exposure or training in AR technologies.

4.2. Correlation Between AR Readiness and Digital Literacy

To further explore the relationship between students' preparedness for engaging with Augmented Reality (AR) and their digital literacy competencies, Pearson product-moment correlation analysis was conducted. This analysis aimed to determine the strength and direction of linear associations between the four dimensions of AR readiness—attitude, familiarity, confidence, and perceived usefulness—and the five domains of digital literacy. Identifying these correlations is essential to understand whether students who are more ready to use AR also tend to possess higher digital competencies, and which aspects of readiness are most influential in this regard.

Table 2. Pearson correlation between AR readiness and digital literacy domains

AR Readiness Dimension	Information Literacy	Communication	Content Creation	Digital Ethics	Problem-Solving
Attitude Toward Tech Adoption	.44**	.41**	.37**	.35**	.39**
Familiarity with AR	.33**	.31**	.29**	.27**	.30**
Confidence in Using AR	.48**	.46**	.42**	.39**	.45**
Perceived Usefulness of AR	.51**	.49**	.44**	.41**	.47**

The results reveal statistically significant and positive correlations ($p < .01$) between all AR readiness dimensions and the five digital literacy domains. This indicates that students who demonstrate greater readiness to engage with AR—whether in terms of openness to technology, familiarity with AR concepts, confidence in usage, or belief in its educational value—are also more likely to exhibit stronger digital literacy skills.

The strongest correlation was found between Perceived Usefulness of AR and Information Literacy ($r = .51$), followed closely by its relationship with Communication and Collaboration ($r = .49$). These findings suggest that when students believe AR offers meaningful support to their learning process, they are also more capable of retrieving and evaluating digital information, as well as engaging in effective digital communication.

Confidence in Using AR also showed robust correlations across all digital literacy domains ($r = .42$ to $.48$), underscoring the importance of not only having access to AR tools but also feeling capable and self-assured in using them. This echoes prior research indicating that confidence is a critical mediator in the adoption and effective use of educational technologies (Zarraonandia et al., 2022).

Conversely, while Familiarity with AR demonstrated the lowest overall correlations ($r = .27$ to $.33$),

its consistent statistical significance suggests that even basic exposure to AR concepts contributes positively to students' digital competencies. Interestingly, Attitude Toward Technology Adoption was moderately correlated with all domains, highlighting that a general disposition toward innovation, while beneficial, may not be as impactful as direct experience or perceived utility.

4.3. Regression Analysis: Predicting Digital Literacy from AR Readiness

To examine the extent to which students' readiness to engage with Augmented Reality (AR) can predict their overall digital literacy, a multiple linear regression analysis was conducted. This approach allows for the simultaneous assessment of multiple predictor variables—specifically the four AR readiness dimensions—on a single dependent variable, namely digital literacy. The analysis helps to determine not only the individual contribution of each AR readiness factor but also the collective explanatory power of the model in predicting students' digital competence.

Table 3. Multiple Regression Predicting Digital Literacy from AR Readiness

Predictor Variable	B	SE	β	t	p
Attitude Toward Tech Adoption	0.213	0.062	.212	3.44	.001
Familiarity with AR	0.167	0.059	.168	2.83	.005
Confidence in Using AR	0.276	0.055	.278	5.02	.000
Perceived Usefulness of AR	0.309	0.058	.312	5.33	.000

$R^2 = .39$, Adjusted $R^2 = .38$, $F(4, 351) = 56.25$, $p < .001$

The results of the regression model indicate a statistically significant and substantial relationship between AR readiness and digital literacy ($F(4, 351) = 56.25$, $p < .001$), with the four predictors jointly explaining 39% of the variance in students' digital literacy scores (Adjusted $R^2 = .38$). This level of explanatory power is notable, particularly in educational research where behavioral and attitudinal outcomes are influenced by multiple contextual factors (Hair et al., 2019).

Among the predictors, Perceived Usefulness of AR emerged as the strongest and most significant factor ($\beta = .312$, $p < .001$), followed closely by Confidence in Using AR ($\beta = .278$, $p < .001$). These findings imply that students who believe AR tools are beneficial for their learning and feel capable of using such tools are more likely to demonstrate higher levels of digital literacy. This aligns with previous studies emphasizing the role of self-efficacy and perceived value in the successful adoption of educational technology (Ferri et al., 2020; Zarraonandia et al., 2022).

