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A Systematic Literature Review of Technology-Based Physics Instruction in Pre-University or Matriculation College

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Abstract

Technology-based physics instruction refers to the use of digital tools such as simulations, interactive modules, virtual and augmented reality, mobile applications, and AI-assisted systems to enhance the teaching and learning of physics by enabling students to visualise abstract concepts, conduct virtual experiments, and engage with interactive representations. This systematic literature review examines research published between 2015 and 2025 on technology integration in physics education across secondary, pre-university/matriculation college, and university levels. Using the PRISMA framework, 21 empirical studies were identified from Scopus and Web of Science and analysed to determine the physics topics addressed, the types of technologies used, and the levels of education most frequently studied. The findings indicate that university-level research dominates, especially studies employing Virtual Reality (VR), Augmented Reality (AR), and simulations to support advanced and abstract content, while secondary school studies appear in moderate numbers. Only a small proportion of research focuses on the pre-university or matriculation context, despite its structured curriculum and crucial role in preparing students for tertiary physics. Across the reviewed studies, technology consistently enhances conceptual understanding, engagement, and learning motivation; however, gaps remain concerning curriculum alignment, classroom practicality, and learner readiness at the matriculation level. These findings highlight the need for more context-specific empirical research to understand how technology can effectively support physics learning in fast-paced, exam-oriented pre-university/matriculation college programmes.

Keywords: Technology-Based, Physics, Pre-University, Matriculation, PRISMA

Introduction

The field of physics education has undergone significant transformation in response to technological advancement and educational reform aimed at improving student engagement and conceptual understanding (Kurniawan et al., 2019; Vidak et al., 2021). As global education systems transition toward digital and blended learning, particularly after the COVID-19 pandemic, there has been a growing emphasis on active learning, interactivity, and learner-centered pedagogies to enhance the effectiveness of science instruction (Burchard et al., 2019; Yunzal, Jr. & Casinillo, 2020). However, traditional lecture-based instruction in physics often struggles to meet these modern pedagogical demands, resulting in persistent challenges such as low student engagement, limited conceptual mastery, and difficulty visualizing abstract phenomena (Campos et al., 2020; Vidak et al., 2021). To address these issues, innovative approaches that leverage technology in physics instruction have been increasingly explored as promising solutions.

Technology-based instruction, encompassing tools such as digital simulations, virtual laboratories, interactive multimedia, augmented reality (AR), and learning management systems (LMS), has emerged as a transformative approach in physics education (Anandita et al., 2025; Vidak et al., 2021). For instance, AR technologies have been systematically reviewed, showing opportunities such as improved visualization, reduction in cognitive load, and engagement, but also noting challenges linked to hardware/software limitations and extraneous cognitive load.

By embedding features such as simulation-based experimentation, real-time feedback, and collaborative virtual environments, technology-based instruction aligns closely with modern pedagogical goals of physics education and has demonstrated potential to improve conceptual understanding, motivation, and retention among students ((Umiliya et al., 2023; Yunzal, Jr. & Casinillo, 2020). Despite these promising results, research on technology-based physics instruction at the matriculation level remains relatively limited, especially in terms of systematic evaluation across different technologies and outcomes.

Several systematic reviews have examined technology enhanced learning in science and physics education, focusing on aspects such as cognitive outcomes, engagement, and simulations (Vidak et al., 2021). These reviews provide valuable insights into how technology supports learning processes; however, most are broad in disciplinary scope, limited by the age or grade levels studied or focus only on specific technologies such as PhET or AR without considering the full spectrum (Umiliya et al., 2023; Vidak et al., 2021; Yunzal, Jr. & Casinillo, 2020).

This review examines current trends in technology-enhanced physics education by identifying the topics most frequently supported with digital tools, the types of technologies commonly employed, the educational levels in which such approaches are implemented, and the areas where research remains limited. By analysing these patterns, the review provides a clearer picture of how technologies such as augmented reality, virtual environments, simulations and mobile applications are being used to strengthen students' understanding of key physics concepts, while also highlighting the lack of studies focusing specifically on pre-university or matriculation contexts. It will guides the educators on selecting the effective tools with the best teaching strategies. There is also limited evidence specific to pre-university or matriculation students, and studies often do not differentiate outcomes between matriculation and other pre-university. It will then wish to help curriculum planners to integrate digital tools effectively and align physics teaching with latest technology skills.

