# Integrating AI Into Online Engagement Models for Engineering Education: A Comprehensive Review

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***Abstract*— In the present era, where online learning has taken the spotlight in higher education, especially in engineering education, student engagement remains a critical determinant of academic success. Online engagement models that structure strategies to captivate and sustain students' involvement in virtual learning environments play a vital role in addressing the unique challenges of remote education. This comprehensive review examines the potential of Artificial Intelligence (AI) to revolutionise these models in the context of engineering education. The study identifies how AI tools, such as adaptive learning systems and intelligent tutoring systems, can enhance personalisation, provide real-time feedback, and create interactive learning experiences by analysing literature from leading academic databases over the last decade. The review also discusses the broader implications of AI integration, considering both opportunities and challenges for educators and institutions. Limitations and future research directions are identified, including the need for cross-cultural validations, longitudinal studies, and the extension of these findings to other fields of education. This research adds to the expanding corpus of literature on student engagement, offering a unique perspective on the intersection of AI and online student engagement by guiding engineering educators in creating a more effective, inclusive, and adaptive virtual learning environment.**

***Keywords*— Online Student Engagement; Engineering Education; Online student engagement models; Artificial intelligence in education; AI-enhanced learning; Virtual learning environments.**

***ICTIEE* Track*: (*Pedagogy of Teaching & Learning)**
**ICTIEE Sub-Track: Enhancing Pedagogy for e-Learning**

## I. INTRODUCTION

TODAY when the educational landscape is rapidly evolving, online learning has developed into a cornerstone of education, especially in engineering education (Allen & Seaman, 2017). With the global paradigm shift towards digital platforms, focusing on student involvement is even more important. Hence, engaging students effectively in virtual environments has become vital in today's era. Engagement is one of the key predictors of academic success and retention, especially in rigorous fields like engineering where practical application and interactive learning are vital components of teaching-learning (Fredricks, Blumenfeld, & Paris, 2004). Many researchers have worked on various engagement models that can be deployed for effective online student engagement. Integrating artificial intelligence (AI) into student engagement models offers unprecedented opportunities to enhance learning experiences, personalize education, and improve outcomes (Holmes et al., 2019). Through this comprehensive review, we seek to explore the potential of AI being integrated into existing online student engagement models tailored for engineering students. Moreover, existing research treats student engagement and AI as separate domains, without fully exploring their intersection and potential synergies.

Expanding research on student engagement and understanding how these models can be effectively applied in online engineering education is a field of interest for many researchers. Despite many existing models for student engagement, there is a noticeable gap in the literature regarding their integration with online student engagement models specifically tailored for engineering education. In this paper, we have tried to address this gap by conducting a comprehensive review of the online student engagement models within the context of engineering education and evaluating how AI technologies can be integrated to enhance these models. This paper strives to provide a comprehensive understanding of these models and offer insights into their practical applications, strengths, and limitations. Unlike prior studies, this review not only compares engagement models but also introduces AI as a transformative tool for these frameworks, providing a novel perspective that is currently underexplored in the literature.

This review employs a comprehensive methodology that involves systematically searching and analysing literature from major academic databases, including EEE Xplore, Web of Science, Scopus, Ebsco, ResearchGate and Google Scholar. The inclusion criteria focused on studies published in the last decade that discuss online student engagement models, AI applications in education, and their implications for engineering education. We provide an overview of the key online student engagement models used in engineering education, discussing their theoretical underpinnings, design principles, and practical applications. Next, we evaluate these models in the context of AI integration, exploring how AI technologies can address their limitations and enhance their effectiveness. Finally, we present key findings, recommendations for future research, and practical guidelines for educators and institutions seeking to implement AI-driven engagement strategies in online engineering programs.

