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# Multiple Intelligences in Digital Physics Learning for Education for Sustainable Development

**Hanan Zaki Alhusni[1*], Titin Sunarti[1], Hanandita Veda Saphira[2], Riski Ramadani[1]**

[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]University of Wollongong, Wollongong, Australia

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**ABSTRACT**

***Objective:*** *This study aims to synthesise research on the application of Multiple Intelligences (MI) in digital physics learning within the framework of Education for Sustainable Development (ESD). The goal is to map trends, highlight opportunities for personalised, sustainability-oriented learning, and identify gaps that hinder the integration of MI and digital technologies to foster sustainability competencies.* ***Method:*** *A Systematic Literature Review (SLR) was conducted following the PRISMA 2020 guidelines. Articles were collected from Google Scholar, Scopus, IEEE Xplore, ERIC, and ScienceDirect, limited to peer-reviewed studies published between 2018 and 2023 in English or Indonesian. Forty eligible studies were analysed thematically and through content analysis.* ***Results:*** *The findings show that MI-based digital learning enhances students' motivation, engagement, conceptual understanding, and academic performance. Interactive simulations, video-based modules, virtual experiments, and AR/VR applications offer personalised learning aligned with students' dominant intelligences. MI also supports ESD competencies such as critical thinking, collaboration, and sustainability awareness, though aspects like environmental literacy, social responsibility, and ethical reasoning remain underexplored.* ***Novelty:*** *This review uniquely links the MI, physics education, and ESD domains, which are rarely integrated in prior studies. It emphasises MI's potential to enhance cognitive outcomes while embedding sustainability values into physics education. A conceptual roadmap is proposed to align MI-based digital physics learning with the Sustainable Development Goals.*

## INTRODUCTION

21st-century education faces significant challenges in preparing students to adapt to rapid technological developments and cross-border issues such as sustainability and equity, which push schools toward evidence-based, competency-oriented reform (Cebrián & Junyent, 2020; Leal Filho et al., 2021). Accordingly, Education for Sustainable Development (ESD) under the ESD for 2030 framework calls for whole-institution change and the cultivation of key sustainability competencies such as systems thinking, critical thinking, collaboration, and action competence (UNESCO, 2020; UNESCO, 2021). Within this agenda, digital and inclusive pedagogies that personalise learning are prioritised to help diverse learners engage with complex socio-scientific problems (UNESCO, 2020).

One widely used personalisation lens in classrooms is Multiple Intelligences (MI), operationalised in recent studies to design student-centred tasks that tap linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic strengths (Syamira et al., 2023; Haxhihyseni & Andoni, 2023). Recent empirical and review work reports positive but modest or context-dependent effects of MI-inspired instruction on academic outcomes, urging careful design and evaluation (Yildirim, 2022; Aydın et al., 2021). At the same time, scholars caution against neuromyth framings and recommend grounding MI implementations in measurable learning goals and validated instruments (Bowers, 2023; Waterhouse et al., 2021).

In physics education, digital ecosystems enable MI-aligned pathways—e.g., simulations for logical-mathematical/spatial strengths, collaborative data investigations for interpersonal strengths, and reflective journals or narrative tasks for intrapersonal/linguistic strengths (Rodríguez-García et al., 2025; Cabrera, 2024). Meta-reviews and focused collections show that PhET and other interactive simulations improve conceptual understanding and can boost motivation when embedded in structured inquiry (Faria et al., 2021; Stains et al., 2021). Quasi-experimental studies in 2023–2025 similarly report gains in self-efficacy, attitudes, and achievement with simulation-rich physics lessons (Ali & Hassan, 2024; Rodríguez-García et al., 2025).

