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Enhancing Cognitive Engagement in Smart Classrooms: A Systematic Review of Educational Technology Integration

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Abstract: The rapid development of educational technology has accelerated the transformation of traditional classrooms into smart learning environments. Despite technological advancements, synthesising how these innovations influence students' cognitive engagement remains underexplored. This systematic review addresses this gap by analysing literature across three intersecting domains: smart classrooms and student engagement, cognitive engagement and educational technology, and educational technology integration in smart classrooms. Grounded in the TPACK (Technological Pedagogical Content Knowledge) and ICAP (Interactive, Constructive, Active, Passive) frameworks, the study investigates pedagogical, content, and technological factors that enhance cognitive engagement. Following PRISMA guidelines, 75 peer-reviewed articles were systematically reviewed. Key findings indicate that pedagogical strategies such as interactive collaboration, teacher-student feedback, self-efficacy, self-regulation, and motivation cultivation significantly elevate cognitive engagement. Content factors, including subject-matter expertise and technology-enhanced resources, are critical for fostering deep learning. Technologically, tools like Learning Management Systems (LMS), Interactive Whiteboards (IWB), AI, and VR support active, constructive, and interactive engagement modes. The integration of TPACK and ICAP offers a robust framework for designing cognitively engaging smart classrooms, emphasizing the alignment of pedagogical intent with technological affordances. Practical guidelines are proposed for educators, instructional designers, and policymakers, advocating for competence-supportive teaching, diversified digital content, and purposeful technology integration. This review underscores the necessity of a holistic approach to smart classroom design, where cognitive engagement emerges from synergistic interactions among pedagogy, content, and technology.

Keywords: Cognitive Engagement, Educational Technology, Smart Classroom

1. Introduction

In recent years, the transformation of traditional classrooms into smart learning environments has been accelerated by advances in educational technology (Yu et al., 2022). The Chinese government has acknowledged the importance of technology in education and has launched many policies to promote technology integration. Nevertheless, practical implementation still needs to match the expectations (Lin Chenhui, 2024). Smart classrooms as a technology integration environment used IoT devices, interactive displays, learning analytics platforms, and adaptive systems, to provide more personalized and engaging learning environments (Sarsar et al., 2023). These developments emerge in response to the growing need for education systems to cultivate deeper forms of student engagement, particularly cognitive engagement, which is closely tied to meaningful learning and academic achievement (Nie Ni, 2024; Zhou, 2024).

However, the simple existence of technology does not ensure effective learning outcomes. Instead, it is the level of students' mental investment, effort regulation, and conceptual processing that determines the efficacy of these environments. Cognitive engagement acts as the bridge between technological affordance and learning performance, making it a key mediating variable for instructional success in smart classrooms (Fredricks et al., 2004; Henrie et al., 2015). Hence, understanding and enhancing cognitive engagement is essential to maximise the educational potential of smart classrooms.

Despite the technological progress and increased implementation of smart classrooms worldwide, there remains a critical gap in synthesising how these innovations affect student cognitive engagement (Ma et al., 2024). While numerous studies examine student engagement from general perspectives or focus on specific technologies (Wang & Xue, 2024), few have systematically integrated findings across domains to highlight how smart classroom technologies directly influence cognitive engagement—the extent to which learners invest in effortful, strategic, and reflective learning processes. This review seeks to address this gap by systematically analysing literature from three intersecting domains:

i. Smart Classrooms and Student Engagement (including the cognitive engagement branch);
ii. Cognitive Engagement and Educational Technology (smart classroom applicable);
iii. Educational Technology (smart classroom applicable) and student engagement (including cognitive engagement branch).

By doing so, it aims to uncover technological, pedagogical, and content factors that contribute to cognitive engagement in smart classrooms under the theoretical function of TPACK framework (Mishra & Koehler, 2006) and ICAP framework (Chi & Wylie, 2014). This study is directed by the research questions as follow:

i. What pedagogical factors can enhance student cognitive engagement in smart classrooms?
ii. What content factors can enhance student cognitive engagement in smart classrooms?
iii. What technological factors can enhance student cognitive engagement in smart classrooms?
iv. What guidelines can enhance student cognitive engagement in smart classrooms?