### *A. Student Engagement*

A learner's interest in their education is referred to as engagement. Pupils who are actively involved in their studies take the time to absorb new information. Academic achievement, retention, and general student satisfaction are all strongly impacted by student engagement, which is an essential part of the educational process. It depicts the extent to which students exhibit interest, participation and motivation in their learning process (Fredricks, Blumenfeld, & Paris, 2004). Engagement is often categorized into three dimensions (Fredricks et al., 2004; Kahu, 2013):

- Behavioural engagement: which includes participation in academic and extracurricular activities,
- Emotional engagement: which is reflecting students' emotional responses to learning and their sense of belonging,
- Cognitive engagement: referring to students' devotion to learning and their inclination towards the efforts required for grasping complex ideas.

Research consistently shows that higher levels of engagement lead to better educational outcomes, including improved grades, higher determination and an in-depth understanding (Trowler, 2010; Kahu, 2013). However, keeping the students engaged in online learning environments is particularly challenging because the students might experience isolation and lesser connection to the faculty, peers and to the content being discussed (Dixson, 2015; Richardson et al., 2017). Many models have been developed to address these challenges, especially in online settings where the physical and social presence is inherently reduced.

### *B. AI in Student Engagement*

Within the sphere of education, AI is emerging as a disruptive force. AI-driven tools like intelligent tutoring systems, personalized learning platforms, and adaptive assessments, are increasingly being utilized to create interactive and responsive educational experiences for both educators and students (Luckin et al., 2016). With the development and use of AI-enabled virtual teaching assistants and chatbots, students' queries can be resolved instantly, fostering a sense of connection and support even in virtual teaching-learning (Roll & Wylie, 2016). Moreover, AI-powered analytics can identify patterns in students' behaviour, and therefore, help in designing engaging learning experiences (Hwang & Tu, 2021). As AI continues to evolve, its potential to transform student engagement in online education, particularly in fields like engineering will be increasingly realized by both educators and learners.

## II. Research Questions

*RQ1. What are the key components and dimensions of the online student engagement models relevant to engineering education?*
*RQ2. How can AI integration into these models address their limitations and improve engagement?*

## III. Methodology

### *A. Research Design*

This literature review is based on the follows the PRISMA ("Preferred Reporting Items for Systematic Reviews and Meta-Analyses") guidelines (Moher et al., 2009) to ensure a rigorous and comprehensive analysis of existing research on online student engagement models for engineering students, with a focus on the integration of AI. The PRISMA framework 2020 (Haddaway et.al., 2022) is widely recognized for its robust approach, making it an ideal choice for this study.

### *B. Data Sources and Search Strategy*

We conducted a comprehensive search across several academic databases, including "IEEE Xplore, Web of Science, Scopus, Ebsco, ResearchGate and Google Scholar". The search terms used were:

- "Online student engagement models"
- "Engineering education"
- "Artificial intelligence in education"
- "AI-enhanced learning"
- "Virtual learning environments"
- "Student engagement in online learning"
- "Online student engagement models in engineering education"

These words were selected to encompass an extensive range of relevant studies focusing on traditional as well as AI-enhanced engagement models in the context of online engineering education.

### *C. Inclusion and Exclusion Criteria*

Table I describes the inclusion and exclusion criteria considered for this study.

### *D. Data Selection and Extraction*

The initial search yielded many articles. The study selection process was conducted in four stages:

- Identification: All records identified through database searching were collected and duplicates were removed.
- Screening: The studies were initially screened on their "Titles and abstracts" based on the inclusion and exclusion criteria.
- Eligibility: Full-text articles were assessed for eligibility. Studies that did not meet the criteria were excluded.
- Inclusion: The final set of studies included in the review were those that met all the inclusion criteria.

TABLE I
INCLUSION AND EXCLUSION CRITERIA

| Parameters | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Time period | Studies published within the last ten years 2014-2024. | Research papers published before 2014. |
| Language | Studies published in English. | Articles not published in English. |
| Focus | Studies that explicitly discuss student engagement models in online engineering education. | Research that does not specifically address engineering education or online learning contexts |
| Relevance | Research that includes student engagement models with a relevance of AI integration. | Studies that do not include empirical data or lack a clear focus on student engagement. |
| Footnote | Footnote Text | 8 pt, justified |
| Appendix, Acknowledgement, References | Unnumbered Section | 10 pt, centered, Small caps |
| Bibliography | Bibliography | 10 pt, justified |