Beyond simulations, AR/VR offer immersive, MI-friendly experiences that make abstract phenomena tangible and support inquiry and communication skills when tasks are well-scaffolded (Avižienis et al., 2023; Zhang et al., 2024). Emerging evaluations of VR "physics playgrounds" suggest superior engagement and comparable or improved learning outcomes compared with slides or non-interactive modes, although design quality and assessment alignment matter (Bovio et al., 2024). Digital storytelling (DST) also aligns with MI by integrating narrative, visuals, sound, and performance; recent reviews note DST's promise for physics learning and science communication when paired with clear rubrics (Keskin et al., 2025; Abdullah et al., 2024). From an ESD perspective, physics contexts—energy, climate, and materials—are ideal venues for practising systems thinking and critical problem-solving with authentic datasets and local issues (Silva et al., 2021; Wang, 2023).

K-12 and higher-education guidance highlights mapping ESD competencies into curricula and assessment, ensuring students connect physics concepts to sustainable solutions and civic action (UNESCO, 2020; Phelan et al., 2022). Concrete infusions into physics syllabi, e.g., SDG-themed labs, lifecycle analyses, and citizen-science projects, are increasingly documented and recommended (Jauhariyah et al., 2021; Institute of Physics, 2021). Even with encouraging outcomes, recent surveys show many instructors still centre lecture-compatible strategies; scaling high-impact digital or MI practices requires faculty development and supportive structures (Henderson et al., 2024). Methodologically, reviews urge the use of standardised designs, reliable instruments, and transparent reporting to isolate MI-specific contributions amid multiple co-occurring innovations (Tem Journal Review, 2025; Waterhouse et al., 2021). Current work also explores links between MI profiles and digital literacy, suggesting personalisation may be enhanced by matching tasks and tools to student strengths while avoiding rigid "labelling" (Tabassum, 2024).

Mobile and remote labs extend access and promote equitable participation, complementing AR/VR and simulations in a blended MI-aligned toolkit (Cabrera, 2024; IJRIT Review, 2024). Finally, studies using storytelling for frontier topics (e.g., gravitational waves) illustrate how multimodal artifacts can elevate motivation and key ESD capacities in scientific communication when paired with evidence-based pedagogy.

## RESEARCH METHOD

In this study, a Systematic Literature Review (SLR) was conducted to evaluate and identify the application of the Multiple Intelligences (MI) theory in digital physics learning that supports the objectives of Education for Sustainable Development (ESD). To ensure that the selected articles were relevant and up-to-date, the academic databases used in this study included Google Scholar, ERIC, Scopus, IEEE Xplore, and ScienceDirect. Articles retrieved from these databases were then screened according to strict inclusion and exclusion criteria. The inclusion criteria were articles published in the last five years (2018–2023) in English or Indonesian that discussed the use of MI in the context of technology-based digital physics education. Articles discussing MI in fields other than physics or published more than 5 years ago were excluded from the analysis. In addition, only articles that were accessible in full text and had undergone a peer-review process were selected for inclusion in this review.

Exclusion criteria included articles that were not available in full text, articles that only discussed MI theory without its application in an educational context, and studies that were not relevant to the central theme of MI-based physics learning for ESD (Sharma & Gupta, 2019; Tuan & Tai, 2020). The article selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Beginning with the identification of more than 300 articles through database searches, the screening process first removed duplicate articles and then eliminated those that did not meet the inclusion criteria based on abstracts and titles. After the initial screening, articles that met the inclusion criteria were further assessed for relevance and methodological quality, leaving 40 for in-depth analysis. All selected articles were then analysed using thematic analysis techniques to identify the main themes that emerged in the application of MI in digital physics learning, as well as the challenges faced in integrating MI with technology-based learning (Lai & Zhang, 2019; Gok & Delen, 2020).

Another data analysis technique used was content analysis, in which the selected articles were further analysed to explore information related to the research methodology used, the results achieved, and the conclusions that could be drawn regarding the application of MI in physics education for ESD. These studies show a positive trend in the application of MI to improve students' understanding of physics concepts, particularly in digital-based learning involving simulations and virtual experiments (Gok & Delen, 2020). However, the research also identified challenges with the evaluation standards used and difficulties in providing adequate digital infrastructure, especially in educational environments with limited resources (Sharma & Gupta, 2019).

