Chapter 6 - A Model of Pedagogical AI-Enabled Smart Learning Environment

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Chapter Highlights

- This chapter explores how advancements in smart and mobile technologies are reshaping traditional learning environments. It delves into the concept of smart learning environments, which adapt and provide support to learners based on their individual behaviors and needs.
- It discusses the role of technology in personalizing learning experiences, emphasizing the importance of adapting content, providing feedback, and addressing real-world contexts to meet the diverse needs of learners.
- This section reviews various models of smart learning environments developed in the literature, highlighting their strengths and limitations in terms of pedagogical support and learning visualization.
- The chapter introduces a novel model, the "Pedagogical AI-Enabled Smart Learning Environment." This model integrates pedagogical support, learning visualization, and AI technologies to provide a comprehensive framework for inclusive learning experiences.
- The chapter outlines the cyclical learning process within this new model, which includes learner profiling, pedagogical support, adaptive content, performance evaluation, learning visualization, and learner support. It describes how these components work together to enhance the learning experience.
- The chapter also highlights how emerging technologies like smart cameras, cloud storage, virtual labs, and smart web interfaces can enhance the teaching and learning process within this new smart learning environment.
- It concludes by discussing potential future developments, such as the integration of augmented reality and AI algorithms, to further enhance the pedagogical AI-enabled smart learning environment and provide accurate support for learners' needs.

Abstract

The advancements in smart and mobile technologies are changing the design of learning environments. These technologies can create a smart learning environment that can personalize learning content for different learners based on their learning behaviors and needs. A smart learning environment uses technology to modify and give relevant assistance in the right places and times based on individual learners' learning behaviors. This can be discovered by examining their learning behaviors, performances, and the real-world circumstances in which they find themselves. Several smart learning environment models have been developed based on distinct foundations and research perspectives to serve varying learning demands. However, a well-defined model that explicitly includes pedagogical support and learning visualization modules to assist learners in the learning process for inclusive experiences is lacking. This chapter combined pedagogical support and learning visualization with the modules in a smart learning environment to develop a novel model known as a pedagogical AI-enabled smart learning environment. This integrated model can provide learning support and skill development and drive the design of a learning environment for inclusive learning experiences.

Introduction

The increasing developments in learning analytics, sensing, smart, mobile, and wearable technologies are changing the sphere of the learning environment. These technologies can be used to develop a smart learning environment that can provide a personalized adaptive system to support diverse learning behaviors (García-Tudela et al., 2021; Peng et al., 2019;). A smart learning environment is " a technology-supported learning environment that makes adaptations and provides appropriate support in the right places and at the right time based on individual learners' learning behavior and needs" (Hwang et al., 2008). This might be determined by analyzing their learning behaviors, performances, and the real-world contexts in which they are situated. The idea of a one-size-fits-all class has not effectively delivered the learning needs of students in a contextual setting (Egielewa et al., 2021; Zhu et al., 2016). Thus, several research works have advocated for designing a learning environment that can provide personalized learning content based on learner learning behavior to provide inclusive learning experiences (Egielewa et al., 2021; Khan & Alotaibi, 2021; Serbia & Loan, 2020).

Several models of smart learning environments have been developed based on various foundations and research perspectives to support diverse learning needs (Egielewa et al., 2021; Hwang, 2014; Rosmansyah et al., 2022; Serrano et al., 2021; Zhu et al., 2016). However, there is a lack of a well-defined model that includes pedagogical support and learning visualization to support the learning process for inclusive learning experiences. Hwang (2014) developed a model of a smart learning environment with the following learning modules: "An adaptive learning content, learning performance evaluation module, adaptive learning task module, personal learning support, and inference engine." The literature has used and referenced the model to develop a smart learning environment. However, the model lacks explicit integration of pedagogical support and learning visualization modules to guide the learning process and provide a means for evaluating learning performances. The question addressed in this chapter is: How can a pedagogical AI-enabled smart learning environment model be developed to provide learning support for inclusive experiences? Addressing this question will provide insights into how the

learning modules in a smart learning environment are integrated with pedagogical support and learning visualization to support skills and knowledge development for inclusive learning experiences.

