International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume: 8 Issue: 30 (June 2026) PP. 556-576

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.gaexcellence.com/ijmoe

SCIENCE TEACHERS' BEHAVIOURAL INTENTION TO USE METAVERSE-BASED LEARNING PLATFORMS: A CONCEPTUAL PAPER

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Article Info:

Article history:
Received date: 27.04.2026
Revised date: 11.05.2026
Accepted date: 01.06.2026
Published date: 24.06.2026

To cite this document:

Wider, C., Lay, Y. F., & Shaafi, N. F. (2026). Science Teachers' Behavioural Intention to Use Metaverse-Based Learning Platforms: A Conceptual Paper. *International Journal of Modern Education, 8*(30), 556-576.

Abstract:

The emergence of metaverse-based learning platforms has introduced new possibilities for immersive, interactive, and collaborative science education. These environments are particularly relevant to science teaching because they can support the visualisation of abstract or invisible scientific phenomena, virtual experimentation, inquiry-based learning, and STEM interaction. However, existing research on educational metaverse adoption has focused mainly on student users and general technology acceptance models, with limited attention to science teachers as pedagogical decision-makers who determine whether such platforms are instructionally useful and practically manageable. This concept paper proposes a framework to explain science teachers' behavioural intention to use metaverse-based learning platforms. Using a conceptual synthesis approach, the paper integrates literature on technology readiness, technology self-efficacy, and technology acceptance. The framework incorporates optimism and innovativeness as positive dimensions of the Technology Readiness Index, together with technology self-efficacy, perceived usefulness, and perceived ease of use. By integrating the Technology Readiness Index, Social Cognitive Theory, and the Technology Acceptance Model, the framework explains how teachers' readiness and confidence may shape their perceptions of usefulness and ease of use, which subsequently influence behavioural intention. Rather than merely applying TAM to a new technological context, this paper extends TAM by theorising the antecedent roles of teachers' technology readiness and self-efficacy in shaping acceptance beliefs toward immersive science learning

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume: 8 Issue: 30 (June 2026) PP. 556-576

environments. The framework also offers practical implications for teacher preparation, platform design, and policy planning related to metaverse-supported science education.

DOI: 10.35631/IJMOE.830036

Keyword:

Behavioural Intention; Innovativeness; Metaverse-Based Learning Platforms; Optimism; Perceived Ease of Use; Perceived Usefulness; Science Teachers; Technology Readiness; Technology Self-Efficacy

Introduction

Immersive digital technologies have increasingly transformed the design, delivery, and experience of teaching and learning by enabling more interactive, experiential, and spatially mediated learning environments (Onu et al., 2024; Damaševičius & Sidekerskienė, 2024; Zhong et al., 2026). Among these technologies, the metaverse has gained growing attention in education because it enables users to interact in virtual environments through avatars, simulations, digital objects, three-dimensional spaces, and collaborative learning activities (Chen et al., 2023; Damaševičius & Sidekerskienė, 2024; Li & Chen, 2025). Unlike conventional online learning platforms, metaverse-based learning environments offer more immersive, interactive, and experiential forms of learning that can support simulation, exploration, collaboration, co-creation, and learner engagement (Onu et al., 2024; Al-Adwan & Al-Debei, 2024; Wang et al., 2025). In educational contexts, the value of the metaverse lies not merely in its technological novelty but in its potential to create learning experiences that are difficult to achieve through traditional classroom methods.

This potential is especially pertinent in the field of science education. Many scientific concepts are abstract, microscopic, dynamic, or difficult to demonstrate directly in ordinary classroom settings (Reeves & Crippen, 2020). Concepts such as atomic structure, electricity, chemical reactions, human anatomy, ecosystems, forces, and astronomical phenomena often require visualisation, experimentation, manipulation, and repeated observation to support meaningful understanding. Virtual laboratories, simulations, and immersive environments may allow students to observe, manipulate, and explore scientific phenomena in ways that are safer, more flexible, and more accessible than physical classroom settings alone (Dyrberg et al., 2017; Reeves & Crippen, 2020; Chen & Huang, 2024; Boettcher & Terkowsky, 2026). When learners are provided with meaningful interaction, immediate feedback, and opportunities for exploration, immersive learning environments can also foster both cognitive and affective engagement (Makransky & Lilleholt, 2018; Makransky & Petersen, 2021; Di Natale et al., 2020; Zhong et al., 2026). Therefore, science education represents a distinctive context for metaverse adoption because science teaching depends heavily on inquiry, laboratory simulation, STEM interaction, and visual representation of concepts that cannot always be observed directly (Rutten et al., 2012; de Jong et al., 2013; Chen et al., 2023; Chen & Huang, 2024).

Despite these pedagogical possibilities, the successful implementation of metaverse-based learning depends heavily on teachers. Teachers are not merely users of educational technology; rather, they are instructional decision-makers who determine whether, when, and how digital tools are integrated into teaching practice (Ertmer, 1999; Ertmer, 2005; Ertmer et al., 2012). Previous research on educational technology integration has shown that teachers' beliefs, confidence, perceived value, and perceptions play important roles in technology adoption (Ertmer, 2005; Ertmer et al., 2012; Scherer et al., 2019). Even when technologies are available, teachers may not adopt them if they do not perceive the tools as useful, easy to use, manageable, or suitable for classroom needs. This argument is consistent with technology acceptance research, which emphasises the role of perceived usefulness, perceived ease of use, enjoyment, innovativeness, and related beliefs in shaping users' intention to adopt educational technologies (Scherer et al., 2019; Al-Adwan & Al-Debei, 2024; Al-Adwan et al., 2024; Maghaydah et al., 2024; Oh et al., 2025).

The issue is especially important in the Malaysian science education context. Digital education transformation is reshaping the landscape of teaching and learning in Malaysia, while immersive technologies such as virtual reality, augmented reality, artificial intelligence, and the metaverse have the potential to enrich science learning through simulations, three-dimensional visualisations, collaborative virtual spaces, and interactive environments. The Malaysian Digital Education Policy emphasises the development of digitally fluent students, quality digital content, infrastructure, teacher competence, and digitally empowered education leadership (Ministry of Education Malaysia, 2023). However, the pedagogical potential of the metaverse can only be realised if science teachers possess the readiness, competence, and positive behavioural intention to integrate it meaningfully into teaching and learning.