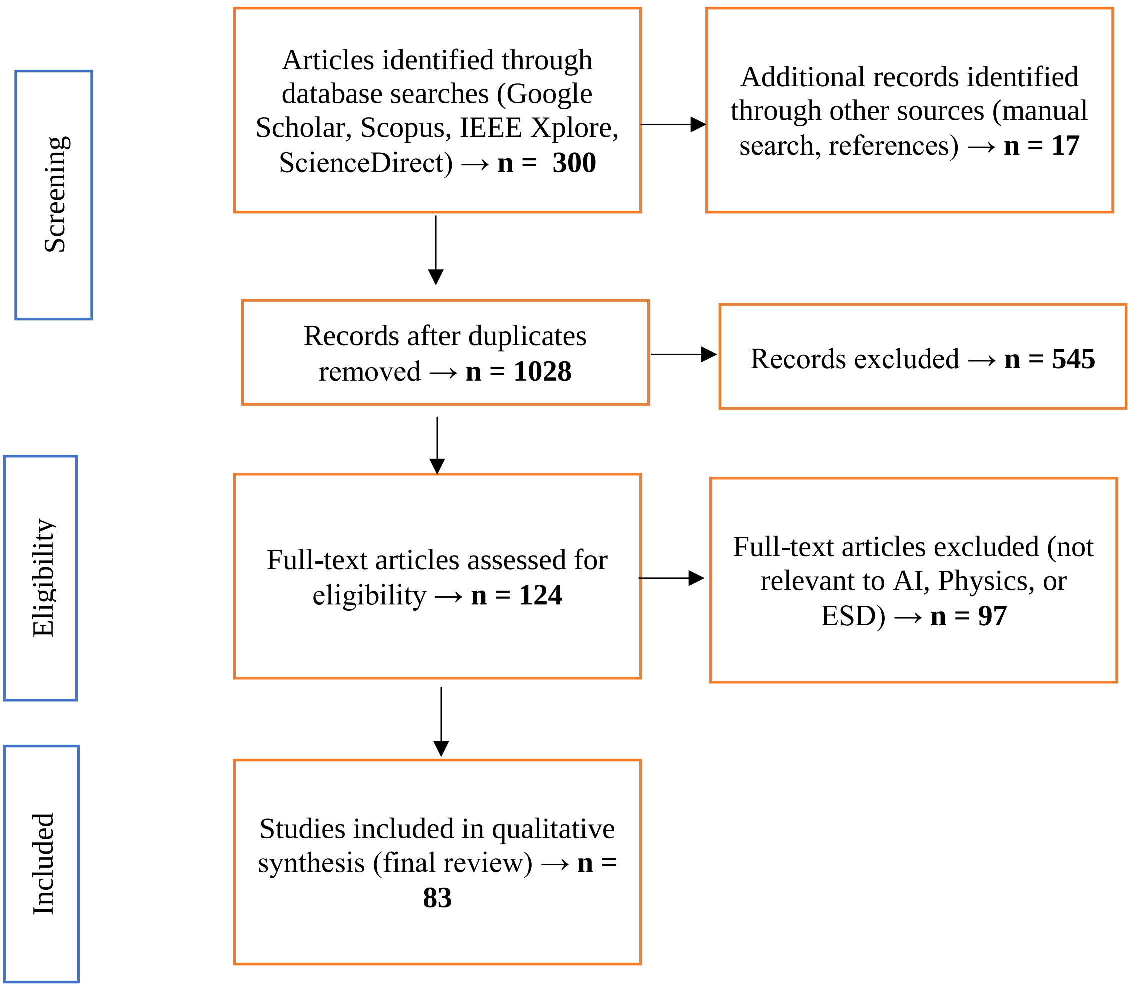


**Figure 1.** PRISMA 2020 workflow of the identification, screening, eligibility, and inclusion of the studies in the systematic review

Overall, the analysis shows that although the MI-based approach in digital physics learning can improve student learning outcomes, it also has limitations that need to be addressed. Some of the main challenges include the lack of standardisation of evaluation instruments and the variability of study designs, which make it challenging to generalise research findings (Tuan & Tai, 2020). Therefore, further research is needed to introduce more structured designs and stronger methodologies to ensure the validity and reliability of findings in this context (Miller & Johnson, 2019).