By answering these questions, the review offers a comprehensive overview of factors on enhancing students' engagement in the smart classroom that contributes both to practical guidelines and academic understanding. Its findings are expected to inform educators seeking to optimize classroom strategies, designers developing educational technologies, and policymakers crafting infrastructure and training programs to support effective technology integration.

2. Literature review

This literature review focuses on the intersection of smart classrooms, cognitive engagement, and educational technology through the lens of the TPACK and ICAP frameworks. It synthesizes current research, identifies theoretical and empirical gaps, and establishes a foundation for developing a comprehensive framework to improve student engagement in smart classroom environments.

2.1 Smart Classroom

Smart classrooms are technologically enhanced learning spaces designed to create interactive, adaptive, and data-driven educational experiences (Dai et al., 2023). Typical features include IoT-enabled devices, real-time analytics, smartboards, automated attendance systems, and sensor-based feedback mechanisms (Alhasan et al., 2023). These environments aim to support personalized learning, seamless teacher-student interaction, and immediate responsiveness to learner needs (Alfoudari et al., 2021). It is noteworthy that the environment of the smart classrooms is characterized by interactivity, which offers significant advantages for students and teachers, particularly in the context of practices, active learning, and educational technology (Al-Sharhan, 2016).

2.2 Cognitive Engagement

Cognitive engagement relates to students' investment in learning, which is characterized by their motivation to exert mental effort and use complex cognitive strategies. It goes beyond behavioural compliance and emotional interest, focusing on deep learning processes such as self-regulation, metacognition, and critical thinking (Fredricks et al., 2004). Key frameworks such as the ICAP model (Chi & Wylie, 2014) distinguish levels of engagement namely: “Interactive, Constructive, Active, and Passive” which provide a robust lens for evaluating how students process information. Existing literature shows that cognitively engaged students are more likely to experience long-term knowledge retention and academic success.

However, there remains a need to examine how learning environments, particularly those infused with technology, facilitate such engagement. For example, the smart classroom context. Cognitive engagement is critical to smart classrooms in both theory and practice. The effective implementation of smart classrooms depends on more than just the integration of technology. It requires ensuring that students are deeply engaged in learning processes. Among the three aspects of engagement namely behavioral, emotional, and cognitive engagement, cognitive engagement is particularly vital in smart classrooms as it determines how actively and meaningfully students process, reflect on, and apply knowledge (Fredricks et al., 2004).

2.3 Educational Technology for Engagement

Educational technology covers a wide range of tools and platforms used to support learning, including LMS, IWB, VR, and intelligent tutoring systems (K. P. Gupta, 2022; N. H. A. Husni et al., 2022; Yinghui Shi et al., 2021). These tools can scaffold complex thinking, offer personalized feedback, and promote active learning. Research indicates that digital technologies can enhance various aspects of student engagement, yet most studies emphasize behavioural outcomes (e.g., participation rates) rather than cognitive processes (Maričić & Lavicza, 2024; Venn et al., 2023). Technologies like adaptive learning platforms and AI-driven content personalization show promise in promoting higher-order thinking skills, but empirical evidence linking them directly to cognitive engagement is still limited (Hao & Razali, 2025).

2.4 Integration of TPACK and ICAP Frameworks

The TPACK framework outlines the areas of knowledge that teachers need to integrate technological, pedagogical and content knowledge to teach effectively with technology(Mishra & Koehler, 2006). In contrast to the mere combination of the three aspects of technology, content, and pedagogy, TPACK represents the dynamic integration of these three aspects and is critical to facilitating the implementation of contextualised, technology-enhanced (TE) instruction by educators(Mishra & Koehler, 2008).

The ICAP theory was originally proposed in 2009 (Chi, 2009) and outlined three cognitive modes of engagement: Active, Constructive, and Interactive. The theory also presented evidence from existing literature to support the prediction that Interactive mode would be the most effective, followed by Constructive and then Active. In 2014, ICAP was further extended to include the Passive mode (Chi & Wylie, 2014).