Literature Review

Augmented Reality (AR) and Other Emerging Technologies in Physics

Innovation and technology are always changing. Today's paradigm has shifted from traditional education to technology-based education. (Ashdan Baba & Zorlu, 2022; Dadan Sumardani et al., 2019). Students in elementary, secondary, and higher education can study in a new way thanks to technology-based instruction. According to the fourth Sustainable Development Goal (SDG), which highlights the importance of high-quality education, it is anticipated that kids would receive high-quality education through the use of technology (Jing, 2024). The usage of augmented reality in technology-assisted learning is growing (Suprapto et al., 2020). Teaching and learning can benefit from a variety of technology. Among them is Augmented Reality (AR). AR can be described where users can see a mixture of objects in the virtual and real world in real time (H. Suhaimi et al., 2023). AR is a widely used technology in many facets of our lives (Makhataeva & Huseyin Atakan Varol, 2020) which combines the real world and the virtual world created through computers (Archana & Kingsly Stephen, 2025; Irfan et al., 2024; Julie Carmigniani et al., 2011). AR has the ability to facilitate multimedia learning because it creates an interactive learning environment capable of providing a learning experience similar to the real world (Alia Hadid et al., 2019; Khoshnevisan & Res, 2018) and offering better understanding (Christopeh Stolzenberger et al., 2022).

Learning can be more successful with AR-based instruction. Numerous research cover a wide range of topics, including mathematics, (Cai et al., 2019; Ikhsan et al., 2019), Chemistry (Fitriyah et al., 2023; Ningrum et al., 2021; Nor Farhah Saidin et al., 2019), Physical Education (Nur Azlina Mohamed Mokmin & Nurul Nabilah Izzati Ridzuan, 2022), Biology (Dzulqarnain et al., 2025; Muliani et al., 2025), Science (Sontay & Karamustafaoğlu, 2021), Early Childhood Education (RM Yilmaz, 2016) and Physics (Anggi Datiatur Rahmat et al., 2023; Karim et al., 2024; Wibowo et al., 2022) where AR is used to teach and learn. Since AR delivers an interactive learning environment with multimedia support that incorporates scaffolding, it can help and guide students in better understanding the real world (Alia Hadid et al., 2019; Khoshnevisan & Res, 2018).

Augmented reality (AR), video animation, interactive simulations especially PhET simulations, immersive virtual or mixed reality (VR/MR), and inexpensive sensor or smartphone laboratories are just a few of the instructional technologies used in physics education that have grown rapidly in recent years. Interventions using augmented reality (AR) have been shown to enhance conceptual visualization, motivation, and learning outcomes (Handayani et al., 2024). PhET interactive simulations have provided significant learning benefits especially in fundamental physics topics (Ben Boumediane et al., 2025; Umi Purnama & Nurhania, 2025). Mobile apps and marker triggered 3D models included into module pages are common solutions that let students see and work with for example virtual circuit components and Newtonian scenarios (Li et al., 2011; Silvie Afifatuz Zulfah & Mukhoiyaroh, 2022). AR content has been integrated into digital and print modules, along with access to PhET simulations for more in-depth testing (Mukhtarkyzy et al., 2022).

AR instruction enhanced critical thinking abilities and learning outcomes, when compared to traditional training (Faridi et al., 2021; Nusroh et al., 2022). The integration AR in learning environment help in students' retention and understanding. Compared to conventional approaches, an interactive 3D circuit model classroom deployment with eighth graders demonstrated better conceptual understanding and retention (Li et al., 2011). The efficiency of a school-based AR with the integration of PhET module in promoting learning activities and problem-solving abilities on vibrational and wave themes was found to be benefial among students (Mukhtarkyzy et al., 2022).

PhET simulations facilitate the investigation of Newtonian mechanics and energy concepts by enabling variable manipulation and instantaneous visual feedback (Ben Boumediane et al., 2025). Technology-based curricula such as Phet have incorporated simulations as linkages to offer chances for virtual practicum and experimentation (Mukhtarkyzy et al., 2022). To monitor and enhance training and student comprehension, certain implementations integrate PhET with learning analytics (Umi Purnama & Nurhania, 2025). Teachers reported usability and pedagogical value, and a survey of 120 students revealed that the simulation group outperformed a traditional instruction group in terms of normalized learning gains on Newton's laws (Ben Boumediane et al., 2025). Study also shown that using simulations improves student motivation and interest as well as information retention for abstract concepts that are challenging to physically show (Ben Boumediane et al., 2025; Umi Purnama & Nurhania, 2025). Students who used PhET performed noticeably better than those who used traditional methods, according to an experimental study (Umi Purnama & Nurhania, 2025). In this study, those who are in the experimental group shown higher motivation and more consistent grades.