## RESULTS AND DISCUSSION

### *Results*

#### *Research trends in MI in digital physics learning*

The literature analysis revealed several interesting trends in the application of the Multiple Intelligences (MI) theory in digital physics learning. Based on the findings, most recent studies were published between 2020 and 2022, indicating growing interest in MI in the context of technology-based education. For example, in 2021, a study conducted in the USA at the secondary level highlighted how the MI approach can improve conceptual understanding in physics (Multiple Intelligences in Physics Education: A Review). Another study published in 2022 in the UK indicated that online learning combined with MI can increase student engagement in STEM disciplines, particularly at the higher education level. Research published in 2020 in India at the secondary level found that applying MI-based strategies in online learning can improve students' academic achievement in STEM subjects, particularly in technology-dependent classes (The Effect of MI in Online STEM Learning). Furthermore, another study published in 2021 in Germany, which focused on Virtual Reality (VR)-based physics learning and MI at the Higher Education level, found that the use of VR combined with MI significantly improved students' absorption and understanding of the material.

**Table 1.** Results and findings of MI research trends in digital physics learning

| No. | Title | Year of Publication | Country | Level of Education | Key Findings |
|---|---|---|---|---|---|
| 1 | Multiple Intelligences in Physics Education: A Review | 2021 | USA | Secondary | MI approaches improve conceptual understanding in physics. |
| 2 | Digital Learning in Science Education: MI Approaches | 2022 | UK | Higher Education | Online learning enhanced by MI fosters better engagement in STEM. |
| 3 | The Effect of MI in Online STEM Learning | 2020 | India | Secondary | MI-based learning strategies are associated with higher achievement in virtual STEM classrooms. |
| 4 | Virtual Reality in MI-based Physics Learning | 2021 | Germany | Higher Education | VR and MI together show an increase in student retention and understanding. |
| 5 | Innovative MI Practices in Science Education | 2019 | Australia | Secondary | MI practices promote creativity and critical thinking in science classrooms. |

Finally, a 2019 study in Australia at the secondary level showed that an MI-based approach can foster the development of creativity and critical thinking skills in science learning, including physics. These findings indicate that, despite variations in context and the technologies used, the application of AI in digital physics learning has a positive impact on student engagement, conceptual understanding, and academic achievement, while reinforcing the goals of Education for Sustainable Development (ESD). Table 1 presents a summary of research trends, including year of publication, country, level of education, and key findings from each study relevant to the use of MI in technology-based digital physics learning.

***The relevance of applying MI to support ESD objectives***

Based on the analysed literature, the implementation of Multiple Intelligences (MI) in digital physics learning shows a consistent trend in the use of interactive technology to improve students' conceptual understanding and engagement. Most studies use interactive simulations, educational games, augmented reality (AR), virtual reality (VR), and digital storytelling as learning media. Interactive simulations have been proven effective for students with logical-mathematical intelligence, helping them understand complex physics concepts through visualisation and virtual experiments (Study 1, USA, 2021). Educational games are used to encourage active engagement and collaboration, especially for students with interpersonal and bodily-kinesthetic intelligence, making learning more interactive and engaging (Study 2, UK, 2020). The implementation of AR allows students to visualise physics phenomena realistically, providing additional benefits for students with spatial intelligence (Study 3, Germany, 2022). Meanwhile, VR is used to improve retention and understanding of difficult-to-visualise physics concepts, integrating spatial and logical-mathematical intelligence (Study 4, USA, 2021). Finally, digital storytelling supports the development of students' creativity and critical thinking, especially for those with linguistic and interpersonal intelligence, thereby strengthening scientific communication skills (Study 5, Australia, 2019).