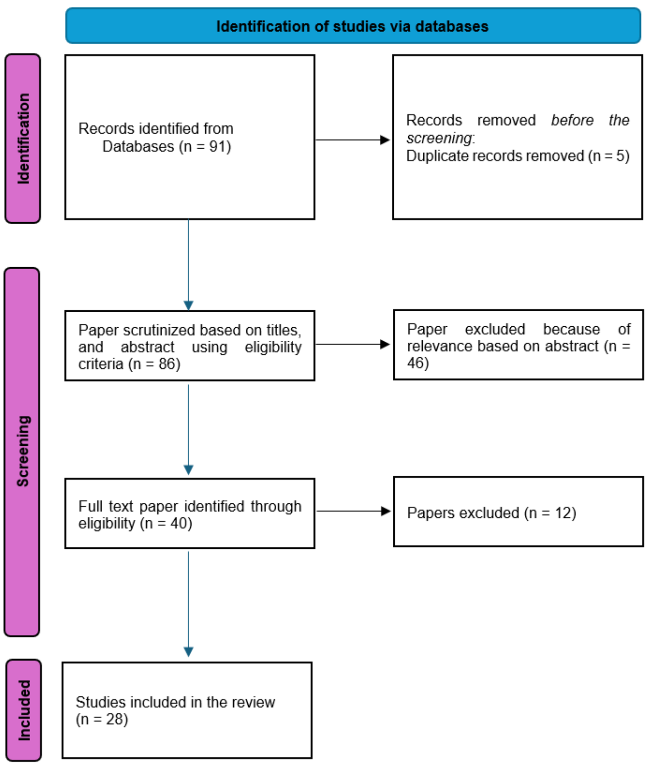


Fig. 1. PRISMA Flow Diagram

A PRISMA flow diagram that comprises the total records found, records to be considered after initial screening, records deemed eligible for this study, and the ones included, as well as the rationale behind exclusions at each stage, demonstrates the process of selection of the studies (Fig. 1).

*E. Quality Assessment*

The checklist by the "Critical Appraisal Skills Programme (CASP)" was employed for the quality assessment of the included studies (CASP, 2024). This tool helped evaluate each study's methodological rigour and credibility, focusing on aspects such as study design, data collection methods, and validity of the findings.

## IV. DATA ANALYSIS

The extracted data from the studies which we selected included:

- Study characteristics (authors, publication year, study design)
- Model characteristics (name, components, dimensions)
- Application contexts (how the model was applied)
- Integration of AI (types of AI technologies used, their roles in enhancing engagement)
- Outcomes and findings (impact on student engagement, strengths, and limitations)

The analysis followed a narrative synthesis approach (Rodgers et al., 2009), allowing us to summarize and interpret the findings from the included studies. The data were organized thematically to highlight the key components and dimensions of each engagement model, their applications in online engineering education, and the role of AI in enhancing these models.

*A. Overview of Included Studies*

In total, 28 studies were considered for this review. These studies provided insights into the various components and applications of the various online student engagement models, including the role of AI, in the context of engineering education.

*B. Key Components and Applications*

The online student engagement models for engineering students incorporate various components and dimensions that are essential for fostering effective engagement in virtual learning environments. These components and dimensions can be broadly categorized into behavioural, emotional, cognitive, and social engagement. Table II summarizes the key components and applications of the models under study.

*1) Behavioural Engagement*

Behavioural engagement refers to students' participation in academic activities, such as classes, submitting assignments, and engaging in discussions. It is a critical dimension as it directly influences students' learning outcomes and retention rates (Fredricks, Blumenfeld, & Paris, 2004). Models like the "Student Engagement Framework" (SEF) emphasize the importance of active participation and consistent performance in academic tasks (Kahu, 2013).

*2) Emotional Engagement*

Emotional engagement involves students' feelings towards their learning experience, including interest, enthusiasm, and a sense of belonging. It is crucial for sustaining motivation and commitment to learning. The "Engaged Learning in Online Learning" (ELB) framework highlights the role that positive emotions and a sense of community play in enhancing engagement (Redmond et al., 2018).