When the TPACK framework is combined with the ICAP framework, which classifies cognitive engagement levels, educators gain a dual lens for analysing and designing smart classroom interventions. This integration provides a structured approach to examining how teaching strategies (pedagogical knowledge), digital tools (technological knowledge), and subject matter (content knowledge) collectively influence students’ cognitive engagement. Few studies have systematically applied both frameworks in smart classroom research, highlighting an important gap addressed by this review.

2.5 Synthesis of Gaps in Existing Literature

Previous researches tend to examine components of cognitive engagement, educational technology, or smart classrooms in isolation. There is a paucity of integrative reviews that explore their intersection, especially through established theoretical frameworks. Additionally, many studies lack a cognitive engagement focus or fail to consider how technologies are pedagogically implemented. This review addresses these gaps by synthesizing evidence across factors on enhancing students' engagement within smart classrooms and proposing a more comprehensive framework integration for future research and practice.

3. Methodology

This study employs a systematic review method to ensure a transparent, replicable, and comprehensive synthesis of relevant literature. This review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to identify, screen, and analyze sources across selected databases (Moher et al., 2009).

3.1 Research Design

A systematic review design was chosen to aggregate existing research findings related to cognitive engagement, educational technology, and smart classrooms. This method enables the identification of patterns, gaps, and emerging themes from a wide body of literature.

3.2 Search Strategy

Databases searched included Scopus, Web of Science, ProQuest. The integration of these three databases ensures a balanced and comprehensive search strategy, combining the strengths of high-impact journal indexing (Scopus and WoS) with access to broader scholarly and practitioner literature (ProQuest), aligning with the interdisciplinary nature of educational technology research. Full search strings combined Boolean operators and keywords namely : “smart classrooms and student engagement,” or “cognitive engagement and educational technology,” or “educational technology and student engagement”. Searches were refined through title, abstract, and keyword screening.