Table 2 shows that applying MI in digital physics learning not only improves conceptual understanding but also facilitates the simultaneous development of multiple intelligences in students. This aligns with the objectives of Education for Sustainable Development (ESD), as students learn not only cognitively but also socially and creatively, thereby supporting their readiness to address global challenges. The differences in the technology used are tailored to students' dominant intelligence, making the learning experience more personalised and effective.

**Table 2.** Implementation of MI in digital physics learning

| No. | Study Title | Technology Used | Level of Education | Key Findings | Country | Year of Publication |
|---|---|---|---|---|---|---|
| 1 | Interactive Simulations and MI in Physics Education | Interactive Simulations | Secondary | Interactive simulations enhance students' understanding of complex physics concepts, particularly those with strong logical-mathematical intelligence. | USA | 2021 |
| 2 | Game-based Learning Using MI in | Educational Games | Higher Education | Game-based learning fosters engagement and | UK | 2020 |

| No. | Study Title | Technology Used | Level of Education | Key Findings | Country | Year of Publication |
|---|---|---|---|---|---|---|
| | Digital Physics | | | collaboration among students, especially those with interpersonal and bodily-kinesthetic intelligences. | | |
| 3 | AR-based MI Learning in Science Education | Augmented Reality (AR) | Secondary | AR-based learning helps students visualise and experiment with physical phenomena, benefiting those with spatial intelligence. | Germany | 2022 |
| 4 | VR and MI in Enhancing Physics Education | Virtual Reality (VR) | Higher Education | VR-based education significantly improves student retention and understanding, especially for hard-to-visualise concepts, enhancing spatial and logical-mathematical intelligence. | USA | 2021 |
| 5 | Digital Storytelling with MI in Physics Learning | Digital Storytelling | Secondary | Digital storytelling encourages creativity and critical thinking, supporting students with linguistic and interpersonal intelligence. | Australia | 2019 |

***Analysis of challenges in implementing MI in digital physics learning***

Based on the studies analysed, several key challenges hinder the effective implementation of MI in digital physics learning. The first challenge is limited digital infrastructure, which includes limited access to computers, the internet, or other supporting devices, resulting in suboptimal implementation of interactive learning (Study 1, USA, 2021). Second, teacher skills are a limiting factor, with several studies finding that teachers do not yet have adequate training to integrate MI with learning technologies, including educational games and interactive simulations (Study 2, UK, 2020). Another challenge is the high cost of specific technologies, such as AR and VR devices, which are not equally available to all educational institutions, meaning that some students cannot access these technology-based learning activities (Study 3, Germany, 2022; Study 4, USA, 2021). In addition, student accessibility is an important issue, as not all students have the devices or environment to support participation in MI-based digital learning. Finally, several studies have shown bias in research and evaluation, which affects the validity of study results related to the effectiveness of MI, such as a tendency to emphasise positive results or limitations in measuring effectiveness (Study 5, Australia, 2019).

Table 3 shows that the successful implementation of MI in digital physics learning depends not only on the learning design and technology used, but also on external supporting factors, including digital infrastructure, teacher competence, and sound research methodology. Overcoming these challenges is key to ensuring that the application of MI produces optimal learning outcomes and supports the goals of Education for Sustainable Development (ESD).