*3) Cognitive Engagement*

Cognitive engagement pertains to the investment in learning, including the implementation of deep learning strategies and critical thinking. This dimension is vital for developing problem-solving skills and higher-order thinking, especially in engineering education. Models such as the "Online Student Engagement Scale" (OSE) focus on promoting deep cognitive processing and self-regulation (Dixson, 2015).

TABLE II
COMPONENTS AND APPLICATIONS

| S. No. | Model | Components | Applications |
|---|---|---|---|
| 1 | "Engagement, Learning, and Belonging Framework" (ELB) by Jindal-Snape et al. (2019) | Engagement, Learning, Belonging, Sense of Community. | Enhances students' sense of belonging and quality learning experiences in online engineering courses |
| 2 | "Online Engagement Framework" by Redmond et al. (2018) | Social presence, Cognitive presence, Teaching presence, Emotional presence. | Emphasizes the importance of social, cognitive, teaching, and emotional presence to foster student engagement in virtual settings. |
| 3 | "Model of Student Engagement in Online Learning" (MSEOL) by Bolliger & Martin (2018) | Social presence and Collaborative activities | Tailored for online learning environments, considering the unique challenges and opportunities of engaging students in online engineering courses. |
| 4 | "Technology-Enhanced Learning Engagement Framework" (TELEF) by Bond et al. (2019) | Learner characteristics, learning design, Learning environment, Engagement outcomes, Digital tools and platforms. | Focuses on how learner characteristics, learning design, and the learning environment influence engagement outcomes in technology-enhanced learning. |
| 5 | "Integrated Engagement Framework" by Henrie et al. (2015) | Affective engagement, Behavioural engagement, and Cognitive engagement. | Integrates different dimensions of engagement (affective, behavioural, cognitive) and explores how they interact to influence overall student engagement in engineering education. |
| 6 | "Student Engagement Framework" (SEF) by Kahu (2013). | Behavioural Perspective, Psychological Perspective, Sociocultural Perspective, Holistic Perspective. | Guiding research and practice, informing institutional policies and practices, enhancing student support services, and improving student engagement measurement approaches. |
| 7 | "Dynamic Engagement Framework" by Trowler (2015) | Structural elements (institutional support, resources), Student dispositions (motivation, identity), and Relational elements (interaction with peers and faculty). | Considers the dynamic interactions between structural, dispositional, and relational elements that influence student engagement in online settings. |
| 8 | "Student Engagement Scale" (OSE) by Dixson (2015). | Skills Engagement, Emotional Engagement, Interaction Engagement, Performance Engagement. | Assessment of Student Engagement, Course Improvement and Feedback, Research and Evaluation, Professional Development, Benchmarking and Institutional Assessment. |
| 9 | "Model of Engagement in STEM Education" by Freeman et al. (2014) | Active learning, Inclusive teaching, Peer collaboration, Continuous assessment. | Focuses on active learning, inclusive teaching practices, peer collaboration, and continuous assessment to foster engagement in STEM fields. |
| 10 | "Experiential Learning Engagement Framework" by Kolb et.al. (2017) | Actual experience, Insightful observation, conceptualization, and research. | Highlights the importance of Actual experience, Insightful observation, conceptualization, and research. in engaging engineering students online. |

*4) Social Engagement*

Social engagement involves interactions with peers, instructors, and the broader learning community. It fosters collaborative learning and the development of communication skills. The "Model of Student Engagement in Online Learning" (MSEOL) underscores the importance of social presence and collaborative activities in virtual environments (Bolliger & Martin, 2018).

*5) Technological Integration*

Since online learning has become a popular pedagogy, the integration of technology has become a significant dimension of engagement models. The "Technology-Enhanced Learning Engagement Framework" (TELEF) focuses on leveraging digital tools and platforms to enhance learning experiences (Bond et al., 2019). The use of "Learning Management Systems" (LMS), virtual labs, and

### C. AI Integration in Engagement Models

The integration of artificial intelligence (AI) in student engagement models offers innovative approaches to enhance online learning experiences. AI can provide personalized, adaptive, and interactive learning environments that can cater to individual student needs and preferences (Holmes et al., 2023).