Study involving the use of AR and PhET highlight dynamic representations and visualization as ways to enhance comprehension of abstract processes, implying that animation-like visualizations enhance learning when combined with interactivity (Ben Boumediane et al., 2025; Handayani et al., 2024; Mukhtarkyzy et al., 2022). The use of AR and PhET simulations offers unique affordances that are backed by empirical findings. While PhET offers manipulable simulations that produce quantifiable normalized learning improvements, AR stresses embodied 3D visualization and collaborative gains.

Physics Topics Commonly Addressed Using Technology

Technology-enhanced learning in physics tends to focus on topics that involve abstract reasoning, mathematical manipulation, and conceptual visualisation. Gravitation is one of the most frequently addressed topics, particularly concepts such as gravitational force, orbital motion, and escape velocity (Karim et al., 2024). Such topics are commonly chosen because students struggle to connect formulas with physical meaning, and digital tools, including AR, simulations, and virtual environments, which provide visual cues and step-by-step cognitive support.

Moreover, the integration of AR strongly supports the learning of physics concepts that require mental imagery or spatial reasoning. Topics such as mechanics, kinematics, Newton’s laws, electricity, and optics, due to their reliance on dynamic representations (Anggi Datiatur Rahmat et al., 2023; Wibowo et al., 2022). By offering 3D simulations, animations, and scaffolded calculations, technology allows students to bridge the gap between theoretical formulas and real-world phenomena, making these domains particularly suited for AR- and simulation-based instructional approaches.

Interactive simulations and 3D virtual laboratories are often used to teach mechanics topics including kinematics, oscillations, and analogues of classical experiments. These tools facilitate both conceptual investigation and quantitative practice. Undergraduate students' pre and posttest in a study shown significantly improved scores while using PhET interactive simulations for kinematics especially in the topic of vector addition and projectile motion (TW Chinaka, 2021). For advanced training, 3D virtual laboratory environments (PhysLab) use simulated experiments like the Wilberforce pendulum and nonlinear oscillators (Price & Price-Mohr, 2019).

The topic of electromagnetism (EM) education involving investigate circuits and fields in high school and college classroom implementations have been documented frequent use of simulators, multimedia, and mobile applications. In mobile learning situations, smartphone and tablet apps have been assessed as didactic resources for solving electromagnetism problems and referencing formulas (Blanca Ibáñez et al., 2014; Villaruel, 2025). Models of electrical conduction (Drude theory) and particle devices (Cyclotron) are examples of PhysLab simulations that demonstrate how virtual experiments can demonstrate higher-level electromagnetic ideas (Price & Price-Mohr, 2019). When physical access is restricted, virtual and remote laboratories are mentioned as a generic category that supports EM laboratory experiences (Jan et al., 2022).

Virtual experiments, interactive simulators, and specialized computer platforms are used to teach topics related to quantum and modern physics, including spectroscopy, radioactivity, nuclear physics, basic quantum ideas, and computational quantum simulations. The purpose of the use are to solve conceptual challenges and give access to otherwise unavailable experiments in both teacher education and student inquiry. A teacher-education course on quantum ideas relied heavily on virtual experiment software to help differentiate between classical and quantum images in graduate-level pedagogy (Métioui & Trudel, 2013). In secondary classrooms, interactive PhET simulations have been used to improve comprehension and interest in spectroscopy, radioactivity, and nuclear themes (Nyirahabimana et al., 2023; Vilarta Rodriguez et al., 2020). In order to include realistic quantum-mechanical modeling into research-style tasks and training, sophisticated computational platforms that combine user direction with automated quantum simulations such as AI-guided quantum material simulators are proposed (Barrionuevo & Aguirre, 2025). Modern physics experiments that are challenging to carry out physically in classroom settings are made accessible using virtual and remote labs (Jan et al., 2022).