Interestingly, Attitude Toward Technology Adoption ($\beta = .212$) and Familiarity with AR ($\beta = .168$) also contributed significantly to the model, albeit with slightly lower effect sizes. This suggests that while general enthusiasm toward new technology and basic awareness of AR concepts are relevant, they may not be sufficient alone to drive meaningful gains in digital literacy. Rather, a combination of cognitive (knowledge), affective (attitude), and behavioral (confidence and usage) factors seems essential in fostering digital competence.

4.4. Discussion

The findings of this study provide compelling evidence that university students' readiness for Augmented Reality (AR) plays a significant role in enhancing their digital literacy—a critical competency in navigating contemporary digital learning environments. The positive and statistically significant relationships between all four AR readiness indicators and the five digital literacy domains suggest that AR is not merely a technological novelty but a pedagogical enabler for broader cognitive and digital skill development.

The high mean scores in digital literacy, particularly in information and data literacy and communication, reflect students' comfort with accessing and processing digital content. This is consistent with earlier findings by Tang and Chaw (2022), who observed that students in technology-rich programs tend to demonstrate stronger foundational digital skills. However, the relatively lower score in safety and digital ethics aligns with previous concerns about students' lack of critical awareness regarding data privacy, misinformation, and ethical use of technology (Reddy et al., 2023).

One of the most salient findings was the predictive power of perceived usefulness and confidence in using AR on students' digital literacy. These two factors contributed most significantly to the regression model, suggesting that belief in the value of AR and practical confidence in its use are key levers for digital skill acquisition. This supports the Technology Acceptance Model (TAM), which posits that perceived usefulness and ease of use are central to technology adoption (Venkatesh & Davis, 2000). Recent work by Ismail et al. (2021) also underscores the role of self-efficacy and perceived utility in mediating students' digital engagement with emerging technologies.

Interestingly, while attitude toward technology and familiarity with AR were also significant predictors, their lower beta coefficients suggest that passive exposure or positive perception alone is insufficient to drive digital competence. This distinction emphasizes the need for instructional interventions that go beyond motivational rhetoric to include hands-on, experiential learning with AR tools. As suggested by López-Belmonte et al. (2023), embedding AR within active learning strategies—such as project-based learning or simulations—can significantly elevate students' critical and creative digital literacies.

Moreover, the results affirm the role of AR as a catalyst rather than a standalone solution. When integrated with intentional pedagogical design, AR fosters not only technological engagement but also metacognitive growth, including skills such as problem-solving, digital content creation, and ethical judgment. This aligns with the argument presented by Alsop and Tomita (2022), who emphasize that the value of immersive technologies lies in their ability to create authentic and reflective learning contexts.

From an institutional perspective, the findings suggest that higher education stakeholders should not focus solely on access to AR tools but also prioritize readiness-building measures—including digital literacy workshops, AR training, and curriculum redesign. This dual approach ensures that students do not merely consume AR content but actively engage with and create it in ethically informed ways.

5. CONCLUSION

This study investigated the relationship between university students' readiness to engage with Augmented Reality (AR) and their digital literacy competencies within the evolving context of disruptive educational technologies. The findings demonstrate that AR readiness is positively associated with all domains of digital literacy, highlighting the technology's transformative potential as a pedagogical tool rather than merely a technological addition.

Students showed high openness to technology adoption and moderate digital competencies, particularly in areas such as information literacy and communication. However, notable gaps remain in areas like digital ethics and hands-on confidence with AR tools. The regression analysis further confirmed that perceived usefulness and confidence in using AR were the strongest predictors of digital literacy, underscoring the importance of meaningful, confident engagement with AR to foster critical digital skills.

These findings emphasize that fostering digital literacy through AR requires more than technological access—it demands deliberate instructional strategies that cultivate readiness, build confidence, and embed AR into active learning processes. By strategically integrating AR within curriculum design and teacher training, institutions can better prepare students to thrive in a rapidly evolving digital landscape.

Future research should expand on these findings by exploring longitudinal impacts of AR integration, incorporating diverse student populations, and examining additional moderating variables such as motivation, prior experience, and learning styles. As educational environments continue to evolve, understanding and enhancing student readiness for emerging technologies will remain a critical component of digital education reform.