Theoretical Background and Related Works

Smart Learning Environment

The advancement in smart, mobile, and wearable technologies is transforming how people compute and interact daily. These technologies are transforming the design of learning environments into smart learning environments capable of personalizing inclusive learning experiences. A smart learning environment considers a learner's characteristics and tailored learning content and offers feedback on the learner's learning process (Chen et al., 2016; Hwang, 2014). The smart learning environment and the smart devices can interact with a learner and make learning decisions based on the learners' actions. Data analytics can provide learners success by visualizing their learning progress, and tutors can utilize it to deliver helpful feedback by providing personalized assistance. Smart learning environments provide tailored learning materials, supportive tools, and learning ideas at the appropriate time and format for inclusive learning experiences (Freigang et al., 2018; García-Tudela et al., 2021; Peng et al., 2019).

A smart learning environment is a hybrid learning system that provides learners and other stakeholders with a motivational learning process while simultaneously achieving learning outcomes due to intelligent tools and techniques. This emerging learning environment can support learning diversities (Rosmansyah et al., 2022). It comprises contextual awareness, location awareness, real-world scenarios, recommendation systems, numerous engagement channels, assistance, personalization, and adaption (Hwang, 2014). Learners are more motivated to attain their goals when these features support inclusive learning experiences (Egielewa et al., 2018; Serbia & Loan, 2020).

Smart Learning Environment and Pedagogical Approach

The rapid development of advanced technologies enables flexible and efficient learning processes based on students' behavior. This process permits mixing content knowledge and skills to understand learners' needs (Dash et al., 2017). Students produce understanding through critical thinking and learning skills, which are significant to fostering learning abilities. Students accept learning processes and skills development that match their learning needs (Hwang, 2014; Khan & Alotaibi, 2021; Rosmansyah et al., 2022). In traditional education, these differences are less concerning as the learning content design is "one-size-all" (Shunk, 2002; Westbrook et al., 2014). However, this practice is ineffective in meeting individual students' learning experiences (Egielewa et al., 2021; Serrano et al., 2021; Zhu et al., 2016).

Thus, a new pedagogy should consider the needs and allow for active engagement of students, skills development, collaborative model of teaching and learning, learner responsibilities, interests, preferences, and intrinsic motivation that promote personalized expertise among students (Canţer, 2013; Egielewa et al., 2021; Zhu et al., 2016). It means both self and peer assessments are useful for formative evaluation. In contrast, peer assessment

involves students taking responsibility for assessing the work of their peers. This kind of assessment can offer an opportunity for engagement and is a powerful strategy for reinforcement of learning and skills development. It is crucial to advocate for integrating technology and pedagogy to establish a cohesive ecosystem that offers continuous and immediate documentation of knowledge advancements while fostering the development of skills that can be effortlessly transferred to learners as they transition between different learning environments (Chen et al., 2016). Furthermore, a smart pedagogy that provides opportunities for collaboration, peer assessment, critical thinking, and self-assessment must be integrated into the design of a smart learning environment for active learning engagement (Chen et al., 2016; Egielewa et al., 2021). More specifically, pedagogies such as self-regulated learning processes, social constructive learning, Collaborative learning, reflective and inquiry-based learning processes, etc., can support active engagement in a smart learning environment. These pedagogies have supported interaction and engagement in a learning process. They can support the needs of digital learners who need not only knowledge but skills for high-order thinking to contribute to the development of a society and workforce (Cao et al., 2020; Iqbal et al., 2020; Nguyen et al., 2022; Rosmansyah et al., 2022).

Models of Smart Learning Environment

Several models of a smart learning environment have been discussed in the literature that can support personalized adaptive systems for inclusive learning experiences (García-Tudela et al., 2021; Khan & Alotaibi, 2021; Peng et al., 2019; Rosmansyah et al., 2022; Serbia & Loan, 2020; Serrano et al., 2021). These models were developed from various foundations and perspectives, providing bases for research and discussion.

Rosmansyah et al. (2022) developed a simple model of a smart learning environment based on mapping existing smart learning environment models, frameworks, and best practices. The components of this model are standard policy, curriculum (represents the philosophical and ideological foundation of education), domain module (contains learning material), learner module (learner behavioral characteristics), pedagogy module (learning process), interface module (collaboration & communication), and supporting resources (administrative & support policies). Similarly, Khan Alotaibi (2021) developed an architecture of a smart learning environment based on soft computing. This architecture comprises user learning data, AI and agents, and smart learning-based tools. The goal of the model is to use AI-based technology to process user inputs. Additionally, it serves as a platform for managing inputs, reports, and data analysis tools. While these models provided components for designing a smart learning environment, they lack a well-defined structure and how they can be connected and modeled to provide a pedagogy for supporting personalized adaptive learning experiences.