Nevertheless, evidence suggests that the use of digital technology among Malaysian science teachers remains limited. The Malaysian Digital Education Policy Report indicated that the use of computers in science teaching and learning remains low, with 82% of science teachers in Malaysia almost never or never using computers during teaching and learning activities (Ministry of Education Malaysia, 2023). In addition, Malaysian teachers' digital competency levels were also reported to be relatively low, with only 2.2% of teachers achieving the advanced competency level, while 57.9% remained at the basic level (Ministry of Education Malaysia, 2023). These findings suggest that teachers' current level of digital competence and technology integration may still be insufficient to support the implementation of more advanced immersive technologies such as metaverse-based learning platforms.

Using the metaverse in science teaching and learning requires more than basic technological familiarity. Science teachers need to design immersive learning activities, manage student interactions in virtual environments, guide students through simulations, select scientifically accurate three-dimensional content, and evaluate whether virtual experiments support scientific inquiry rather than function merely as attractive digital displays (Thohir et al., 2023; Roy et al.,

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EISSN: 2637-0905
Volume: 8 Issue: 30 (June 2026) PP. 556-576
2023; Maghaydah et al., 2024; Chen & Huang, 2024). Therefore, science teachers' behavioural intention to use metaverse-based learning platforms is an important area of conceptual and empirical investigation. Behavioural intention is widely recognised in technology acceptance research as a key indicator of whether individuals are likely to adopt a particular system or behaviour in the future (Davis, 1989; Ajzen, 1991; Scherer et al., 2019; Al-Adwan & Al-Debei, 2024; Al-Adwan et al., 2024; Ibili et al., 2023).

Although studies on metaverse adoption in education are growing, several limitations remain in the existing literature. Many studies have focused on student users, particularly university students, and have commonly framed adoption through general technology acceptance models such as TAM and UTAUT (Al-Adwan & Al-Debei, 2024; Al-Adwan et al., 2024; Alfaisal et al., 2024; Xie et al., 2025; Alzahrani & Alzahrani, 2026). However, learner-centred studies do not fully explain the adoption decisions of teachers, who are responsible for designing, facilitating, and evaluating technology-supported instruction. Recent educator-focused studies suggest that perceived usefulness, perceived ease of use, readiness, institutional support, knowledge management, and willingness to engage in immersive classes are important in explaining metaverse acceptance among educators and academics (Abdulmuhsin et al., 2025; Bhat et al., 2026; Mehta et al., 2026). Nevertheless, previous studies that integrate teachers' technology readiness, technology self-efficacy, and TAM-based acceptance beliefs in explaining intention to use metaverse-based learning platforms remain scarce, particularly in school science education contexts (Maghaydah et al., 2024; Xie et al., 2025). This gap is important because science teachers must evaluate not only whether metaverse-based platforms are technologically usable, but also whether they are pedagogically useful, scientifically accurate, and manageable for actual science instruction.

Therefore, this concept paper proposes a teacher-centred conceptual framework to explain science teachers' behavioural intention to use metaverse-based learning platforms. The framework integrates optimism and innovativeness as positive dimensions of technology readiness, technology self-efficacy, perceived usefulness, and perceived ease of use. The novelty of the proposed framework lies in its combination of dispositional readiness, capability belief, and acceptance beliefs to explain how science teachers evaluate metaverse-based learning platforms before intending to use them in science teaching. Specifically, the proposed model suggests that optimism, innovativeness, and technology self-efficacy influence science teachers perceived usefulness and perceived ease of use, which subsequently influence their behavioural intention to use metaverse-based learning platforms in science teaching.

Literature Review

Metaverse-Based Learning Platforms in Science Education

Metaverse-based learning platforms can be understood as immersive digital environments that allow users to interact with virtual objects, simulations, avatars, and other users in shared digital spaces (Chen et al., 2023; Damaševičius & Sidekerskienė, 2024; Onu et al., 2024). These platforms differ from conventional learning management systems because they extend beyond static text, video, or online discussion. Instead, they offer spatial, interactive, and experiential learning opportunities that can support active participation, exploration, collaboration, and simulated practice (Chua & Yu, 2024; Onu et al., 2024; Samala et al., 2024; Zhong et al., 2026). In this concept paper, the term refers specifically to immersive educational environments that

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EISSN: 2637-0905
Volume: 8 Issue: 30 (June 2026) PP. 556-576
can be used to support science teaching and learning through virtual experimentation, simulation, and collaborative inquiry.

In science education, immersive platforms may provide meaningful opportunities to address some limitations of conventional classroom instruction. Science learning often requires students to understand phenomena that are difficult to observe directly, such as microscopic structures, chemical reactions, energy transfer, planetary movements, and biological systems. Virtual and immersive environments can help students visualise difficult-to-observe phenomena and engage with scientific concepts through simulation-based activities (Chen & Huang, 2024; Cook et al., 2025; Zhong et al., 2026). For example, virtual laboratories may allow students to explore abstract or microscopic topics, repeat procedures, receive guidance and feedback, and engage in safer and more flexible science learning environments (Boettcher & Terkowsky, 2026; Pribadi et al., 2024; Samala et al., 2024). These affordances indicate that science education is a pertinent context for investigating teachers' adoption of metaverse technologies, particularly in the context of immersive simulations that facilitate experiential learning, inquiry, collaboration, and visualisation (Chen & Huang, 2024; Damaševičius & Sidekerskienė, 2024; Zhong et al., 2026).

The nature of science learning itself is also closely linked to the potential of metaverse-based learning platforms. Science education often emphasises inquiry, experimentation, observation, and conceptual explanation. Metaverse-based and related immersive learning environments may support these processes by enabling students to conduct virtual experiments, manipulate variables, explore scientific models, and collaborate with peers in simulated environments (Chen & Huang, 2024; Hamidani et al., 2025; Wang et al., 2025). Such opportunities may increase students' engagement and support conceptual understanding when they are guided by appropriate pedagogical design and teacher facilitation (Onu et al., 2024; Damaševičius & Sidekerskienė, 2024; Zhong et al., 2026). Thus, the educational value of immersive environments depends on how teachers transform technological affordances into purposeful science learning tasks.