Geometrical and physical optics, including absorption and diffusion phenomena, are often taught through animations, image sequences, Java applets, and custom interactive simulations. Design studies focus on challenging learners' preconceived notions and using simulation to foster conceptual transformation. Diagnostic-confrontation-reconstruction cycles are used in interactive computer environments intended for light absorption and diffusion to address learners' preconceptions and facilitate conceptual change (Laumann, Schlummer, et al., 2024; Wibowo et al., 2022). Simulation capabilities that specifically identify and correct typical student mistakes in optics are recommended by reviews of computerized physics learning environments (Wibowo et al., 2022).

Inquiry base learning is based on investigation, and scaffolded experimentation are all made possible by cross-cutting platforms like remote labs, 3D virtual laboratories, and customized simulation software. Virtual labs are not only similar to traditional experimental activities in terms of their application, usability, and efficacy in accomplishing the learning objectives for which they were originally assigned, but they also outperform them in terms of performance, as shown by the notable improvement according to a study in Moroccan secondary schools (Menchafou et al., 2024). For secondary and intermediate courses, PhysLab is an example of a 3D video game-based virtual lab that covers a multitopic suite of simulated experiments (Price & Price-Mohr, 2019).

Research Questions

This research aims to achieve the following objectives or research question (RQ):

RQ1: What physics topics are most frequently addressed in technology-enhanced or AR-based learning studies?
RQ2: What types of technologies (e.g., AR, VR, simulations, mobile applications) are commonly used in the teaching and learning of physics?
RQ3: At which educational levels (secondary, pre-university, or university) are these studies most often conducted?
RQ4: What research gaps exist regarding the use of technology or AR in teaching physics at the pre-university or matriculation level?

Research Methodology

The reviewer used the technique called Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) and conducting steps of the review process which are identification, screening, eligibility and data abstraction and analysis. Systematic literature reviews involve reviewing documents according to clearly formulated questions and using systematic and explicit methods to select and critically appraise relevant studies. The review focused on two primary sources of publications such as Scopus and Web of Science to ensure the high-quality standards. The combination of keywords such as "physics education", "technology-based", and "virtual reality" was used via functions of phrase searching and Boolean operator (OR, AND). To ensure the articles chosen are in the physics education field and technology/augmented/virtual, each database used a specific search string, as shown in Table 1 below:

Table 1
Specific search string used on two primary sources

Databases	Keywords used
Scopus	TITLE-ABS-KEY (("physics education" OR "physics teaching" OR "learning physics") AND ("technology-based" OR "digital learning" OR "ICT integration" OR "educational technology" OR "virtual lab" OR "virtual laboratory" OR "simulation" OR "PhET" OR "augmented reality" OR "virtual reality" OR "mobile learning" OR "e-learning" OR "online learning") AND ("pre-university" OR "foundation" OR "matriculation" OR "a-level" OR "college preparatory" OR "pre college" OR "sixth form"))
Web of Science	("physics education" OR "physics teaching" OR "learning physics") AND ("technology-based" OR "digital learning" OR "ICT integration" OR "educational technology" OR "virtual lab" OR "virtual laboratory" OR "simulation" OR "PhET" OR "augmented reality" OR "virtual reality" OR "mobile learning" OR "e-learning" OR "online learning") AND ("pre-university" OR "foundation" OR "matriculation" OR "a-level" OR "college preparatory" OR "pre college" OR "sixth form")

The screening was the second procedure carried out where articles were either included or excluded based on a specific set of criteria as shown in Table 2. This review limited the screening process to only include the articles published between 2015 and 2025 as the number of published studies was sufficient to perform a representative review. The choice of 2015 to 2025 for the screening process was made to ensure that the review includes the most recent and up-to-date research in the field. By focusing on articles published within this timeframe, the review aims to capture the latest developments, findings, and methodologies relevant to the topic under investigation. This ensures that the review provides a comprehensive and current overview of the research landscape, enhancing its relevance and applicability to contemporary contexts. Therefore, based on this, the timeline between 2015 and 2025 was selected as one of the inclusion criteria. With the aim to avoid confusion, only those written in English were considered. Since the SLR objective related to Physics education and technology/ augmented/ virtual based instruction, choosing social science research studies as one of the criteria believed to increase the possibility of acquiring more articles.

Table 2
Inclusion and exclusion based on each criterion.

Criterion	Inclusion	Exclusion
Timeline	2015 – 2024	2014 – earlier
Document type	Articles	Review articles, chapter of book, proceedings
Language	English	Non-English
Subject Area	Social Science	Non-social science studies (e.g.: English language or general education)

This process had excluded 117 articles as they did not fit the inclusion criteria and removed one duplicated articles as shown in Figure 1.