6. REFERENCES

Akçayır, M., & Akçayır, G. (2019). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review, 27*, 1–11. https://doi.org/10.1016/j.edurev.2018.11.001

Alsop, G., & Tomita, M. (2022). Rethinking digital competence: A critical reflection on immersive technologies in higher education. *British Journal of Educational Technology, 53*(6), 1251–1266. https://doi.org/10.1111/bjet.13217

Al-Khalifah, A. H., et al. (2021). Digital literacy skills of higher education students in Saudi Arabia: Challenges and opportunities. *Education and Information Technologies, 26*, 3269–3287. https://doi.org/10.1007/s10639-020-10400-6

Çetin, M., & Türkan, A. (2023). Investigating students' acceptance of augmented reality in higher education. *Interactive Learning Environments, 31*(1), 42–56. https://doi.org/10.1080/10494820.2022.2046105

Faridi, A., & Subekti, A. S. (2023). Augmented reality in pre-service teacher education: Impacts and prospects. *International Journal of Emerging Technologies in Learning (iJET), 18*(4), 102–113.

Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching: Opportunities and challenges in the digital transformation of education. *Sustainability, 12*(20), 8299. https://doi.org/10.3390/su12208299

Fisher, R., et al. (2021). Students' digital literacy and the impact on learning outcomes in higher education. *Education and Information Technologies, 26*, 7339–7356. https://doi.org/10.1007/s10639-021-10548-w

Huang, R. H., et al. (2020). The effectiveness of AR technology in education: A meta-analysis. *Educational Technology Research and Development, 68*(4), 1981–2009. https://doi.org/10.1007/s11423-020-09788-z

Ibáñez, M.-B., & Delgado-Kloos, C. (2021). Augmented reality for STEM learning: A systematic review. *Computers & Education, 160*, 104024. https://doi.org/10.1016/j.compedu.2020.104024

Ismail, R., Samsudin, M. A., & Nordin, N. (2021). The role of self-efficacy and perceived usefulness in adopting augmented reality among university students. *Education and Information Technologies, 26*, 6869–6886. https://doi.org/10.1007/s10639-021-10537-z

Lin, H., & Chen, T. L. (2020). The effects of augmented reality on learning performance and motivation in university students. *Educational Technology & Society, 23*(3), 56–68.

López-Belmonte, J., Segura-Robles, A., & Fuentes-Cabrera, A. (2023). Augmented reality in active learning: Effects on digital competence and motivation in higher education. *Interactive Learning Environments, 31*(2), 331–346. https://doi.org/10.1080/10494820.2022.2072135

Ng, W., et al. (2020). Conceptualising and measuring digital literacy for higher education. *Technology, Pedagogy and Education, 29*(3), 287–301. https://doi.org/10.1080/1475939X.2020.1733019

Reddy, P., Sharma, B., & Chaudhary, K. (2023). Ethical digital citizenship in the age of AI and misinformation: A study of university learners. *Australasian Journal of Educational Technology, 39*(1), 40–56. https://doi.org/10.14742/ajet.7970

Saad, A., et al. (2021). Augmented reality in education: Applications and challenges. *Education and Information Technologies, 26,* 4199–4221. https://doi.org/10.1007/s10639-021-10436-3

Safar, A. H., et al. (2022). Evaluating the impact of augmented reality on students' motivation and learning outcomes in science education. *Education and Information Technologies, 27,* 1385–1404. https://doi.org/10.1007/s10639-021-10656-7

Tang, Y. M., & Chaw, L. Y. (2022). Digital literacy and online learning experience: A study among Malaysian undergraduates. *Education and Information Technologies, 27*, 10519–10541. https://doi.org/10.1007/s10639-021-10877-w

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the Technology Acceptance Model: Four longitudinal field studies. *Management Science, 46*(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Wang, F., et al. (2021). Augmented reality in second language acquisition: A review of empirical research. *Journal of Educational Computing Research, 59*(6), 1146–1175. https://doi.org/10.1177/0735633121990862

Zarraonandia, T., et al. (2022). Developing digital literacy through immersive technologies: An exploratory study. *British Journal of Educational Technology, 53*(3), 543–562. https://doi.org/10.1111/bjet.13183