However, the value of metaverse-based learning platforms cannot be separated from teacher acceptance. Even when a platform has strong technological affordances, it may not be meaningfully implemented unless teachers perceive it as suitable, useful, and manageable for their teaching needs (Chua & Yu, 2024; Maghaydah et al., 2024; Abdulmuhsin et al., 2025). Science teachers, therefore, constitute a theoretically and practically significant user group because they make pedagogical decisions about how immersive platform features are translated into students' science learning experiences (Chen & Huang, 2024; Onu et al., 2024; Mehta et al., 2026). Understanding science teachers' intention to use metaverse-based learning platforms is important to ensure that immersive technologies are not treated merely as technological innovations but as pedagogical tools that require teacher readiness, confidence, competence, and acceptance (Chua & Yu, 2024; Oh et al., 2025; Mehta et al., 2026).

Science Teachers and Technology Integration

Science teachers play a central role in integrating technology into science education. They are responsible for selecting appropriate learning tools, designing classroom activities, guiding students' learning experiences, and ensuring that technology use supports curriculum goals and scientific inquiry (Aidoo, 2023; Thohir et al., 2023; Phillips et al., 2025). In technologically rich environments, teachers must also manage technical, pedagogical, and classroom-related challenges, including limited resources, time constraints, assessment design, student engagement, and alignment between digital tools and intended learning outcomes (Aidoo, 2023; Sambo et al., 2025; Zhong et al., 2026). Their acceptance decisions are therefore tied not only to personal preference but also to curriculum alignment, classroom management, assessment demands, and the integrity of science learning activities (Chua & Yu, 2024; Wang et al., 2025; Mehta et al., 2026).

Teacher technology integration is influenced by both external and internal factors. External factors include access to infrastructure, technical support, training, and institutional policies, while internal factors include teacher beliefs, confidence, readiness, self-efficacy, and perceptions of usefulness (Ertmer, 1999; Ertmer, 2005; Scherer et al., 2019). Internal factors are often important because teachers may still avoid technology use even when technological infrastructure is available (Ertmer, 2005; Scherer et al., 2019). For emerging immersive technologies, these internal factors may be even more influential because teachers must make adoption decisions under conditions of novelty, uncertainty, and limited classroom precedent (Chua & Yu, 2024; Maghaydah et al., 2024; Zhong et al., 2026).

When integrating immersive learning platforms into science teaching, science teachers may face additional challenges. They may need to learn how to operate immersive platforms, organise virtual activities, manage student interactions in digital spaces, and evaluate whether virtual experiences support learning objectives (Chua & Yu, 2024; Maghaydah et al., 2024; Mehta et al., 2026). These demands make perceived usefulness and perceived ease of use highly context-specific, because a technically impressive platform may still be rejected if it is difficult to manage during inquiry activities or misaligned with science curriculum requirements (Scherer et al., 2019; Thohir et al., 2023; Oh et al., 2025). Consequently, teachers' perceptions of metaverse-based learning platforms may depend not only on the platforms' technological features but also on their pedagogical fit, usability, classroom manageability, and relevance to science teaching (Chua & Yu, 2024; Abdulmuhsin et al., 2025; Mehta et al., 2026).

Therefore, a teacher-centred framework is needed to explain science teachers' behavioural intention to use metaverse-based learning platforms. Such a framework should consider not only acceptance beliefs such as perceived usefulness and perceived ease of use but also teachers' technology-related dispositions, readiness, and confidence. The present paper, therefore, treats science teachers not as generic technology users but as pedagogical decision-makers whose readiness and self-efficacy shape how they interpret the instructional value and usability of immersive educational technologies (Scherer et al., 2019; Thohir et al., 2023; Chua & Yu, 2024; Maghaydah et al., 2024).

Technology Readiness: Optimism and Innovativeness

Technology readiness refers to an individual's tendency or preparedness to embrace and use new technologies (Parasuraman, 2000). The Technology Readiness Index identifies four dimensions of technology readiness: optimism, innovativeness, discomfort, and insecurity (Parasuraman, 2000). Later, Parasuraman and Colby (2015) refined the model through TRI 2.0. In this concept paper, only the two positive dimensions of technology readiness, namely optimism and innovativeness, are included because they represent enabling dispositions toward technology use. This focus is consistent with the purpose of the framework, which is to explain how positive readiness dispositions may shape teachers' acceptance beliefs toward metaverse-supported science instruction. Recent studies that integrate technology readiness with technology acceptance continue to show that optimism and innovativeness are important enabling factors in users' acceptance of educational technologies (Kampa, 2023; Çeşme & Akdağ Çimen, 2026).

Optimism refers to a positive view of technology and the belief that technology can improve control, flexibility, and effectiveness (Parasuraman, 2000; Parasuraman & Colby, 2015). Previous studies integrating technology readiness with technology acceptance suggest that optimism can positively influence users' perceptions of technological usefulness and ease of use (Kampa, 2023; Çeşme & Akdağ Çimen, 2026). Therefore, science teachers who are optimistic may be more likely to recognise the instructional benefits of metaverse-based learning platforms, including virtual laboratories, simulations, and three-dimensional representations that can support science visualisation and exploration (Chen et al., 2023; Chen & Huang, 2024; Damaševičius & Sidekerskienė, 2024).

Innovativeness refers to an individual's tendency to try new technologies and act as a technology pioneer (Parasuraman, 2000; Parasuraman & Colby, 2015). Innovative science teachers may be more willing to explore metaverse-based learning platforms, test virtual laboratories, experiment with immersive simulations, and adapt their teaching strategies to new digital environments (Agarwal & Prasad, 1998; Al-Adwan & Al-Debei, 2024; Kampa, 2023). Personal innovativeness has been recognised as an important factor in technology adoption because innovative users are more likely to explore unfamiliar systems and identify their potential value (Agarwal & Prasad, 1998). For science teaching, innovativeness may be particularly relevant because immersive technologies remain emerging in educational practice and require teachers to evaluate their pedagogical fit before classroom integration (Chua & Yu, 2024; Maghaydah et al., 2024; Oh et al., 2025).