3.3 Inclusion and Exclusion Criteria

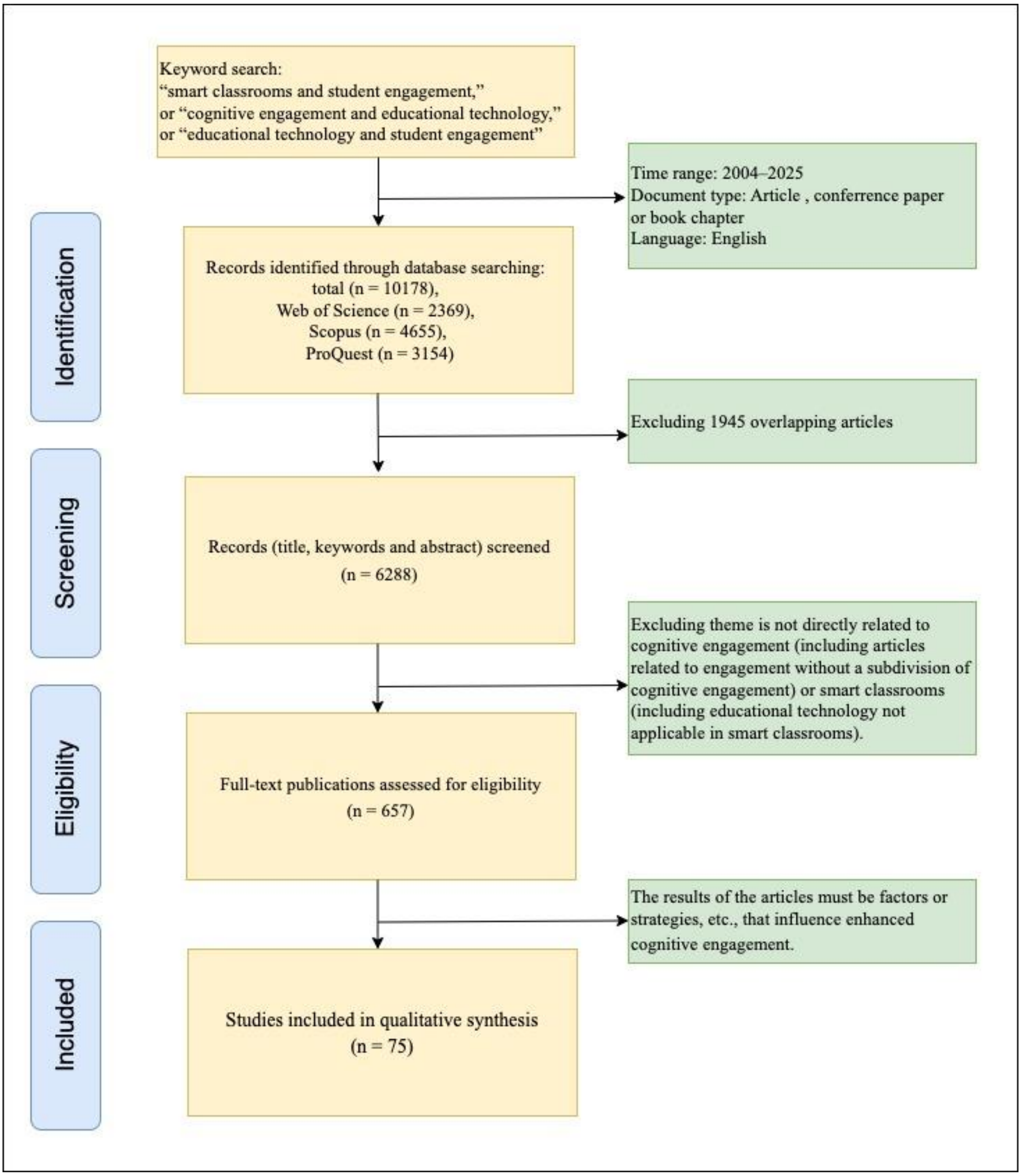
This review included articles published during the period 2004-2025 because the use of cognitive engagement as a branch of engagement accurately began in 2004 (Fredricks et al., 2004). Eligible studies focused on K12 and higher education contexts involving smart classroom technologies and their influence on cognitive engagement. Only articles, conference papers and book chapters written in English and those providing empirical or theoretical insights were included. Excluded materials consisted of conference abstracts, opinion pieces, dissertations, and articles not directly related to cognitive engagement (including articles related to engagement without a subdivision of cognitive engagement) or smart classrooms (including educational technology not applicable in smart classrooms). The results of the articles must be factors or strategies, etc., that influence enhanced cognitive engagement.

3.4 Selection procedure

Firstly, the keywords “smart classrooms and student engagement,” or “cognitive engagement and educational technology,” or “educational technology and student engagement” were searched. Under the basic constraints (Time range: 2004–2025; Document type: Article, Conference paper or Book chapter; Language: English), 10,178 articles were obtained, including Web of Science (n = 2369), Scopus (n = 4655), ProQuest (n = 3154). After Excluding 1945 overlapping articles a total of 6,288 articles remain to be referenced. Based on this, critically screened articles by excluding themes not directly related to cognitive engagement (including articles related to engagement without a subdivision of cognitive engagement) or smart classrooms (including educational technology not applicable in smart classrooms) and obtained 657 articles. After intensive reading, the results of articles must be factors or strategies, etc., that influence enhanced cognitive engagement. Ultimately 75 articles were included. Figure 1 outlines the search and selection procedures utilized as follows:

Figure 1

Procedures for Search and Selection of Articles



3.5 Data Extraction and Coding

A structured coding scheme was used to extract key data, such as cognitive engagement factors or strategies. Studies were categorized based on TPACK framework's three core areas and also alignment with ICAP cognitive engagement level framework.

3.6 Quality Assessment

Articles were assessed using a quality appraisal tool adapted from existing educational research rubrics. Criteria included clarity of research design, theoretical grounding, methodological rigor, and relevance to the review questions. Only studies rated as moderate or high quality were retained for synthesis.