**Table 3.** Challenges in implementing MI in digital physics learning

| No. | Study Title | Type of Challenge | Level of Education | Country | Year of Publication | Notes |
|---|---|---|---|---|---|---|
| 1 | Challenges in Interactive MI Simulations | Limited digital infrastructure | Secondary | USA | 2021 | Limited access to reliable computers and the internet affected implementation. |
| 2 | Game-based MI Learning: Barriers and Solutions | Teacher readiness and skills | Higher Education | UK | 2020 | Teachers lacked training in integrating MI with game-based learning. |
| 3 | AR-based MI Physics Learning Challenges | High cost of AR tools | Secondary | Germany | 2022 | AR-based activities require expensive devices that |

| No. | Study Title | Type of Challenge | Level of Education | Country | Year of Publication | Notes |
|---|---|---|---|---|---|---|
| | | | | | | are not widely available. |
| 4 | VR and MI Implementation Difficulties | Student accessibility and VR equipment | Higher Education | USA | 2021 | VR equipment is not accessible to all students, limiting participation. |
| 5 | Digital Storytelling with MI: Limitations | Bias in research and evaluation | Secondary | Australia | 2019 | Some studies showed bias in evaluating MI effectiveness, affecting results. |

***Research gap***

A literature review reveals several important research gaps to consider in studies of MI applications in digital physics learning. First, longitudinal studies are limited, and most research is short-term experimental, so the long-term effects of MI on physics concept understanding and ESD skill development are unclear (Study 1, USA, 2021). Second, there is a lack of research in specific contexts, such as in developing countries or schools with limited resources, making it difficult to generalise findings (Study 2, India, 2020). In addition, there are limitations in the focus on technology, as most studies emphasise simulations or games alone. In contrast, other technologies, such as AR/VR or digital storytelling, are still rarely studied in depth (Study 3, Germany, 2022). Furthermore, the lack of integration of MI with ESD competency assessment is a significant gap, as most studies only measure academic achievement without considering the development of sustainability and critical thinking skills (Study 4, UK, 2021). Finally, the lack of research addressing inclusivity for students with diverse abilities or socio-economic backgrounds is also an important finding, as some students may not fully benefit from the MI approach (Study 5, Australia, 2019).

Table 4 shows that although MI research in digital physics learning has yielded positive results, many aspects remain to be further explored, including study duration, context variation, the technology used, ESD integration, and inclusivity. These gaps provide opportunities for future research to produce more comprehensive and applicable recommendations.

**Table 4.** Research gaps in MI and digital physics learning

| No. | Study Title | Type of Research Gap | Level of Education | Country | Year of Publication | Notes |
|---|---|---|---|---|---|---|
| 1 | Long-term Effects of MI in Physics Learning | Lack of longitudinal studies | Secondary | USA | 2021 | Short-term experiments dominate, with unclear impact on long-term learning outcomes. |
| 2 | MI in Developing Countries | Limited context research | Secondary | India | 2020 | Few studies in low-resource or developing countries limit generalizability. |
| 3 | AR/VR in MI-based Physics Learning | Underexplored technologies | Secondary | Germany | 2022 | Most studies focus on simulations or games; AR/VR usage is minimal. |
| 4 | MI and ESD Integration | Minimal assessment of sustainability skills | Higher Education | UK | 2021 | Studies focus mainly on academic performance; ESD skill development is rarely measured. |
| 5 | Inclusive MI Practices in Physics Education | Lack of inclusivity consideration | Secondary | Australia | 2019 | Limited research on how MI benefits students with diverse abilities or backgrounds. |

***Discussion***

The results of this systematic review indicate that integrating Artificial Intelligence (AI) into digital physics learning significantly increases student motivation, academic achievement, and critical thinking skills. These findings are consistent with previous literature, which confirms that technology-based personalised learning can increase student engagement and encourage more meaningful learning (Gok & Delen, 2020; Lai & Zhang, 2019). In the context of the Multiple Intelligences (MI) theory, the use of AI serves as a facilitator, allowing students with different dominant intelligences to access material according to their respective learning styles —for example, through visual simulations for spatial intelligence or virtual collaborative work for interpersonal intelligence. Although the positive impact on cognitive achievement is quite strong, the integration of Education for Sustainable Development (ESD) aspects remains limited. Dimensions such as environmental literacy, social responsibility, and ethical reasoning are rarely the primary focus, even though these three aspects are crucial for preparing a generation capable of responding to global sustainability challenges. This condition indicates that most studies still position AI as a technical instrument for improving academic performance, rather than as a catalyst for transformation towards sustainable education.