Previous studies have continued to support the integration of technology readiness with technology acceptance. The Technology Readiness and Acceptance Model remains useful for explaining how users' readiness influences perceived usefulness, perceived ease of use, and intention to use technology (Lin et al., 2007; Kampa, 2023). In an educational technology context, Kampa (2023) found that optimism positively influenced perceived usefulness and perceived ease of use in mobile learning acceptance, while innovativeness influenced perceived ease of use but not perceived usefulness. Çeşme and Akdağ Çimen (2026) similarly showed that optimism and innovativeness positively influenced TAM-related acceptance and that TAM mediated the relationship between technology readiness and teachers' intention to use online education. Collectively, these studies support the present framework by suggesting that positive readiness dispositions can function as antecedent conditions that shape later acceptance beliefs. In the context of metaverse-based learning platforms, this means that science teachers' optimism and innovativeness may shape how they evaluate the usefulness, ease of use, and instructional value of immersive technologies before forming behavioural intention to use them (Maghaydah et al., 2024; Chua & Yu, 2024; Oh et al., 2025).

Technology Self-Efficacy

Technology self-efficacy refers to an individual's belief in their ability to use technology successfully. The concept is rooted in Social Cognitive Theory, which explains that individuals' beliefs about their capabilities influence their choices, effort, persistence, and behaviour (Bandura, 1997). In technology contexts, computer self-efficacy has been used to explain users' confidence in performing technology-related tasks (Compeau & Higgins, 1995). From this perspective, self-efficacy is not simply a measure of technical skill; it is a capability belief that influences whether teachers approach or avoid challenging technology-mediated teaching tasks.

In this concept paper, technology self-efficacy refers to science teachers' confidence in their ability to use metaverse-based learning platforms for teaching. This includes confidence in navigating immersive environments, operating platform tools, managing virtual learning activities, guiding students during simulations, and using metaverse features for science instruction. Recent research on immersive and metaverse-related educational technologies suggests that teachers' or learners' confidence in using these technologies is important because immersive environments require both technical operation and pedagogical orchestration (Nikou, 2024; Al-Adwan et al., 2025; Zhong et al., 2026). Teachers with high technology self-efficacy may be more willing to explore unfamiliar platforms and overcome technical difficulties, whereas teachers with low technology self-efficacy may perceive metaverse-based learning platforms as difficult, risky, or burdensome (Scherer et al., 2019; Nikou, 2024; Alzahrani & Alzahrani, 2026). Because immersive science teaching involves both technical operation and pedagogical orchestration, technology self-efficacy is expected to influence how manageable and useful teachers perceive these platforms to be (Scherer et al., 2019; Al-Adwan et al., 2025; Bhat et al., 2026).

Previous studies have indicated that technology-specific self-efficacy is important in technology acceptance. Computer self-efficacy explains users' confidence in performing technology-related tasks, which may influence how they evaluate and use digital systems (Compeau & Higgins, 1995). In immersive technology contexts, Nikou (2024) found that mobile self-efficacy predicted perceived ease of use among student teachers intending to use mobile augmented reality in primary science teaching. In the context of metaverse-based learning platforms, Al-Adwan et al. (2025) reported that teachers' Eduverse/metaverse-related self-efficacy was associated with perceived usefulness and adoption intention, while Alzahrani and Alzahrani (2026) found that self-efficacy significantly influenced perceived usefulness, perceived ease of use, and intention to use a metaverse collaborative platform. Similarly, Bhat et al. (2026) examined metaverse-based educational technology adoption through an extended TAM model that included self-efficacy, perceived usefulness, perceived ease of use, enjoyment, and behavioural intention. These findings justify positioning technology self-efficacy as a teacher capability factor that precedes TAM-based evaluations in the proposed framework. Accordingly, technology self-efficacy is proposed as an antecedent of perceived usefulness and perceived ease of use in the present framework.

Perceived Usefulness and Perceived Ease of Use

The Technology Acceptance Model (TAM) is one of the most widely used models for explaining users' acceptance of technology. Davis (1989) proposed that perceived usefulness and perceived ease of use are key determinants of technology acceptance. Perceived usefulness refers to the extent to which an individual believes that using a system will improve performance, while perceived ease of use refers to the extent to which an individual believes that using a system will be free of effort (Davis, 1989). Subsequent research has frequently extended TAM by incorporating external variables such as technology readiness, self-efficacy, and personal innovativeness to explain technology adoption more comprehensively (Lin et al., 2007; Scherer et al., 2019; Kampa, 2023; Nikou, 2024; Çeşme & Akdağ Çimen, 2026). In metaverse and immersive education contexts, recent studies also show that perceived

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EISSN: 2637-0905
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usefulness, perceived ease of use, self-efficacy, personal innovativeness, and related acceptance beliefs are important in explaining users' intention to adopt metaverse-based educational technologies (Al-Adwan & Al-Debei, 2024; Maghaydah et al., 2024; Alzahrani & Alzahrani, 2026; Bhat et al., 2026). In this framework, TAM is not used as a standalone model; rather, it functions as the acceptance mechanism through which teachers' readiness and self-efficacy are translated into behavioural intention.

In this concept paper, perceived usefulness refers to science teachers' belief that metaverse-based learning platforms can improve science teaching effectiveness (Davis, 1989; Scherer et al., 2019). A science teacher may perceive a metaverse platform as useful if it helps students visualise abstract science concepts, conduct virtual experiments, actively participate in learning, collaborate with peers, or understand scientific processes more meaningfully (Chen et al., 2023; Chen & Huang, 2024; Damaševičius & Sidekerskienė, 2024; Zhong et al., 2026). Perceived usefulness is therefore conceptualised in pedagogical rather than merely technical terms, because the key issue is whether immersive tools enhance the teaching and learning of science.

Perceived ease of use refers to science teachers' belief that metaverse-based learning platforms are easy to learn, navigate, and operate (Davis, 1989; Chua & Yu, 2024). A platform may be perceived as easy to use if teachers can understand its interface, prepare activities efficiently, guide students effectively, and manage lessons without excessive technical difficulties (Scherer et al., 2019; Nikou, 2024; Alzahrani & Alzahrani, 2026). This construct is especially important for science teachers because the perceived effort of managing immersive lessons may affect whether they are willing to adopt virtual laboratories and simulation-based activities in real classroom conditions. Recent metaverse education studies further suggest that perceived ease of use remains central in shaping intention to use immersive and collaborative digital platforms (Maghaydah et al., 2024; Bhat et al., 2026).