#### 1) Personalized Learning

Students' data collected can be analysed through AI systems and which in turn can personalize their learning paths, adapting content and assessments to match individual learning styles and paces. This personalization can significantly enhance cognitive and behavioural engagement by ensuring that students are neither uninterested nor exhausted (Krstić, 2022).

#### 2) Intelligent Tutoring Systems (ITS)

ITS uses AI to provide real-time feedback and support hence, mimicking the role of a human tutor. These tools can determine a student's areas of strength and weakness and provide focused interventions to enhance learning outcomes. (VanLehn, 2011). ITS have been shown to enhance cognitive engagement by promoting active problem-solving and critical thinking skills.

#### 3) Predictive Analytics

AI-driven predictive analytics can identify weak learners by analysing patterns in their engagement and performance data. Early identification allows for timely interventions, such as personalized support and resources, which can improve student emotional and behavioural engagement (Arnold & Pistilli, 2012).

#### 4) Chatbots and Virtual Assistants

Instant guidance and support are provided to the learners by AI chatbots and virtual assistants as they resolve the queries of students and facilitate access to learning resources. These tools can enhance social and emotional engagement by fostering a sense of presence and immediacy in online learning environments (Kooli and Chokri, 2023).

#### 5) Adaptive Learning Technologies

Adaptive learning technologies use AI algorithms to adjust the difficulty and pace of instructions based on student performance. This dynamic adaptation helps maintain an optimal challenge level for the student, hence promoting sustained cognitive engagement (Taylor et.al., 2021).

#### 6) AI-Enhanced Collaborative Tools

AI can enhance collaborative learning by facilitating group formation based on complementary skills and learning styles. It can also provide real-time analytics on group dynamics, helping instructors to intervene and support effective collaboration (Akgun and Greenhow, 2021).

#### 7) Gamification and Simulation

AI can enhance gamification and simulation by creating adaptive and immersive learning experiences. These tools can simulate real-world engineering problems, providing students with practical, hands-on experience in a virtual environment,

TABLE III
STRENGTHS AND LIMITATIONS

| S. No. | MODEL | Strengths | Limitations |
|---|---|---|---|
| 1 | "Engagement, Learning, and Belonging Framework" (ELB) by Jindal-Snape et al. (2019) | Focuses on belonging and quality learning experiences. | Relatively new, limited validation studies. |
| 2 | "Online Engagement Framework" by Redmond et al. (2018) | Emphasizes comprehensive engagement in online settings. | Requires substantial resources for effective implementation. |
| 3 | "Model of Student Engagement in Online Learning" (MSEOL) by Bolliger & Martin (2018) | Tailored for online environments. | May require adaptation for specific engineering contexts. |
| 4 | "Technology-Enhanced Learning Engagement Framework" (TELEF) by Bond et al. (2019) | Focuses on technology-enhanced learning. | Technology access and proficiency can be a barrier. |
| 5 | "Integrated Engagement Framework" by Henrie et al. (2015) | Comprehensive integration of engagement dimensions. | Complex implementation. |
| 6 | "Student Engagement Framework" (SEF) by Kahu (2013). | Focuses on Institutional Practice, acknowledges the dynamic nature of Engagement, and emphasizes social and cultural context in shaping student experiences. | The one-size-fits-all approach can be misleading. |
| 7 | "Dynamic Engagement Framework" by Trowler (2015) | Considers dynamic interactions. | Requires detailed data collection. |
| 8 | "Student Engagement Scale" (OSE) by Dixson (2015). | Comprehensive measurement approach as it measures multiple facets of student engagement, adaptation to online learning. | Potential Bias in Self-Reporting by students, limited measurement scope, context-specific applicability, emphasis on quantitative data. |
| 9 | "Model of Engagement in STEM Education" by Freeman et al. (2014) | Emphasizes active learning and collaboration. | May be resource intensive. |
| 10 | "Experiential Learning Engagement Framework" by Kolb et.al. (2017) | Focuses on experiential learning. | Requires hands-on activities, challenging in purely online settings. |

thereby enhancing behavioural as well as cognitive engagement (Shahid et al., 2019).