4. Results and Discussion

This study selection PRISMA method (Fig 1) resulted in the inclusion of 75 articles that addressed factors or strategies to enhance cognitive engagement. In this section, the results of the above factors are coded under both the TPACK framework and the ICAP framework. The vertical table header focuses on the three core concepts of the TPACK framework: pedagogical knowledge, content knowledge and technological knowledge. The horizontal table header focuses on the three dimensions of the ICAP framework that can be measured to enhance cognitive engagement: active, constructive and interactive. The list of the factors to enhance students' cognitive engagement in the context of a smart classroom is integrated as shown in Table 1 as follow:

Table 1

Factors to Enhance Students' Cognitive Engagement

Categories	Factors			References Sources
	Active	Constructive	Interactive	
Pedagogical Knowledge			Social support	(Ouyang & Chang, 2019);(Yafei Shi et al., 2021);(Huang et al., 2024)；(Liu et al., 2023);(Guoqing et al., 2022);(Ma et al., 2022);(Wang & Eccles, 2012);
			Interaction	(Wang et al., 2014);(Smart & Marshall, 2013);(He et al., 2024);(Sung et al., 2021);(Sharif Nia et al., 2023);(Xu et al., 2020);(Lim, 2017);
		Perceived		(Walker & Greene, 2009);(Greene et al., 2004);(Sedaghat et al., 2011);(Schunk & Mullen, 2012);(Gao et al., 2020); (Salas-Pilco et al., 2022);
		Set Goal		(Walker & Greene, 2009);(Greene et al., 2004);(Sedaghat et al.,

Categories	Factors			References Sources
	Active	Constructive	Interactive	
		Competence-supportive		2011);(Anderman & Patrick, 2012);(Ardi & Rianita, 2022); (K. Gupta, 2022); (Chans & Castro, 2021); (Huang & Wang, 2023);(Zhang et al., 2022);
		Motivation		(Yafei Shi et al., 2021);(Walker & Greene, 2009);(Blumenfeld et al., 2006); (Sedaghat et al., 2011);(Walker et al., 2006);(Guoqing et al., 2022);(Dubey et al., 2023); (Salas-Pilco et al., 2022);(Ramirez-Arellano, 2024);
		Pedagogical affordance		(Yafei Shi et al., 2021);(Ma et al., 2022);(Hoi, 2022);(Luan et al., 2020);(Zhong et al., 2022);(Xu et al., 2020);
			Teacher questioning	(Smart & Marshall, 2013);(Mason, 2011);
	Belonging			(Walker & Greene, 2009);
		Self-efficacy		(Walker & Greene, 2009);(Greene et al., 2004);(Arabzadeh et al., 2013) ;(Walker et al., 2006);(Guoqing et al., 2022);(Shi et al., 2023); (He et al., 2024);(Shi et al., 2018);(Zhen et al., 2020);(Schunk & Mullen, 2012);(Linnenbrink & Pintrich, 2003);(Sökmen, 2019);(Sung et al., 2021);(Sriwiyanti et al., 2021);(Kuo et al., 2021);(Emiru & Gedifew, 2024);
			Feedback	(Mayordomo et al., 2022);(Sökmen, 2019);(Redmond et al., 2024);
		Inquire Learning		(Blumenfeld et al., 2006);(Lu et al., 2022);(He et al., 2024);
			Collarboration	(Blumenfeld et al., 2006); (Zhong et al., 2022);(Ardi & Rianita, 2022);(Qiao et al., 2024);
	Autonomy			(Rotgans & Schmidt, 2011);(T. K. F. Chiu, 2021);(Huang & Wang, 2023);(Chans & Castro, 2021);(K. Gupta, 2022)
	Personalised Learning			(Nguyen et al., 2024);(Ramirez-Arellano, 2024);
		Academic identification		(Walker et al., 2006);(Salas-Pilco et al., 2022);
		Reflective Thinking		(Lu et al., 2022);