Previous research has supported the relevance of TAM in teacher technology adoption. The present framework extends this line of research by linking TAM beliefs to teachers' technology readiness and self-efficacy in the specific context of science education. Therefore, the proposed framework includes perceived usefulness and perceived ease of use as central acceptance beliefs through which science teachers evaluate whether metaverse-based learning platforms are instructionally valuable and practically manageable.

Behavioural Intention to Use Metaverse-Based Learning Platforms

Behavioural intention refers to an individual's willingness or plan to perform a particular behaviour (Ajzen, 1991). In technology acceptance research, behavioural intention is commonly used as an indicator of future technology use because it reflects users' motivational readiness to engage with a system before actual use becomes routine (Davis, 1989; Ajzen, 1991; Scherer et al., 2019). In this concept paper, behavioural intention refers to science teachers' intention to use metaverse-based learning platforms in science teaching. This intention is important because emerging technologies often enter classrooms gradually, beginning with teachers' willingness to experiment before moving toward sustained integration. Recent metaverse education studies similarly position behavioural intention as a key outcome for understanding early-stage adoption of immersive educational technologies (Al-Adwan & Al-Debei, 2024; Maghaydah et al., 2024; Bhat et al., 2026).

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Science teachers' behavioural intention may be reflected through their willingness to try metaverse-based learning platforms, integrate them into science lessons, use them for virtual experiments, participate in training, or recommend them to colleagues (Ajzen, 1991; Davis, 1989; Scherer et al., 2019). Behavioural intention is important because the adoption of emerging educational technologies often begins with teachers' willingness to explore and experiment before actual implementation becomes routine (Scherer et al., 2019; Chua & Yu, 2024; Maghaydah et al., 2024). For this reason, intention is treated as a meaningful outcome variable for conceptualising early-stage adoption of metaverse technologies in science education (Al-Adwan & Al-Debei, 2024; Al-Adwan et al., 2025; Bhat et al., 2026; Xie et al., 2026).

Teachers' perceptions of usefulness and ease of use shape their behavioural intention to use immersive platforms in science teaching (Davis, 1989; Scherer et al., 2019). If science teachers believe that metaverse-based platforms can improve teaching and are manageable in real classroom contexts, they may be more likely to intend to use them. Recent studies on metaverse-based educational technologies show that perceived usefulness, perceived ease of use, self-efficacy, innovativeness, and related acceptance beliefs are associated with users' intention to adopt metaverse or immersive learning systems (Al-Adwan & Al-Debei, 2024; Alzahrani & Alzahrani, 2026; Bhat et al., 2026; Mehta et al., 2026). Conversely, weak perceptions of usefulness or usability may reduce adoption intention even when schools provide technological access (Scherer et al., 2019; Maghaydah et al., 2024). Therefore, perceived usefulness and perceived ease of use are proposed as direct predictors of behavioural intention in the present conceptual framework (Davis, 1989; Scherer et al., 2019; Bhat et al., 2026).

Theoretical Foundation

This concept paper is grounded in three theoretical perspectives: Technology Readiness Index (TRI) (Parasuraman, 2000; Parasuraman & Colby, 2015), Social Cognitive Theory (Bandura, 1997), and the Technology Acceptance Model (Davis, 1989). These perspectives collectively explain science teachers' technology-related dispositions, confidence, and acceptance beliefs toward metaverse-based learning platforms. Rather than treating the variables separately, the framework links these theories in an explanatory sequence in which technology readiness and technology self-efficacy represent antecedent teacher characteristics, perceived usefulness and perceived ease of use represent acceptance beliefs, and behavioural intention represents the expected adoption outcome. This integrated approach is consistent with recent educational technology acceptance studies showing that readiness, self-efficacy, innovativeness, perceived usefulness, perceived ease of use, and behavioural intention are important factors in explaining users' acceptance of emerging digital, immersive, and metaverse-based technologies (Kampa, 2023; Maghaydah et al., 2024; Nikou, 2024; Alzahrani & Alzahrani, 2026; Bhat et al., 2026).

Technology Readiness Index

The Technology Readiness Index (TRI) explains individuals' readiness to embrace and use new technologies (Parasuraman, 2000). It consists of four dimensions, namely optimism, innovativeness, discomfort, and insecurity. Optimism and innovativeness are regarded as positive dimensions that encourage technology use, whereas discomfort and insecurity represent inhibiting dimensions that may discourage users from engaging with new technologies (Parasuraman & Colby, 2015). In this concept paper, optimism and

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innovativeness are selected because the framework focuses on positive teacher-related dispositions that may shape acceptance beliefs. These two dimensions are theoretically important because they explain why some teachers may approach emerging immersive technologies with a sense of opportunity and experimentation rather than avoidance. This focus is supported by recent studies showing that optimism and innovativeness remain meaningful antecedents in technology readiness and acceptance models, particularly in educational technology contexts (Lin et al., 2007; Kampa, 2023; Çeşme & Akdağ Çimen, 2026).

Optimism is crucial because teachers who hold positive beliefs about technology may be more likely to perceive metaverse-based learning platforms as beneficial and manageable. Kampa (2023) found that optimism positively influenced perceived usefulness and perceived ease of use in mobile learning acceptance, while Çeşme and Akdağ Çimen (2026) showed that optimism positively influenced TAM-related acceptance among teachers. Innovativeness is also crucial because teachers who are willing to try new technologies may be more open to exploring metaverse-based learning platforms, experimenting with immersive simulations, and adapting science instruction to digital learning environments (Agarwal & Prasad, 1998; Al-Adwan & Al-Debei, 2024). Within the proposed framework, these readiness dimensions are positioned as distal antecedents that can shape teachers' judgements about the usefulness and ease of use of immersive science learning environments (Lin et al., 2007; Chua & Yu, 2024; Maghaydah et al., 2024). Therefore, Technology Readiness Index provides the foundation for positioning optimism and innovativeness as antecedents of perceived usefulness and perceived ease of use.