Serba and Loan (2020) created QLearn, a web-based smart learning environment. This smart learning environment provides useful feedback and excellent exam preparation. It is based on a collaborative game-based learning technique that enables students to create learning experiences. The QLearn quantifies students' coverage rate of the course material or the level of knowledge supplied. The AI component of QLearn analyzes these measures to forecast students' exam results, determine which topics need more practice, and offer learning strategies based on individual students' needs. Moreover, Vesin et al. (2018) proposed and developed a model for a programming tutoring system (ProTus). It is intended to offer students personalized courses in a range of subjects. The

interactive system enables students to use instructional materials created for various courses and assess their learning progress. The model is made up of the following modules: interactive visualizations (learning activities based on a collection of disparate data sources), personalization (creates recommendations of learning resources for each student and tailors the content to a specific learner), and customization (allows students to change the look of the user interface by displaying or hiding internal frames and turning off/on recommendations). In addition, Hwang (2014) developed a model of a smart learning environment based on the characteristics and capabilities of technology, which consists of the following modules: "An adaptive learning content, learning performance evaluation module, adaptive learning task module, personal learning support, and inference engine." These models provided the theoretical background for a smart learning environment. However, the modules are not integrated and lack pedagogical support and learning visualization to guide the learning process and monitor learning progress.

Thus, it is clear from the literature that research in the smart learning environment is increasing, and the need for developing an AI-enabled learning environment is at the forefront. Additionally, the need for designing intelligent learning environments to inspire various learners while considering their abilities, learning preferences, and interests is increasing (Hoel & Mason, 2018; Rosmansyah et al., 2022; Spector, 2014). However, there is a lack of a well-defined model of an AI-enabled smart learning environment supported by a pedagogy to guide the learning process and learning visualization to monitor learning progress

Pedagogıcal AI-Enabled Smart Learnıng Envıronment

Several applications of a smart learning environment have been discussed in the literature to support personalized adaptive systems for inclusive learning experiences (Freigang et al., 2018; Hwang, 2014; Khan & Alotaibi, 2021; Rosmansyah et al., 2022; Serbia & Loan, 2020; Serrano et al., 2021). However, most of these applications lack specific models underpinning their development. Furthermore, most models lack a pedagogy to guide the learning process and explicit integration of AI. There is a scarcity of a well-defined pedagogical model of a smart learning environment that integrates pedagogical support and learning visualization modules to guide the learning process for inclusive learning experiences. Hwang (2014) provided the foundation for developing a model of a smart learning environment for supporting inclusive learning experiences. However, this model lacks the integration of pedagogical support, learning visualization, and explicit integration of the AI-enabled learning process. Furthermore, the structure of the model is not well-defined to support a pedagogical process. There is a need to include pedagogical support and learning visualization that supports a variety of learning styles and helps learners in the learning process for inclusive learning experiences (Huang et al., 2013; Sumadyo et al., 2018).

Thus, following the methodological approach of Canţer (2013), this chapter integrated pedagogy to support the learning process and learning visualization with modules in the smart learning environment (Hwang, 2014) to develop a novel model of a smart learning environment model called pedagogical AI-enabled smart learning environment. The integrated application supported by this model can provide an opportunity for skills and knowledge development to live and function in society and contribute to the digital workforce. Figure 1 shows

the model of a pedagogical AI-enabled smart learning environment, and each module is discussed for clarity and usage.

Learner profile: This module contains learner learning goals, current knowledge, and personal information. The goal can be a set of achievements that can be achieved at the end of the course. These attributes form a learning portfolio and benchmark for learners' cognitive ability profiles.

Pedagogical support: This module directs learning activities during the learning process. These are guidelines, tools, or resources that support teaching and instruction. For example, social constructive learning, self-regulated learning process, and collaborative learning support can be integrated into the pedagogical support module to guide smart learning activities to improve knowledge and skills. The learning resources or portfolio can be PDF, audio, videos, or other external resources. Pedagogical support provides key performance indicators for the delivery of teaching and learning. It assesses its impact on learners or if there is a need to change the pedagogical approach based on learning technology's prevalent situation or dynamism. The pedagogical support can be integrated into formal or informal learning and online or offline teaching depending on the need and contextual setting.