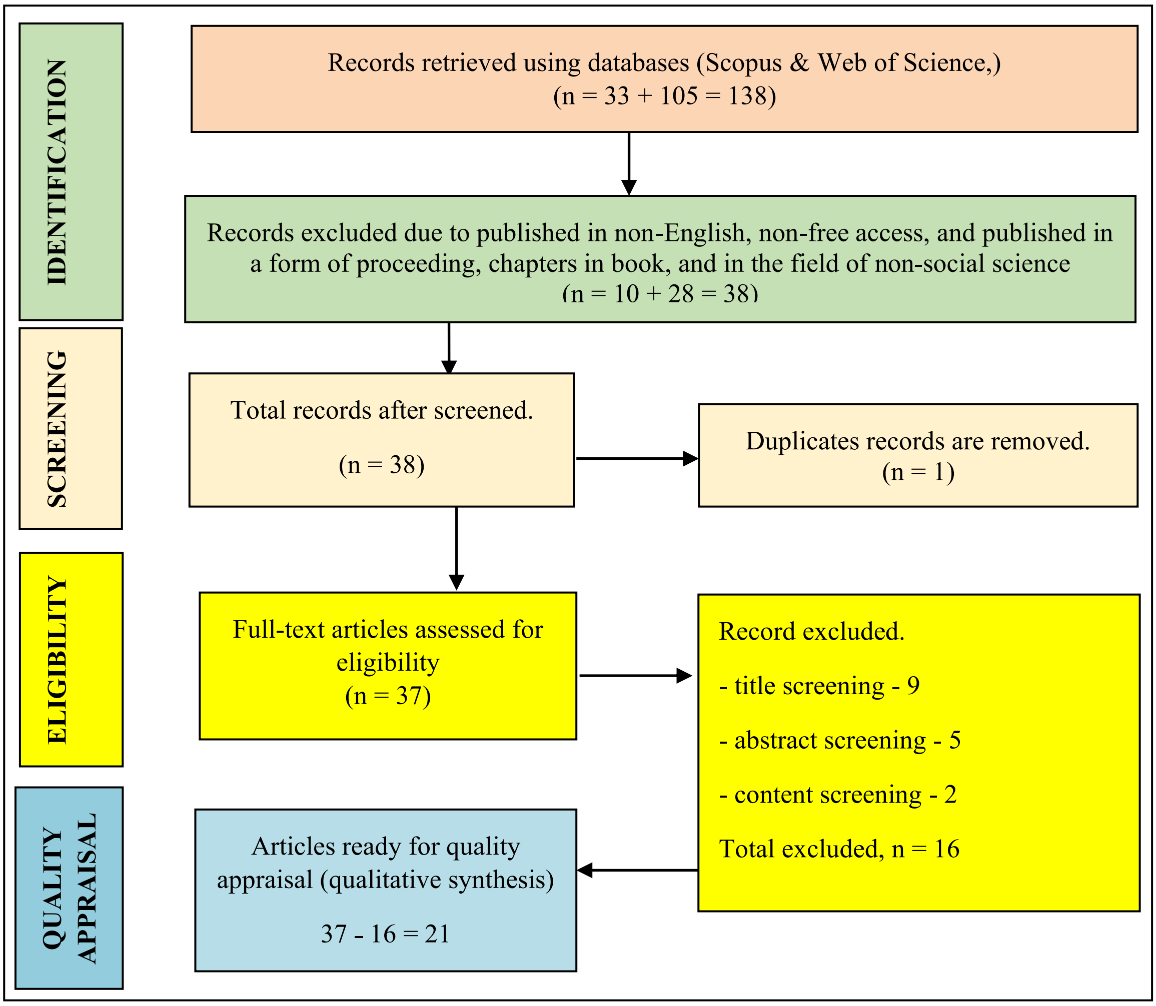

Figure 1 Study selection chart (Adapted from (Moher et al., 2009) PRISMA Framework.

The remaining 21 articles were used for the third process: eligibility. Eligibility is the third process where the authors manually monitor the retrieved articles to ensure all the remaining articles (after the screening process) are in line with the criteria. This process was done by reading the title and abstract of the articles. This process excluded 16 articles focusing on physics education rather english education or computer science of education. This process also focusing on teachers or students using technologies at all levels of educations. Overall, there were only 21 articles selected for further analysis.