Social Cognitive Theory

Social Cognitive Theory explains how individuals' beliefs about their capabilities influence their behaviour (Bandura, 1997). Self-efficacy is a central concept in this theory. Individuals with stronger self-efficacy are more likely to approach challenging tasks, invest effort, and persist when facing difficulties (Bandura, 1997). This theoretical perspective is especially important for science instruction facilitated by the metaverse because teachers may be required to navigate unfamiliar interfaces, manage virtual learning spaces, guide students through simulations, and adapt to novel forms of immersive pedagogy. Recent studies on immersive and metaverse-related educational technologies suggest that teachers' or learners perceived capability to use such tools influences their acceptance of these technologies and their intention to use them for teaching and learning (Nikou, 2024; Al-Adwan et al., 2025; Alzahrani & Alzahrani, 2026; Bhat et al., 2026).

This concept paper uses technology self-efficacy to explain science teachers' confidence in using immersive learning platforms. This confidence is important because these platforms may require teachers to operate unfamiliar tools, manage virtual learning spaces, coordinate student activities, and guide students through immersive science simulations. Accordingly, self-efficacy theory strengthens the framework by explaining how perceived capability can influence teachers' interpretation of both technological difficulty and instructional value. In immersive technology contexts, Nikou (2024) found that mobile self-efficacy was relevant to student teachers' intention to use mobile augmented reality in primary science teaching. In metaverse education contexts, studies have also shown that self-efficacy, perceived usefulness, perceived ease of use, and behavioural intention are important acceptance-related factors (Al-Adwan et al., 2025; Alzahrani & Alzahrani, 2026; Bhat et al., 2026). Therefore, Social Cognitive Theory provides the foundation for positioning technology self-efficacy as an

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antecedent of perceived usefulness and perceived ease of use (Compeau & Higgins, 1995; Scherer et al., 2019; Nikou, 2024).

Technology Acceptance Model

The Technology Acceptance Model provides the foundation for perceived usefulness, perceived ease of use, and behavioural intention (Davis, 1989). According to TAM, users are more likely to accept a technology when they believe it is useful and easy to use (Davis, 1989; Scherer et al., 2019). In the present framework, TAM explains how science teachers' acceptance beliefs may influence their intention to use metaverse-based learning platforms. This is consistent with teacher technology adoption research and recent metaverse-based learning acceptance studies showing that perceived usefulness, perceived ease of use, self-efficacy, perceived interactivity, enjoyment, readiness, and related factors influence users' intention to adopt immersive educational technologies (Scherer et al., 2019; Maghaydah et al., 2024; Mehta et al., 2026; Bhat et al., 2026). TAM is therefore positioned as the proximal acceptance component of the framework because it explains the evaluative pathway between teacher characteristics and intended use.

Perceived usefulness explains whether science teachers believe metaverse-based platforms can improve science teaching, while perceived ease of use explains whether they believe such platforms are manageable and easy to operate (Davis, 1989; Chua & Yu, 2024). These two acceptance beliefs are proposed to influence behavioural intention (Davis, 1989; Scherer et al., 2019). Recent studies on metaverse-based education similarly show that perceived usefulness and perceived ease of use are important predictors of users' willingness or intention to use metaverse technologies in educational settings (Alzahrani & Alzahrani, 2026; Mehta et al., 2026; Bhat et al., 2026). Therefore, TAM provides the core acceptance structure of the proposed conceptual framework. When integrated with the Technology Readiness Index and Social Cognitive Theory, TAM enables the framework to explain not only what teachers believe about the platform but also why those beliefs may develop (Lin et al., 2007; Kampa, 2023; Çeşme & Akdağ Çimen, 2026).

Together, Technology Readiness Index, Social Cognitive Theory, and TAM provide a comprehensive theoretical basis for explaining science teachers' behavioural intention. Technology readiness explains teachers' positive dispositions toward emerging technologies (Parasuraman, 2000; Parasuraman & Colby, 2015), self-efficacy explains teachers' confidence and perceived capability (Bandura, 1997; Compeau & Higgins, 1995), and TAM explains how usefulness and ease of use shape intention (Davis, 1989). This theoretical integration positions optimism, innovativeness, and technology self-efficacy as distal antecedents, perceived usefulness and perceived ease of use as proximal acceptance beliefs, and behavioural intention as the outcome of the proposed model. Such integration is consistent with recent evidence that extended acceptance models are useful for explaining adoption of mobile learning, augmented reality, online education, and metaverse-based educational technologies (Kampa, 2023; Nikou, 2024; Maghaydah et al., 2024; Çeşme & Akdağ Çimen, 2026; Bhat et al., 2026).

Conceptual Framework

The proposed conceptual framework explains science teachers' behavioural intention to use metaverse-based learning platforms through the relationships among optimism, innovativeness, technology self-efficacy, perceived usefulness, and perceived ease of use. The model is not merely a direct application of the Technology Acceptance Model (TAM); rather,

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it extends TAM by incorporating teachers' technology readiness and capability beliefs as antecedent factors relevant to the adoption of immersive science learning environments. This extension is consistent with recent educational technology acceptance studies showing that technology readiness, optimism, innovativeness, self-efficacy, perceived usefulness, perceived ease of use, and behavioural intention can jointly explain users' acceptance of emerging learning technologies (Kampa, 2023; Nikou, 2024; Çeşme & Akdağ Çimen, 2026). In metaverse-based education, extended TAM studies also show that perceived usefulness, perceived ease of use, self-efficacy, interactivity, enjoyment, and related beliefs are important in explaining users' behavioural intention to adopt immersive learning platforms (Maghaydah et al., 2024; Alzahrani & Alzahrani, 2026; Bhat et al., 2026).