Inference engine: This is the knowledge base used to evaluate the "value" of potential learning tasks, strategies, and tools, as well as the possible pairings of these elements. The knowledge base comprises tutoring expertise and knowledge from educators and students. It might also consist of the guidelines for making decisions developed from studying both successful and unsuccessful cases in the past. The inference engine is a computer program that evaluates the current case, including the student's situation and the surrounding contexts, and then makes decisions based on the rules in the knowledge base (Hwang, 2014; Wu et al., 2013a).

Learning performance evaluation: This module evaluates and documents students' performance through online or in-person tests. For a real-world exam, students might be required to observe or engage in real-world forums to discover the solution to a test item (i.e., the real-world objects related to the learning goals) (Hwang, 2014).
Adaptive learning content: This module modifies user content based on each learner's progress, performance, personal characteristics, and the situation in the real world. The learning system organizes and recommends learning materials to suit individual learner's needs (Hwang, 2014).

Learning visualization: This module includes instructions for enhancing learning performance and skills as well as learner learning behavior. This may be action-related, content-related, learner-related, or socially related, and it can help students develop their skills in learning. The learner's learning goal, performance, pedagogy, learning content, and personalized message are all included in the learning visualization modules to help make learning more effective. Students can access this module through the application portal using their login information.

Learner support: This module allows tutors to support learners based on their unique learning requirements. Learning support can take the form of a learning task or learning content guideline, a hint for the task, feedback on their work, or help with learning effectively and efficiently. When determining the type of assistance to be

provided, the features of the learning tasks and content and the learners' learning performance, personal factors, and real-world status are considered.