Data Analysis

The identified papers were systematically evaluated based on the scope of the review. The analysis began with screening the abstracts to determine their relevance, followed by a full reading of each article to address the four research questions. Each abstract was assessed for its theoretical clarity and its contribution to the discussion on technology use in physics education. A qualitative analysis was then conducted using *NVivo* to identify themes related to the physics topics investigated, the types of technologies employed, the educational levels involved, and the existing research gaps, particularly at the pre-university or matriculation level. The results generated from *NVivo* were exported into an *Excel* spreadsheet structured according to the defined parameters: physics topics, types of technology, educational level, research design, and the strengths and gaps related to the use of technology in the teaching of physics.

Results

From the systematic analysis of educational research published between 2015 and 2025 on the use of technology (e.g., AR, VR, simulations, mobile applications) in the teaching and learning of physics across different educational levels, a total of 21 selected empirical studies were identified and used as the basis for the review. These studies formed the foundation for analysing the patterns of physics topics addressed, the types of technologies applied, the levels of education involved, and the existing gaps in current research. The list of articles included in this review is presented in Table 3.

Table 3
List of the 21 selected articles reviewed in this study.

No	Authors and year	Title	Context	Topics
1.	Abdulayeva et al., 2025	The Role of Artificial Intelligence (AI) in Personalised Physics Education	Secondary school (Grade 10)	General physics concepts; AI adaptive learning systems
2.	Chatzidaki et al., 2025	What Makes Digital Learning Effective? Evaluation of a Digital Learning Module about PET	High-school students (Greece & Austria)	Positron Emission Tomography (modern physics); simulations; multimedia learning
3.	Darus et al., 2023	The Development of an Interactive Learning Module for Physics Subject in Post-Secondary Institution: A Need Analysis	Malaysian Matriculation Colleges (8 colleges)	Electromagnetism; conceptual visualisation; smartphone-based interactive modules
4.	Eldy et al., 2025	Gender Differences in Motivation and Problem-Solving in a Physics Course Online Problem-Based Learning	Pre-university (UMS)	Problem-solving in physics; online learning; digital PBL module
5.	Saputri et al., 2025	Improving Problem-Solving Skills through Physics Education Technology-Assisted PBL Electronic Student Worksheets	Lower secondary	Phase changes of matter; PhET simulations; PBL; digital experimentation
6	Shieh et al., 2013	Implementing the Interactive Response System in a High School Physics Context	High school physics classroom	General physics conceptual questions; interactive response system
7.	Tian & Jiang, 2025	Role Adaptation of Malaysian Secondary School Physics Teachers to AI-Assisted Experimental Teaching	Malaysian secondary schools	AI-enhanced experimental teaching; virtual/AI-driven labs; teacher adaptation

No	Authors and year	Title	Context	Topics
8.	Uden et al., 2022	Factors Influencing Students' Attitudes and Readiness towards Active Online Learning in Physics	Labuan Matriculation College	Active online learning; motivation; ICT readiness; digital physics instruction
9.	G Asiksoy, 2023	Effects of Virtual Lab Experiences on Students' Achievement and Perceptions of Learning Physics	First-year engineering students	Virtual labs; simulations; physics laboratory learning; conceptual understanding
10.	Mystakidis et al., 2022	Impact of Virtual Reality Use on the Teaching and Learning of Vectors	First-year engineering students	Vectors in physics; VR visualisation; spatial reasoning in physics
11.	Chen et al., 2020	Developing a Hands-on Activity Using Virtual Reality to Help Students Learn by Doing	10th-grade science/physics students	Energy, electricity, abstract physics concepts; VR-based inquiry/hands-on learning
12.	Drigas & MTL Kontopoulou, 2016	ICTs-based Physics Learning	Review across school to university	Simulations, VR, games; conceptual change; abstract physics representations
13.	Guan et al., 2022a	Optimization of 3D Virtual Reality Technology in High School Physics Direct-Type Teaching	High-school physics	Electricity; mechanics; 3D VR modelling; VR-based experimental demonstration
14.	Gurevych et al., 2021	Using Augmented Reality Technology in Higher Education Institutions	University	AR-enhanced physics visualisation; mobile AR applications; distance learning physics
15.	Laumann, Fischer, et al., 2024	Designing e-learning courses for classroom and distance learning in physics: The role of learning tasks	Middle-school physics	Digital physics learning, task design, engagement, learning outcomes
16.	Odden et al., 2021	Using computational essays to scaffold professional physics practice	University physics	Computational physics, simulations, scientific inquiry, digital modelling
17.	Rizal et al., 2025	Students' Readiness in Using Virtual Reality for Physics Learning	University physics	VR readiness; physics concept visualisation; technology acceptance
18.	Sriadhi et al., 2022	Effectiveness of Augmented Reality-Based Learning Media for Engineering-Physics Teaching	University physics	AR visualisation; engineering-physics concepts; learning outcomes
19.	Guan et al., 2022b	Optimization of 3D Virtual Reality	High-school physics	3D VR modelling; physics