### D. Strengths and Limitations

TABLE IV
STRENGTHS AND LIMITATIONS OF AI-ENHANCED MODELS

| S. No. | Model | Strengths | Limitations |
|---|---|---|---|
| 1 | Adaptive Learning Systems | Provides personalized learning experiences. | Requires advanced AI algorithms and data analytics. |
| 2 | Intelligent Tutoring Systems | Offers real-time assistance and feedback. | Development and maintenance can be resource intensive. |
| 3 | Predictive Analytics | Identifies at-risk students and allows for proactive intervention | Requires robust data collection and analysis capabilities. |
| 4 | Chatbots and Virtual Assistants | Provides instant support and fosters continuous engagement. | Limited to predefined responses and capabilities. |
| 5 | Gamification and Simulation | Creates interactive and engaging learning experiences | Development can be costly and time-consuming. |

Table III highlights the strengths and limitations of the models under discussion.

### E. AI-Enhanced Models

Table IV describes the various features of AI that can enhance the capability of engagement models. AI integration can strengthen student engagement on virtual platforms but it also comes with certain limitations which need to be addressed to harness the full potential of AI integration in online student engagement models.

TABLE V
BENEFITS OF AI INTEGRATION WITH THE TRADITIONAL ONLINE ENGAGEMENT MODELS

| S. No. | Engagement Type | Benefits of AI integration |
|---|---|---|
| 1 | Behavioural engagement | Behavioural engagement is significantly enhanced by AI through real-time monitoring and personalized interventions, but the effectiveness depends on the quality of data and algorithms. |
| 2 | Emotional engagement | Emotional engagement benefits from AI's ability to provide personalized support, yet it may jeopardize the human empathy factor that is crucial for student motivation and well-being. |
| 3 | Cognitive engagement | Cognitive engagement is greatly improved by adaptive learning technologies, which ensure that students are consistently challenged, though the success of these systems is tied to the availability and quality of data. |
| 4 | Social engagement | Social engagement is augmented by AI's ability to facilitate and monitor collaborative activities, but this may come at the cost of reduced personal interaction and potential privacy concerns. |

### F. Comparison of Models

The models discussed in the present study vary in their focus on behavioural, emotional, cognitive, social, and technological aspects of engagement. While some models, like the ELB and Online Engagement Framework, offer multi-dimensional perspectives, others, like the MSEOL and TELEF, emphasize specific aspects like online learning environments and technology-enhanced learning. AI integration with these models enhances their capabilities by providing real-time, personalized and interactive learning experiences to the users.

The comparison of traditional and AI-enhanced student engagement models reveals that AI offers substantial benefits in terms of personalization, adaptability, and real-time support across all dimensions of engagement. However, these benefits come with challenges that need to be carefully managed, including the accuracy of AI algorithms, the risk of reducing human interaction, and concerns about data privacy and security. Table V reveals the benefits of integrating AI with traditional engagement styles.

It is without a doubt that AI-enhanced engagement models offer promising improvements over traditional models, however, they ought to be applied in a way that strikes a balance and makes use of both AI and human components to create an optimal learning environment for online engagement of engineering students.

Based on the above discussion, the following model (Fig. 2) can be adopted where AI integration enables student engagement in online courses.