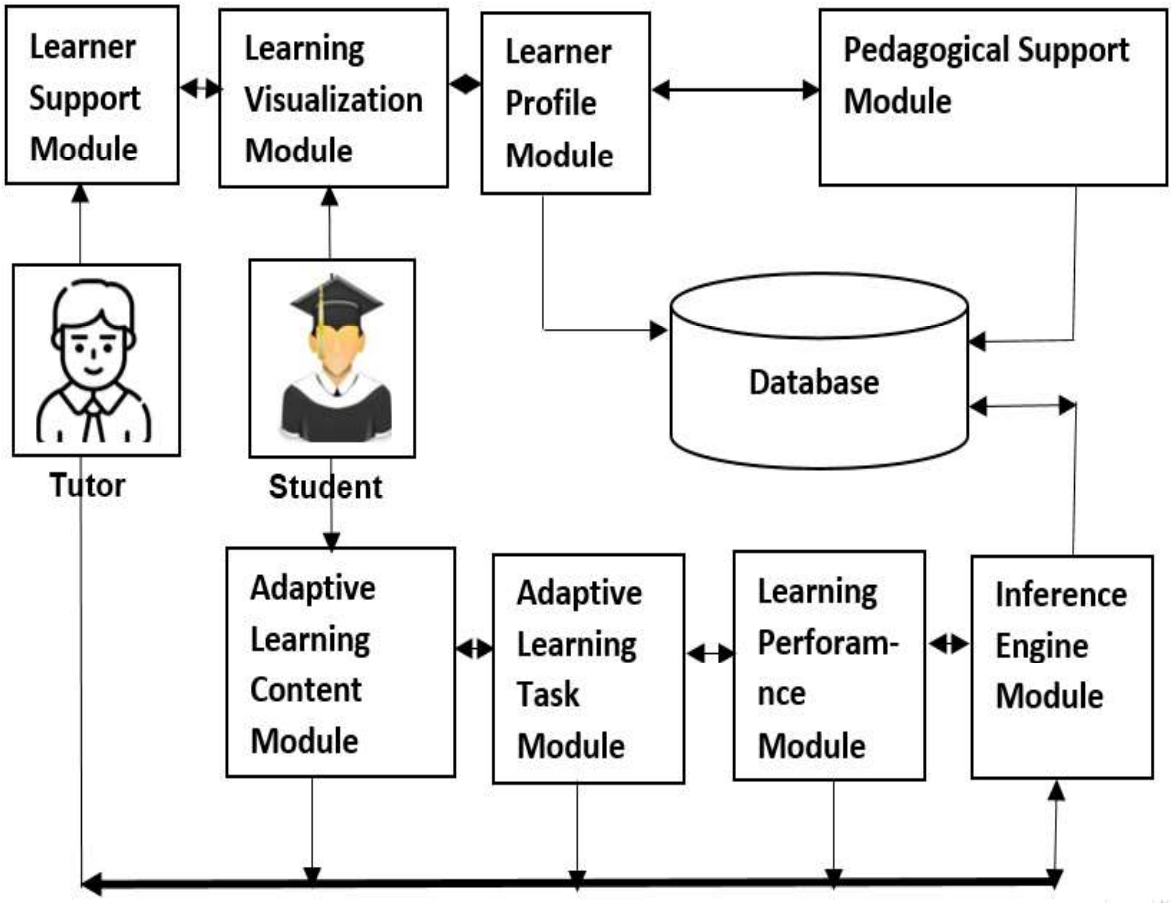

Figure 1: Model of Pedagogical AI-Enabled Smart Learning Environment

The learning process in this model is cyclical and aimed at improving learning experiences. The learner creates an account and logs in through the learner profile module; the module contains personal data and learning goals. After logging into the app, the learner accesses learning resources supported by the pedagogical support module. Pedagogical support provides learning activities and guides the learner in the learning process. All these data are captured into the database module for further analysis. With the help of an AI algorithm, the inference engine will provide adaptive tasks, learning performance evaluation, and adaptive content based on the learner's learning behavior and profiling. The learning performance evaluation module will provide an assessment to gauge learners' level of knowledge and understanding of the course. The adaptive learning task module and adaptive learning content module are the learning activities and the recommended content, respectively, to help learners in the learning experiences. The learning visualization module will provide learner learning behavior and recommendations regarding the learning goal, performance score, pedagogy, and frequently used learning content. This information can be accessed by individual learners and updated learner's profile as the learning continues. The learning support module allows tutors to help with a personal message to improve learners' learning experiences.

The new generation of teaching is more than just books and lecture notes. Technology advancements have made it possible to use various sources for teaching and learning. A smart camera deployed inside classrooms can also capture live lectures and save them to the cloud for later use. If students miss a classroom session, they can watch the lectures whenever they choose because they are saved on the cloud and accessible from anywhere. This bridges the digital gap while also allowing for more learning time. It also eliminates the requirement for copying lecture notes from peers at later levels.

Teachers can also offer homework to their students using a smart web interface that allows them to grade the homework and provide comments to their students. This eliminates physical labor while enhancing instructor and student efficiency. Hands-on practice with the concepts can be provided using the virtual lab setting. Students can access these laboratories using any handheld device or laptop with basic internet connectivity. This can significantly minimize the cost of purchasing lab equipment, machinery, computers, and other such items, as well as the physical space required.

Conclusion

The development of technologies that are smart, mobile, and capable of sensing mobile environments enables the creation of a smart learning environment that can cater to a variety of educational requirements. Nonetheless, despite a growing corpus of research on the smart learning environment, there is a scarcity of well-defined models that describe how the modules of a smart learning environment can be represented and incorporated into a pedagogical AI-smart learning environment. This chapter explored and extended the modules in the smart learning environments with pedagogical support and learning visualization modules, which can support inclusive educational opportunities to meet the needs of diverse learners and promote interaction and authentic learning experiences.

The model can be built and supported by algorithms based on artificial intelligence and technology related to smart and mobile devices to develop an integrated application for individualized learning assistance. Augmented reality can help promote the creation of a smart learning environment. This technology incorporates learning difficulties into a digital world similar to the actual world to assist students in studying at their own speed. For example, an AI algorithm can be integrated into the inference engine of the modules to support recommended systems for adaptive learning contents, performance evaluation, learning status, etc. The model will be experimented with to validate its applicability to produce accuracy in predicting students' learning behavior and needs using an AI algorithm. The algorithm will then be integrated and developed with other modules into an application to support inclusive learning experiences.

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References

Cao, W., Wang, Q., Sbeih, A., & Shibly, F. H. A. (2020). Artificial intelligence based efficient smart learning framework for education platform. *Inteligencia Artificial*, *23*(66), 112-123.

Canţer, M. (2013, July). A hybrid model for an e-learning system which develops metacognitive skills in students. In *International conference on human Interface and the Management of Information* (pp. 9-15). Springer, Berlin, Heidelberg.

Chen, N. S., Cheng, I., & Chew, S. W. (2016). Evolution is not enough: Revolutionizing current learning environments to smart learning environments. *International Journal of Artificial Intelligence in Education*, *26*(2), 561-581.

Dash, S., Mohapatra, C & Behera, P. (2017). Technologies for smart learning. Developing countries. University of Sussex, 2014.