Categories	Factors			References Sources
	Active	Constructive	Interactive	
Content Knowledge		Academic Emotions		(Pekrun & Linnenbrink-Garcia, 2012);
	Situational interest			(Sun & Rueda, 2012)；
			Peer support	(Hoi, 2022);(Luan et al., 2020);(Zhong et al., 2022); (Zaid et al., 2018)
		Multiple sources		(Lu et al., 2022);
		Technology Enhanced Book		(Azizan, 2023);
		Quality of the course content		(Sharif Nia et al., 2023);
Technological Knowledge		Technical affordance		(Yafei Shi et al., 2021);(Blumenfeld et al., 2006);(Venn et al., 2023);(Zhong et al., 2022);(Hazzam & Wilkins, 2023); (Salas-Pilco et al., 2022);(Maričić & Lavicza, 2024);
		Padlet		(Ngan & Hang, 2023);
		LMS		(N. Husni et al., 2022);
		ICT		(Mason, 2011); (Sung et al., 2021);(Sharif Nia et al., 2023);(Sriwiyanti et al., 2021);(Kuo et al., 2021);
		IWB		(Yinghui Shi et al., 2021);(Shi et al., 2019);(Blau, 2011);
		AR		(Wen, 2020);
		VR		(K. Gupta, 2022);
		Gamification		(Qiao et al., 2023);(Ardi & Rianita, 2022);(Tsai, 2024);(Chans & Castro, 2021);(Bouchrika et al., 2021);(Zainudin & Zulkiply, 2023);(Qiao et al., 2024);
		Computer		(Shukor, 2012);
		E-learning		(Dubey et al., 2023);(Bouchrika et al., 2021);
		Social Media		(Xu et al., 2020);
		Mobile		(Lim, 2017);
		AI		(Hao & Razali, 2025);(Nguyen et al., 2024);(Ng et al., 2024);(Redmond et al., 2024);

4.1 Pedagogical Knowledge

Mishra and Koehler (2006) pointed out that Pedagogical Knowledge (PK) concerns the effective management, instruction and guidance of students and teachers. This study identified 21 factors that influence the improvement of cognitive engagement through a systematic review. Examples include self-efficacy (Emiru & Gedifew, 2024), self-regulation (Liao et al., 2023), interaction (He et al., 2024), and feedback (Redmond et al., 2024). In addition, coded them within the cognitive taxonomy of the ICAP framework.

Interactive is regarded as the highest level of cognitive engagement mode., where students collaborate and discuss with peers, leading to co-construction of knowledge (Chi & Wylie, 2014). In

He et al. (2024)'s opinion, enriching the forms of interaction and safeguarding students' subjectivity can dramatically increase students' cognitive engagement in the classroom. Classroom collaboration is thought to play the same role as interaction (Qiao et al., 2024). Similar points of view, peer or social support (Hoi, 2022; Huang et al., 2024; Zaid et al., 2018), teacher questioning (Smart & Marshall, 2013), and feedback (Redmond et al., 2024; Sökmen, 2019) all influence students' cognitive engagement to varying degrees within the category of interaction. For instance, Zaid et al. (2018) indicated that synthesis of peer instruction promotes higher order thinking skills. Smart and Marshall (2013) reported that teachers can affect students' cognitive engagement in three aspects: questioning level, complexity of questions, and questioning ecology when questioning them. Furthermore, Sökmen (2019)'s path analysis showed that teacher-student feedback were positive predictors for all engagement categories.

Constructive mode involves generating new knowledge or understanding by integrating and elaborating on the information, such as through self-explanation or concept mapping (Chi & Wylie, 2014). According to Lu et al. (2022), inquiry learning and reflective thinking could predict cognitive engagement. Similarly, He et al. (2024) argued that enhancing the deep learning that stimulates students' high-level cognitive engagement within smart classroom environments. Furthermore, both Salas-Pilco et al. (2022) and Pekrun and Linnenbrink-Garcia (2012) addressed the fact that academic outputs in identification and emotion can feed into cognitive engagement.

Students engaged in Active mode are basic physical activities that involve some level of cognitive processing, like underlining text or repeating information (Chi & Wylie, 2014). Hence, autonomy is a direct indication of Active cognitive engagement model (W. Chiu, 2021; Huang & Wang, 2023).