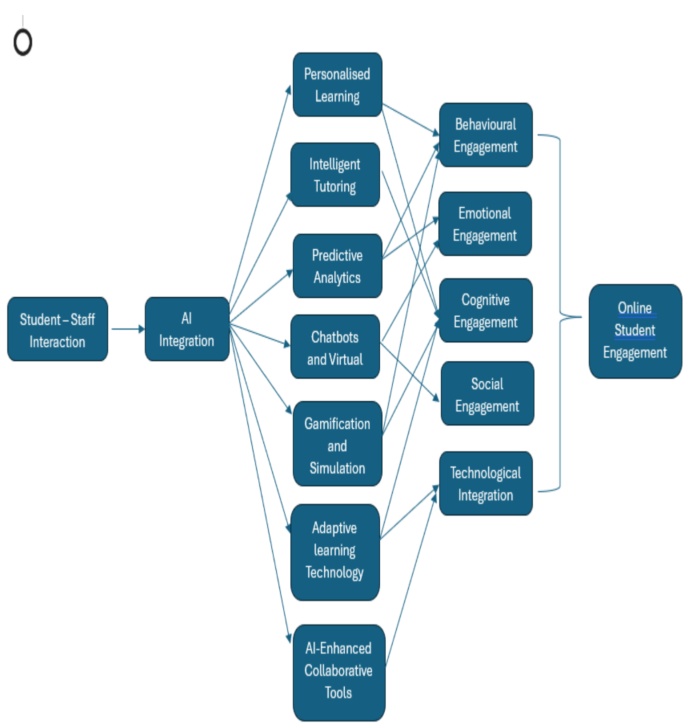


Fig. 2. AI Integration

## V. Practical Implications

The insights from this review suggest that engineering educators and institutions can enhance online student engagement by adopting models that align with their specific contexts and needs and integrating AI to enhance online student engagement. For instance, implementing the Technology-Enhanced Learning Engagement Framework (TELEF) offers a strategic blueprint for institutions to effectively harness technology in ways that support active learning, collaboration, and deeper student engagement. The TELEF's focus on technology integration is particularly relevant in online settings, where the absence of physical presence necessitates innovative methods to maintain student interest and participation. Moreover, the Engagement Learning and Belongingness (ELB) framework, which emphasizes fostering a sense of community and belonging among online students, can be particularly impactful in online engineering education. The ELB framework overcomes the challenge of isolation by ensuring that students experience the connection between their instructors as well as peers.

Furthermore, integrating AI technologies into these existing engagement models offers additional dimensions of personalization and efficiency. Education content can be tailormade to match the individual student needs by the usage of AI tools like the ITS. Moreover, the content can also be interactive and engaging by using the adaptive-learning techniques of AI. These tools can dynamically adjust to a student's learning pace, provide immediate feedback, and offer personalized resources, leading to enhanced engagement and improved educational outcomes. The implications for engineering education are profound, as these AI-enhanced models can aid in bridging the knowledge gap between theory and real-world application which are the critical aspects of engineering education. The review suggests that when institutions strategically combine well-established online engagement frameworks with cutting-edge AI technologies, they can create an environment which is interactive, inclusive, and effective for engineering students.

## VI. Limitations of the Review

This review is limited by the scope of databases searched and the chosen inclusion criteria which may exclude relevant studies in other formats or languages. Moreover, the swiftly evolving AI technologies require the findings to be updated regularly to reflect the latest advancements and applications in the online engagement of students. Moreover, the aspects of the study are confined particularly to engineering education and can be extended to other fields of education as well.

## VII. Future Research Directions

In future, the researchers could explore cross-cultural validations of these models, longitudinal studies to track engagement over time, and the integration of emerging trends in the online engagement of engineering students. The study could also be extended to other courses apart from engineering. Studies could also investigate the long-term impacts of AI-enhanced engagement models on student performance, retention, and satisfaction.

## Conclusion

This review analysis the online student engagement models specifically tailored for engineering education comprehensively. The review highlights the key components, applications, strengths, and limitations of each model, offering valuable insights for engineering educators and institutions. The integration of AI provides real-time, customized and interactive learning experiences for learners, thereby enhancing the effectiveness of the online engagement models.

Understanding and enhancing student engagement is crucial for academic success and professional readiness, especially in engineering education. The insights from this review can guide educators and institutions in selecting and implementing appropriate online engagement models, thereby fostering an effective, inclusive and efficient online learning environment for engineering students. The integration of AI offers stimulating opportunities for enhancing, engaging and learning outcomes for students in online engineering education.

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