Egielewa, P., Idogho, P. O., Iyalomhe, F. O., & Cirella, G. T. (2021). COVID-19 and Digitized education: Analysis of online learning in Nigerian higher education. *E-Learning and Digital Media*, *19*(1), 19-35.

Freigang, S., Schemer, L., & Koehler, T. (2018). An Interdisciplinary Framework for Designing Smart Learning Environments. In *Challenges and Solutions in Smart Learning* (pp. 17-20). Springer, Singapore.

García-Tudela, P. A., Premeds-Espinosa, P., & Solano-Fernandez, I. M. (2021). Smart learning environments: basic research towards the definition of a practical model. *Smart Learning Environments*, *8*(1), 1-21.

Hwang GJ, Tsai CC, & Yang SJH (2008). Criteria, strategies, and research issues of context-aware of ubiquitous learning. *Educ. Technol. Society*, 11(2):81–91.

Hwang, G. J. (2014). Definition, framework, and research issues of smart learning environments context-aware ubiquitous learning perspective. *Smart Learning Environments*, *1*(1), 1-14.

Huang, R., Yang, J., & Zheng, L. (2013). The components and functions of smart learning environments for easy, engaged, and effective learning. *International Journal for Educational Media and Technology*, *7*(1), 4-14.

Iqbal, Hafiz, Roberto Parra-Saldivar, Ricardo Zavala-Yoe & Ricardo A. Ramirez-Mendoza. "Smart educational tools and learning management systems: supportive framework." *International Journal on Interactive Design and Manufacturing (IJIDeM)* 14, no. 4 (2020): 1179-1193.

Khan, F., & Alotaibi, S. R. (2021). A Novel Architecture for Smart Learning based on Soft Computing. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, *12*(6), 1-10.

Mulyadi, D., Huda, M., & Gusmian, I. (2022). Smart learning environment (SLE) in the fourth industrial revolution (IR 4.0): practical insights into online learning resources. *International Journal of Asian Business and Information Management (IJABIM)*, *13*(2), 1-23.

Mulyadi & Gusmian, 2022; Nguyen *et al*., 2022; Iqbal et al., 2020; Cao *et al*., 2020; Sumadyo, et al., 2018; Huang, R., Yang, J., & Zheng, L. (2013).

Nguyen, Lan Thi, Issara Kanjug, Grichawat Lowatcharin, Theeradej Manakul, Kornwipa Poonpon, Weerachai Sarakorn, Anucha Somabut, Niwat Srisawasdi, Saksuriya Traiyarach, and Kulthida Tuamsuk. "How teachers manage their classroom in the digital learning environment–experiences from the University Smart Learning Project." *Heliyon* 8, no. 10 (2022): e10817.

Vesin, B., Mangaroska, K., & Giannakos, M. (2018). Learning in smart environments: user-centred design and

analytics of an adaptive learning system. *Smart Learning Environments*, *5*(1), 1-21.

Peng, H., Ma, S., & Spector, J. M. (2019). Personalized adaptive learning: An emerging pedagogical approach enabled by a smart learning environment. *Smart Learning Environments*, *6*(1), 1-14.

Sumadyo, M., Santoso, H. B., & Sensuse, D. I. (2018, March). Metacognitive components in the smart learning environment. In *Journal of Physics: Conference Series* (Vol. 978, No. 1, p. 012025). IOP Publishing.

Schunk, D. H. (2002). Learning Theories An Educational Perspective Third edition.

Rosmansyah, Y., Putro, B. L., Putrid, A., Utami, N. B., & Suhardi. (2022). A simple model of the smart learning environment. *Interactive Learning Environments*, 1-22.

Serba, C & Loan, L. (2020). QLearn: Towards a framework for smart learning environments. 24th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems. Procedia Computer Science 176 (2020) 2812–2821

Serrano Iglesias, S., Spikol, D., Bote Lorenzo, M. L., Ouhaichi, H., Gómez Sánchez, E., & Vogel, B. (2021). Adaptable Smart Learning Environments supported by Multimodal Learning Analytics. In *European Conference on Technology Enhanced Learning, EC-TEL 2021*

Westbrook J. Durrani N. Brown R. Orr D. Pryor J. Boddy J. & Salvi F. (2014). Pedagogy, curriculum, teaching practices, and teacher education in developing countries. University of Sussex

Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart learning environments*, *3*(1), 1-17.

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