Walker et al. (2006) categorized cognitive engagement into shallow cognitive engagement and meaningful cognitive engagement. Both learning goal scores and perceived ability were positive correlations with meaningful cognitive engagement while performance goals were positive correlations with shallow cognitive engagement. Additionally, Yafei Shi et al. (2021) demonstrated that intrinsic motivation promotes meaningful cognitive engagement, extrinsic motivation promotes shallow cognitive engagement, and pedagogical affordance promotes cognitive engagement at all levels. Simultaneously, students' belonging (Walker & Greene, 2009) and situational interest (Sun & Rueda, 2012) indirectly affect cognitive engagement through motivation. Self-efficacy (Walker & Greene, 2009) and self-regulated (Li & Lajoie, 2022) constraints, as important components of motivational beliefs, have a large body of literature demonstrating their significant impact on cognitive engagement (Emiru & Gedifew, 2024; Guoqing et al., 2022; Liao et al., 2023; Salas-Pilco et al., 2022; Shi et al., 2023). Moreover, K. Gupta (2022) also found that teachers' competence-support can foster behavioral and cognitive engagement. Therefore, training of teachers in educational technology skills to ensure teacher competence-supportive is necessary.

Consequently, student motivation, self-efficacy, self-regulation, goal setting, pedagogical affordance and teachers' competence-supportive will permeate the impact on all levels of cognitive engagement. It cannot be examined unilaterally for their value in enhancing cognitive engagement.

4.2 Content Knowledge

Mishra and Koehler (2006) pointed out that Content Knowledge (CK) is the subject-specific understanding of the discipline or subject matter. Teachers must remain specialized in the subject matter they are in, because students' cognitive engagement is linked positively to their perception of the quality of subject content (Sharif Nia et al., 2023). According to Lu et al. (2022), multiple sources could predict cognitive engagement. Likewise, Azizan (2023) confirmed the effectiveness of using technology-enhanced book-end methods to promote cognitive engagement. In short, teachers can ensure that students' cognitive engagement increases by enriching the form of educational resources and content.

4.3 Technological Knowledge

Mishra and Koehler (2006) pointed out that Technology Knowledge (TK) encompasses an understanding of specific tools, software and hardware. There is a large body of published studies describing the role of technical affordances in enhancing students' cognitive engagement (Hazzam & Wilkins, 2023; Maričić & Lavicza, 2024; Venn et al., 2023; Zhong et al., 2022). While there are fewer articles investigating student cognitive engagement in the context of smart classrooms. However, the LMS (N. H. A. Husni et al., 2022) and IWB (Yinghui Shi et al., 2021), as core two features of the smart classroom, have a critical role to play in facilitating student interaction and constructivist learning (Bian & Mohd Zaid, 2024).

In addition to this, the scope of this study is also focused on educational technologies that can be employed in smart classrooms, such as Padlet (Ngan & Hang, 2023), ICT(Sharif Nia et al., 2023), Gamification (Tsai, 2024), E-learning (Dubey et al., 2023), Computer (Shukor, 2012), Social Media (Xu et al., 2020), Mobile (Lim, 2017), AR (Wen, 2020), VR (K. Gupta, 2022) and AI (Hao & Razali, 2025). Recently, Alsaffar (2025) also confirmed the role of AI-Driven Adaptive Multimedia Systems in guiding cognitive in students' personalized learning process.

Ultimately, educational technologies are used to varying degrees to guide students' active learning, construction, and interaction to enhance cognitive engagement. However, how to fully utilize these technologies to keep a high level of cognitive engagement requires the intergration of educational technology skills (Dogan et al., 2021).

Finally, grounded in the TPACK framework, this section systematically summarizes factors that increase students' cognitive engagement in categories of PK, CK, and TK within smart classroom environments. Drawing upon the ICAP framework (Chi & Wylie, 2014), this analysis integrates empirical findings that identify key pedagogical strategies, technological tools, and content contributing to varying levels of engagement. By synthesizing insights from recent literature, this study obtained a relatively comprehensive and systematic list of factors for enhancing students' cognitive engagement in the context of smart classrooms.

5. Conclusion

This study affirms that combining TPACK and ICAP offers a powerful analytical lens for understanding and designing cognitively engaging smart classrooms:

- Pedagogical Knowledge (PK) reflects strategies that induce deeper ICAP levels.
- Content Knowledge (CK) anchors learning content cognitive processes.
- Technological Knowledge (TK) aligns with tools that enable active and personalized learning.