Optimism and innovativeness are positioned as positive dimensions of technology readiness. These two constructs are proposed to influence science teachers' perceived usefulness and perceived ease of use of metaverse-based learning platforms. This assumption is supported by research integrating technology readiness with TAM, where optimism and innovativeness have been shown to shape users' perceptions of usefulness, ease of use, and intention toward educational technologies (Kampa, 2023; Çeşme & Akdağ Çimen, 2026). Technology self-efficacy is also proposed to influence perceived usefulness and perceived ease of use, because teachers who feel confident using immersive technologies may be more likely to view such platforms as manageable and instructionally valuable (Scherer et al., 2019; Nikou, 2024; Al-Adwan et al., 2025). Finally, perceived usefulness and perceived ease of use are proposed to influence behavioural intention, following TAM and recent metaverse education adoption studies (Davis, 1989; Alzahrani & Alzahrani, 2026; Bhat et al., 2026). This structure reflects the assumption that teachers first bring dispositional and capability-related characteristics to the adoption process, then evaluate the instructional value and operational ease of the platform and finally form an intention to use it in science teaching.

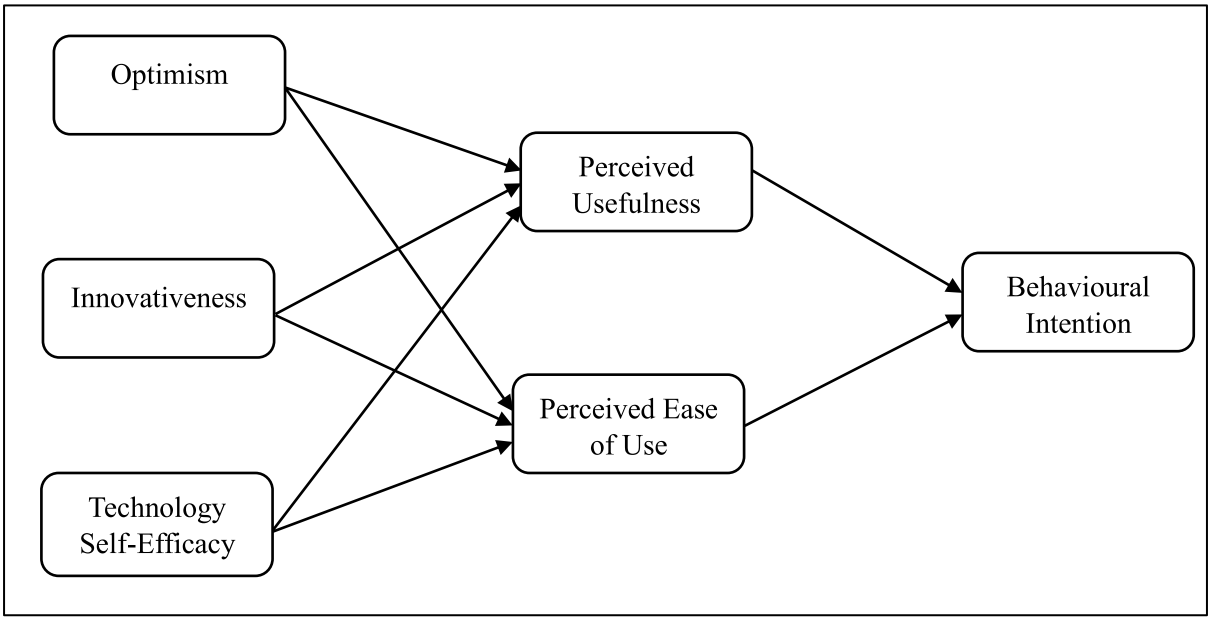

Figure 1: Proposed Conceptual Framework

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As shown in Figure 1, optimism, innovativeness, and technology self-efficacy are proposed as antecedent factors influencing science teachers' perceived usefulness and perceived ease of use of metaverse-based learning platforms. Perceived usefulness and perceived ease of use are positioned as TAM-based belief constructs that directly influence behavioural intention. The framework suggests that teachers' positive technology-related dispositions, together with their confidence in using technology, may shape how they evaluate immersive platforms and whether they intend to use them in science teaching. By linking these constructs, the framework addresses the identified gap by providing a science teacher-centred explanation of metaverse adoption rather than relying solely on a general user acceptance perspective. This teacher-centred positioning is important because metaverse adoption research remains largely student- or higher-education-focused, while teacher readiness, self-efficacy, pedagogical usefulness, and classroom manageability require more specific attention in school science education contexts (Chua & Yu, 2024; Maghaydah et al., 2024; Mehta et al., 2026; Zhong et al., 2026).

Theoretical Contribution

This concept paper makes a theoretical contribution by developing a teacher-centred extension of the Technology Acceptance Model (TAM) for metaverse-supported science education. Existing technology acceptance studies have commonly used TAM and related models to explain users perceived usefulness, perceived ease of use, and behavioural intention toward educational technologies (Davis, 1989; Scherer et al., 2019; Al-Adwan & Al-Debei, 2024; Bhat et al., 2026). However, such models may not fully explain science teachers' adoption of metaverse-based learning platforms because teachers must evaluate not only technological usability but also pedagogical usefulness, classroom manageability, scientific accuracy, and suitability for inquiry-oriented science learning. This concern is consistent with research showing that metaverse and immersive learning adoption is shaped by usefulness, ease of use, readiness, self-efficacy, innovativeness, institutional support, and the perceived instructional value of immersive technologies (Chua & Yu, 2024; Maghaydah et al., 2024; Abdulmuhsin et al., 2025; Mehta et al., 2026). Therefore, this paper extends TAM by incorporating optimism and innovativeness from the Technology Readiness Index and technology self-efficacy from Social Cognitive Theory as antecedent conditions that shape teachers' acceptance beliefs.

The proposed framework contributes to theory by arranging these constructs into a sequential explanatory structure. Optimism and innovativeness represent teachers' positive readiness dispositions toward emerging technologies, while technology self-efficacy represents teachers' perceived capability to use immersive platforms for science teaching (Parasuraman, 2000; Parasuraman & Colby, 2015; Bandura, 1997). These antecedent factors are theorised to influence perceived usefulness and perceived ease of use, which subsequently influence behavioural intention. This structure is supported by recent studies showing that technology readiness, optimism, innovativeness, and self-efficacy can shape TAM-related beliefs and intention to use educational technologies (Kampa, 2023; Nikou, 2024; Çeşme & Akdağ Çimen, 2026). In this way, the framework explains not only whether science teachers may intend to use metaverse-based learning platforms, but also how their readiness and confidence may shape the acceptance beliefs that lead to intention.