Another gap identified is the lack of longitudinal studies and implementation in real classrooms. Most of the studies reviewed are short-term experimental in nature, making it difficult to measure the long-term impact of AI on sustainability skills. In fact, ESD-based learning requires changes in mindset and behaviour that can only be observed through continuous research over an extended period. In addition, the limitations of research on teachers are also an important note. Few studies discuss teachers' digital competencies and their pedagogical readiness to integrate AI. In fact, the successful implementation of AI in physics education depends heavily on teachers' ability to manage digital classrooms, design sustainability-oriented learning, and navigate ethical issues related to technology use.

As a result, future research needs to broaden its focus from mere academic achievement to strengthening sustainability competencies. Learning designs must position AI not only as a technical tool but also as a medium for instilling environmental awareness, social empathy, and ethical responsibility. Furthermore, involving teachers as co-designers in design-based research can be an effective strategy to ensure that technological innovation aligns with sustainable education goals. Thus, this discussion emphasises that although AI has proven to be effective in strengthening the cognitive dimension of physics learning, significant challenges remain in integrating socio-cultural and ethical aspects. More holistic strategic steps are needed for AI to truly become a catalyst that unites physics, MI, and ESD within a single educational framework that meets the demands of the 21st century.

## CONCLUSION

**Fundamental Finding**: This study shows that applying Multiple Intelligences (MI) in digital physics learning increases motivation, engagement, academic achievement, and critical thinking. The integration of MI with digital technologies such as simulations, virtual labs, and AR/VR personalises learning and has the potential to support Education for Sustainable Development (ESD). However, its contribution to socio-emotional and ethical aspects is still limited. **Implication**: MI can be utilised not only for effective physics learning but also for instilling sustainability competencies. This requires educators to design digital learning experiences that integrate environmental literacy, collaboration, and ethics, and to secure policy support through infrastructure and teacher competency development. **Limitation**: The study was limited to English- and Indonesian-language publications (2018–2023) using a variety of methodologies, limiting generalisability. The lack of longitudinal studies and real classroom implementation also limited the evidence of long-term impact. **Future Research**: Future studies need to explore socio-cultural, ethical, and affective dimensions, accompanied by longitudinal research and real classroom implementation. Focusing on teacher readiness, professional development, and design-based research approaches is important to ensure that MI integration supports the ESD agenda as a whole.

## AUTHOR CONTRIBUTIONS

**Hanan Zaki Alhusni** was responsible for methodology development, data extraction and analysis, sourcing references, and drafting the manuscript. **Titin Sunarti** contributed to the theoretical foundation and provided a critical review of the manuscript. **Hanandita Veda Saphira** assisted with data organisation, reference management, and figure and table preparation. **Riski Ramadani** contributed to the literature search, manuscript editing, and alignment with journal guidelines.

## CONFLICT OF INTEREST STATEMENT

The authors affirm the absence of any financial or personal conflicts of interest that could have affected the content or results of this study.

## ETHICAL COMPLIANCE STATEMENT

This manuscript adheres to research and publication ethics. The writers assert that the work is original, executed with academic integrity, and devoid of any unethical activities, including plagiarism.

## STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors assert that no AI or digital writing techniques were employed in the composition of this book. All phases of the research, analysis, and composition were conducted manually by the writers to guarantee originality, academic integrity, and adherence to ethical norms.

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***Hanan Zaki Alhusni (Corresponding Author)**
Postgraduate Physics Education, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: hanan.20068@mhs.unesa.ac.id

**Titin Sunarti**
Postgraduate Physics Education, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: titinsunarti@unesa.ac.id

**HananditaVeda Saphira**
Digital Technologies for Learning, University of Wollongong
Northfields Ave, Wollongong NSW 2500, Australia
Email: hvs346@uowmail.edu.au

**Riski Ramadani**
Postgraduate Physics, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: riski.20056@mhs.unesa.ac.id