By mapping the ICAP levels (Passive, Active, Constructive, Interactive) onto the TPACK domains, this review identifies factors in three categories of TPACK framework for enhancing students' cognitive engagement. Based on these, this study will This study will provide answers to the research questions posed in the introduction:

5.1 What pedagogical factors can enhance student cognitive engagement in smart classrooms?

Pedagogical factors that enhance student cognitive engagement in smart classrooms align with the ICAP framework and include interaction, self-regulation, motivation, and feedback. Interactive strategies—peer collaboration, teacher questioning, and real-time feedback—foster co-construction of knowledge. Constructive engagement is promoted through inquiry learning, reflection, and concept mapping. Active engagement is supported by student autonomy and goal-setting. Motivation, self-efficacy, and pedagogical affordance play cross-cutting roles, influencing all engagement levels. Teachers' competence-supportive behaviors are essential for sustaining engagement.

5.2 What content factors can enhance student cognitive engagement in smart classrooms?

Content factors that enhance student cognitive engagement in smart classrooms are grounded in teachers' deep subject-matter expertise and the strategic use of enriched digital resources. CK plays a pivotal role, with students' engagement closely tied to their perception of content quality. Integrating diverse, technology-enhanced materials can foster higher cognitive engagement. Therefore, content that is multiple, contextualized, and technologically mediated is essential for stimulating students' active and meaningful learning in smart classrooms.

5.3 What technological factors can enhance student cognitive engagement in smart classrooms?

Technological factors that enhance cognitive engagement in smart classrooms involve both the availability and pedagogical application of digital tools. Core smart classroom technologies—such as LMS and IWB—facilitate student interaction and constructivist learning. Additionally, tools such as Padlet, ICT, gamification, E-learning, Computer, Social Media, Mobile, AR, VR and AI offer diverse affordances for active, constructive, and interactive learning. However, sustaining cognitive engagement requires teachers to be proficient in integrating these technologies with pedagogical intent.

5.4 What guidelines can enhance student cognitive engagement in smart classrooms?

5.4.1 Pedagogical Guidelines

- Align teaching strategies with the ICAP framework (Interactive, Constructive, Active, Passive).
- Promote interactive engagement through peer collaboration, effective teacher questioning, and real-time feedback.
- Support constructive engagement using strategies like inquiry-based learning, reflection, and concept mapping.
- Encourage active engagement by fostering student autonomy and setting meaningful learning goals.
- Nurture student motivation and self-efficacy to influence engagement across all ICAP levels.
- Leverage pedagogical affordances that create conducive learning environments.
- Develop competence-supportive teaching behaviours to maintain consistent student cognitive engagement.

5.4.2 Content guidelines

- Demonstrate deep subject-matter expertise to ensure high-quality instruction.
- Design content perceived as relevant and valuable to enhance student investment and participation.
- Integrate diverse and enriched digital resources, including multimedia and contextualized materials.
- Ensure content supports meaningful learning by aligning with students' cognitive levels and learning needs.

5.4.3 Technological Guidelines

- Utilize smart classroom core tools such as LMS and IWB to facilitate interaction and constructivist learning.
- Incorporate a variety of educational technologies (e.g., Padlet, ICT, gamification, E-learning, social media, mobile devices, AR, VR, and AI) to support various engagement modes.
- Focus on pedagogically meaningful technology integration, not just tool usage.
- Provide professional training programmes for teachers to promote their effective application and technological proficiency in instructional contexts.

In conclusion, cognitive engagement is not as an outcome of isolated variables building on these insights, but as an emergent property of a well-aligned, theory-informed ecosystem. It highlights feedback loops—where real-time data from smart technologies inform pedagogical adjustments, which in turn modulate cognitive engagement levels. This TPACK-ICAP integration can serve as a diagnostic and design framework for teachers, designers, and researchers seeking to optimize learning experiences in smart classrooms.

6. Suggestions

Further studies should investigate the longitudinal implications of smart classroom interventions on academic performance and cognitive engagement. There is also a need for mixed-methods and design-based research that investigates how specific technological tools interact with various pedagogical strategies in the context of smart classrooms.

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