The framework also contextualises TAM within science education. Perceived usefulness is conceptualised as teachers' belief that metaverse-based learning platforms can enhance science teaching through visualisation, virtual experimentation, simulation, inquiry learning, collaborative exploration, and STEM interaction. This interpretation is consistent with studies showing that immersive and metaverse-based environments can support simulation, collaboration, experiential learning, and science/STEM-related learning activities (Chen et al., 2023; Chen & Huang, 2024; Damaševičius & Sidekerskienė, 2024; Zhong et al., 2026). Perceived ease of use is conceptualised as teachers' belief that such platforms are manageable for lesson preparation, student guidance, virtual classroom interaction, and science learning activities. This discipline-specific interpretation contributes to technology acceptance research by positioning science teachers not as generic technology users, but as pedagogical decision-makers whose acceptance of immersive technologies depends on both technological and instructional considerations (Ertmer, 2005; Ertmer et al., 2012; Scherer et al., 2019; Mehta et al., 2026).

Practical Implications

The proposed framework has important implications for teacher education, school leadership, platform development, and educational policy. For teacher education programmes, the framework may guide the design of professional development initiatives that strengthen teachers' positive technology readiness and hands-on technology self-efficacy before expecting sustained adoption of metaverse-based learning in science classrooms. This is important because recent studies show that teacher acceptance of immersive or metaverse-related technologies is influenced by perceived usefulness, perceived ease of use, self-efficacy, readiness, and confidence in using digital tools for instruction (Nikou, 2024; Abdulmuhsin et al., 2025; Al-Adwan et al., 2025; Bhat et al., 2026). Professional development should therefore move beyond general digital literacy and provide science teachers with practical experience in designing virtual experiments, facilitating simulations, managing student interactions in immersive environments, and evaluating whether metaverse activities support inquiry-based science learning.

For school leaders, the framework provides a diagnostic tool for understanding why teachers may or may not intend to use metaverse-based learning platforms. Low adoption intention may not simply reflect resistance to technology; it may be linked to limited perceived usefulness, low perceived ease of use, weak technology self-efficacy, insufficient training, or uncertainty about curriculum alignment. This implication is consistent with research showing that technology integration depends on both external conditions such as infrastructure and support, and internal factors such as beliefs, confidence, and perceived value (Ertmer, 1999; Ertmer, 2005; Scherer et al., 2019). In the Malaysian context, where the Digital Education Policy highlights teacher competence, infrastructure, digital content, and digitally empowered leadership, school leaders can use the framework to identify whether teachers need technical support, pedagogical modelling, science-specific digital resources, or confidence-building opportunities (Ministry of Education Malaysia, 2023).

For platform developers, the framework highlights the importance of designing immersive science learning tools that are not only technologically advanced but also pedagogically meaningful and operationally manageable for teachers. Features such as curriculum-aligned virtual experiments, guided simulation templates, intuitive teacher controls, embedded scientific explanations, student-progress dashboards, and classroom management functions may improve teachers' perceptions of usefulness and ease of use. This is important because metaverse-based education research suggests that adoption depends not only on novelty or immersion, but also on whether users perceive the platform as useful, easy to use, supportive of learning, and suitable for the educational task (Maghaydah et al., 2024; Alzahrani &

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Alzahrani, 2026; Bhat et al., 2026). For science education specifically, platform design should support visualisation, experimentation, repeated observation, inquiry, and safe manipulation of phenomena that are difficult to demonstrate in ordinary classrooms (Chen & Huang, 2024; Boettcher & Terkowsky, 2026; Zhong et al., 2026).

For policymakers, the framework suggests that infrastructure provision alone may be insufficient to support meaningful metaverse integration in science education. Effective implementation may also require sustained teacher training, technical support, curriculum alignment, quality digital content, and pedagogical guidance to ensure that metaverse technologies are adopted as purposeful science learning tools rather than isolated digital innovations. This implication aligns with the Malaysian Digital Education Policy's emphasis on teacher competence, infrastructure, digital content, and leadership, but extends it by stressing that advanced immersive technologies require science teachers to develop readiness, confidence, and pedagogical judgement before adoption can become meaningful (Ministry of Education Malaysia, 2023). Policy initiatives should therefore include science-specific metaverse training, exemplar lesson designs, evaluation rubrics for virtual experiments, and support systems that help teachers translate immersive technological affordances into effective science teaching practice.

Conclusion

This concept paper proposed a teacher-centred conceptual framework to explain science teachers' behavioural intention to use metaverse-based learning platforms. The framework integrates optimism and innovativeness as positive dimensions of technology readiness, together with technology self-efficacy, perceived usefulness, and perceived ease of use. By focusing specifically on science teachers, the paper responds to the need for adoption frameworks that recognise the pedagogical demands of science education, including abstract concept visualisation, laboratory simulation, inquiry learning, STEM interaction, and experiential learning.

The proposed model suggests that optimism, innovativeness, and technology self-efficacy influence science teachers' perceptions of the usefulness and ease of use of metaverse-based learning platforms. These acceptance beliefs are subsequently expected to influence behavioural intention. In this way, the framework explains teachers' intention through the combined influence of technology-related dispositions, perceived capability, and TAM-based acceptance beliefs. The model therefore clarifies how positive readiness, and self-efficacy may shape early-stage acceptance of immersive science learning technologies.

The framework contributes to technology acceptance research by positioning teachers' technology readiness and self-efficacy as antecedent factors that shape acceptance beliefs toward immersive science learning environments. It also emphasises the role of science teachers as pedagogical decision-makers whose adoption of immersive technologies depends on both technological and instructional considerations. Practically, the framework provides a conceptual basis for teacher preparation, professional development, platform design, and policy planning related to metaverse-supported science education. Future empirical research may test the proposed framework quantitatively to examine the strength and significance of the proposed relationships among the constructs.

Acknowledgements:	The author would like to express sincere appreciation to the supervisory team and institution for academic guidance and support in the development of this conceptual paper.
Funding Statement:	No Funding

Conflict of Interest Statement:	The author declares no conflict of interest regarding the publication of this paper.
Ethics Statement:	This conceptual paper did not involve human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the manuscript was prepared in accordance with accepted academic integrity and ethical publishing standards.
Author Contribution Statement:	All authors contributed significantly to the development of this manuscript.

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