No	Authors and year	Title	Context	Topics
		Technology in High School Physics Direct-Type Teaching		demonstrations; visualisation of abstract concepts
20.	Wong et al., 2024	Evaluations of Virtual and Augmented Reality Technology-Enhanced Learning for Higher Education	University Physics	VR/AR learning environment; immersive physics-related tasks; learning efficiency
21.	Zhang et al., 2023	Design and Implementation of Virtual Laboratories for Higher Education Sustainability	University Physics	VR labs; virtual experiments; digital hands-on learning environment

Research Question 1 (RQ1)
What physics topics are most frequently addressed in technology-enhanced or AR-based learning studies?

Based on the 22 included studies, the physics topics most frequently explored in technology-enhanced and AR/VR-based learning focus on concepts that are abstract, highly visual, and traditionally challenging to teach. The most common topics include electricity and electromagnetism, mechanics (such as vectors, motion, and Newton’s laws), and modern physics concepts like PhET imaging that require 3D conceptualization. Many studies also address virtual laboratory experiments, computational modelling, and simulation-based learning (e.g., PhET) to support understanding of dynamic processes and microscopic phenomena. Overall, topics that demand spatial reasoning, dynamic visualisation, or high-risk/complex laboratory setups appear most frequently because AR/VR and other digital tools provide clearer, more interactive representations than conventional teaching methods.

Research Question 2 (RQ2)
What types of technologies (e.g., AR, VR, simulations, mobile applications) are commonly used in the teaching and learning of physics?

Across the reviewed studies, the teaching and learning of physics commonly utilise a range of digital and immersive technologies designed to enhance visualisation, interactivity, and conceptual understanding. The most frequently used technologies are virtual reality (VR) for immersive 3D exploration of abstract concepts and laboratory environments, and augmented reality (AR) for overlaying digital objects onto real-world settings to support visualisation of invisible or microscopic phenomena.

Simulation tools, particularly platforms like PhET and custom-developed interactive modules, are also widely used to model dynamic physical processes safely and repeatedly. In addition, several studies employ mobile applications, digital learning modules, virtual laboratories, and AI-assisted systems to personalise learning, support experimentation, and improve accessibility. Overall, VR, AR, and physics simulations emerge as the dominant technological approaches, supplemented by mobile and web-based platforms that extend learning beyond the traditional classroom.

Research Question 3 (RQ3)

At which educational levels (secondary, pre-university, or university) are these studies most often conducted?

Across the analysed studies, technology-enhanced and AR/VR-based physics learning is most frequently conducted at the university level, particularly within engineering physics, introductory physics, and higher-education STEM courses. A substantial number of studies also focus on the secondary school level, especially for topics like mechanics, electricity, and abstract concepts that benefit from visualisation through AR/VR or simulations. Fewer studies target the pre-university or matriculation level, with only a small number of papers addressing Malaysian matriculation or equivalent post-secondary cohorts. Overall, the distribution shows a clear dominance of university/undergraduate level implementations, followed by secondary/high school education, with pre-university/matriculation being the least represented in the literature as in Figure 2.

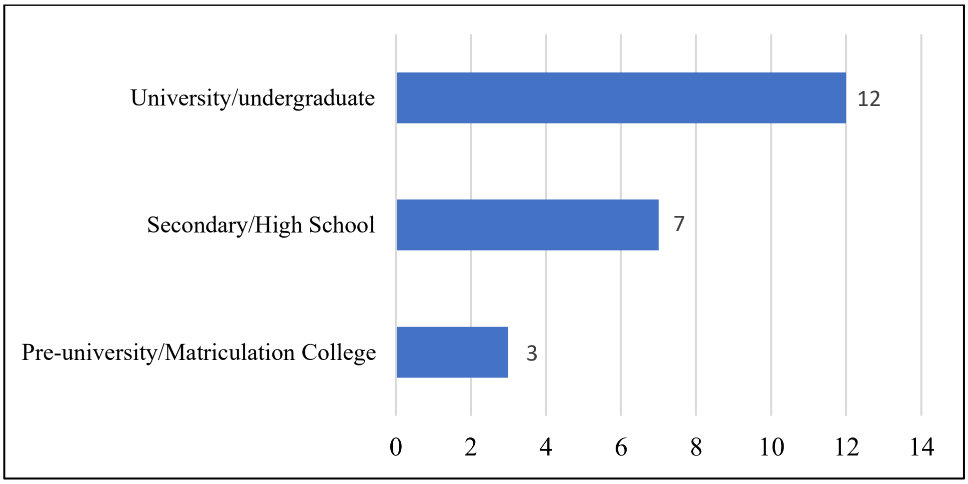

Figure 2 Levels of Education Most Commonly Investigated in Technology-Enhanced Physics Research

Research Question 4 (RQ4)

What research gaps exist regarding the use of technology or AR in teaching physics at the pre-university or matriculation level?

There is a clear lack of focused research on the use of technology, AR, VR, and simulations in pre-university or matriculation physics education. Most existing studies concentrate on secondary or university levels, leaving the pre-university context underexplored. Very few investigations examine how these technologies can strengthen conceptual understanding, support inquiry learning, or enhance virtual laboratory experiences for matriculation students. Research also seldom addresses issues related to curriculum alignment, assessment suitability, or the readiness of teachers and students to adopt these tools in a highly exam-driven environment. Overall, the main gap lies in the absence of context-specific, empirical studies that evaluate the effectiveness and practicality of technology-enhanced approaches for physics learning in matriculation settings.

Discussions

The analysis shows that most technology enhanced physics learning studies are conducted at the university level, indicating that researchers tend to focus on supporting undergraduates who are dealing with more advanced and abstract physics content. At this level, immersive tools such as virtual reality, augmented reality, and complex simulations are often used to help students visualise concepts, explore systems interactively, and experience virtual laboratory environments that may be too costly or risky to conduct physically. This trend also reflects the greater availability of technological facilities and research initiatives in higher education institutions.

A smaller but still meaningful number of studies involve secondary school students. In these settings, technology is commonly used to help learners understand foundational topics such as mechanics, motion, vectors, and electricity. These concepts often require strong spatial reasoning, and digital tools provide clearer visual support than traditional classroom methods. However, the extent of implementation varies across schools, likely due to differences in teacher readiness, infrastructure, and digital access.

Only a limited number of studies focus on the pre-university or matriculation level. Although this stage shares similarities with both secondary and early tertiary physics, it receives far less research attention. There is a clear gap in understanding how digital tools can support the fast paced and exam oriented learning environment typical of matriculation programmes. This underrepresentation highlights the need for future studies that examine how technologies such as virtual reality, augmented reality, and simulations can strengthen conceptual understanding and better prepare students for university level physics.

Conclusion

The overall pattern indicates that university level physics dominates technology enhanced research, showing that most innovations and evaluations are concentrated in higher education settings where resources and research culture are stronger. Secondary school studies appear in a moderate number, mainly to support students in understanding basic but abstract physics concepts through visual and interactive tools. In contrast, the pre-university or matriculation level remains the least represented, suggesting that this stage has not yet received sufficient attention from researchers despite its crucial role in preparing students for tertiary physics learning. This distribution clearly highlights the need for more focused and context specific studies at the pre-university level to ensure that technological tools can effectively support learners during this transitional academic phase.

Limitation and Future Studies

The review highlights that research on technology enhanced physics learning is heavily concentrated at the university level, with secondary studies appearing moderately and very limited work focusing on the pre-university or matriculation context. This imbalance affects the generalisability of findings and reflects a wider gap in understanding how tools such as virtual reality, augmented reality, simulations, and digital modules can support the fast paced and exam oriented nature of matriculation physics. Although current studies demonstrate the value of immersive and interactive technologies for visualising abstract concepts and enriching laboratory experiences, many provide limited detail on classroom implementation, teacher readiness, and curriculum alignment. Future research should therefore prioritise the pre-university setting by conducting context specific empirical studies, exploring real classroom constraints, strengthening teacher professional development, and evaluating long term learning gains so that technology enhanced approaches can be optimally adapted to support students transitioning into university level physics.

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