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Smart Classroom Adoption in Higher Education: A Thematic Review

Mohd Zairul[1,2], Ismi Arif Ismail[1], Mohd Azli Mohamad Jamil[2], Aznida Azlan[2], Ida Suriana Ismail[2], Habibah Ab Jalil[3] & Nurfadhlina Mohamad Sharef[4]

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Abstract

Smart classroom has become a much popular terms in 21st century education recently. The concept of intelligence has created interest among the key players in higher education especially in the era IR 4.0. However, prior research revealed that there is no review paper that talks about the patterns in smart classroom adoption in the higher learning. Hence, this article will conduct a thematic review on the selected publications to explore the direction of this initiative until recent years. The aim of this thematic review is to synthesize literature from 2017 to 2021 on the smart classroom strategies in the higher education using thematic review (TR). A keyword search, followed by a filter using inclusion criteria from SCOPUS, WoS and Science Direct databases, identified 116 peer-reviewed journal articles. However, after the inclusion and exclusion process, only 79 articles were used as the final articles to be reviewed. A thematic review of the 79 articles identified four themes characterizing space, technology, pedagogy and feedback. The results benefit the future study on smart classroom research and what can be the future directions of the study. However, this study only limited to database from SCOPUS, WoS and Science direct for the purpose of thematic review.

Keywords: Smart Classroom, Future Classroom, Higher Education, 21st Century, Ir 4.0, Thematic Review

Introduction

Smart classroom has become a much popular terms in 21st century education recently. The concept of intelligence has created interest among the key players in the higher education especially in the era IR 4.0. Much has been written about the use of technology in the classroom. The term “smart” has become associated with a technology-enhanced classroom. In this paper, we offer a different take on the term “‘smart’ classroom.” A “smart” classroom is one in which the educator and the learners alike engage in a transformative process. Technology may be part of that process, but it is just a means to an end. In general, the term ‘smart classroom’ refers to a physical classroom that integrates advanced forms of educational technology to increase the instructors' ability to facilitate students' learning and the students' ability to participate in formal educational learning experiences beyond the

possibilities of traditional classrooms (Li et al., 2019). Albeit, another definition of smart classroom is a physical classroom that incorporates advanced technology in education in order to enhance the teachers' ability to facilitate students' learning and the students' capabilities to take part in formal educational teaching and learning experiences over the possibilities of normal classrooms (Selim et al., 2020).

In terms of smart environments, there is growing interest in enhancing the capabilities of smart classrooms worldwide. Smart classrooms are educational spaces that incorporate technology in a variety of ways, from the incorporation of digital devices and learning software to the incorporation of sensor networks that assist in tracking classroom processes, gathering data, and providing insights to aid in decision-making for better and faster learning, as well as to provide more convenient teaching and learning conditions for educators (Cebrian et al., 2020). Several studies associated smart learning with a sustainable campus and sustainable competencies (Huang et al., 2019). As a result, a feasible architecture for the construction and operation of smart classrooms is critical for a smart campus. However, Wi-Fi connection remains a problem in certain campuses thus make it almost impossible to make seamless connection (Almarabeh et al., 2016).

The management of classrooms, facilities in the university, as well as sustainable usage remains a problem to many universities and higher education (Enugala & Vuppala, 2018). Numerous solutions, including automatic recording of activities and real-time monitoring of resource usage in classrooms, are being introduced and invested. Numerous solutions, including automatic recording of activities and real-time monitoring of resource usage in classrooms, are implemented. Using students' attendance-monitoring systems as an example, instructors previously had to call students' names or require students to sign their names on attendance check sheets (Enugala & Vuppala, 2018). Thus, IoT and cloud computing technologies can help create a smarter, more sustainable campus by enhancing students' learning methods and increasing the efficiency of daily institutional operations. Nevertheless, prior research revealed that there is no review paper that talks about the trends in smart classroom adoption in the higher learning and the decision to implement this strategy in the higher education. Therefore, the underpinning of this paper is to investigate the patterns and trends in the publications from the year 2017-2021 through the following research question:

What is the focus of the literature on smart classrooms from 2017 to 2021?

Materials and Methods

The term thematic review using ATLAS.ti 9 as the tool as being introduced by Zairul (2021); Zairul (2020) is implemented because the method of this study applies thematic analysis procedure in a literature review. Clarke & Braun (2013) define thematic analysis is a process of identifying the pattern and construct themes over thorough reading on the subject. In comparison to other types of review procedures, TR, or Thematic Review, was chosen because it gives researchers a lot of leeway in analysing data and allows them to approach vast data sets more easily by categorising them into broad topics. The following step is to identify the pattern and construct category to understand the trend of smart classroom in the literature. The tenets of the research are to analyse and interpret the findings for the recommendation of future research in smart classroom topic. The selection of literature was performed according to several selection criteria: 1) publication from 2017- 2021; 2) Have at least keyword(s) smart classroom or future classroom or intelligent classroom, 3) Focusing on Higher Education (HEI's). The sources of literature were the research databases from Web Science of Clarivate Analytics and Scopus of Elsevier and Science Direct. The Network of

Science was chosen because it will hit all indexed journals with a measured impact factor in the Journal Citation Report (JCR) (Carvalho et al., 2013). Science Direct, owing to the multidisciplinary nature of research and multiple sources, and Scopus was chosen as it has the largest collection of peer-reviewed publications. A filter was applied in the Web of Science using “type of documents”, article types, and proceedings papers, NOT review paper. The analysis criteria were contained in the other datasets: “Title, Keywords, and Abstract”.

Table 1
Search strings from selected databases

SCOPUS	(TITLE-ABS-KEY ("Smart classroom" OR "Future Classroom") OR TITLE-ABS-KEY ("Future classroom") AND TITLE-ABS-KEY (higher AND education) AND TITLE-ABS-KEY (higher AND institution)) Year 2017-2021	**14 results**
WoS	("smart class*" OR "future class*" OR "intelligent class*") AND TOPIC: (higher education) AND TOPIC: (higher learning) Refined by: DOCUMENT TYPES: (ARTICLE) Timespan: Last 5 years (Year 2017-2021) Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI.	**9 results**
Science Direct	"future classroom" OR "smart classroom" OR “intelligent classroom” AND “higher education” Year 2017-2021	**70 results**

In this paper different strategies were used to ensure the right publications were obtained. In the SCOPUS searching, the article used (TITLE-ABS-KEY ("Smart classroom" OR "Future Classroom") OR TITLE-ABS-KEY ("Future classroom") AND TITLE-ABS-KEY (higher AND education) AND TITLE-ABS-KEY (higher AND institution)) however the search is limited to year of 2017 until 2021. In the WoS searching the search strings were using ("smart class*" OR "future class*" OR "intelligent class*") AND TOPIC: (higher education) AND TOPIC: (higher learning) with the same limitation of year. The Science Direct search is much more straightforward, which resulted in a greater number of responses to the 70 results (table 1).

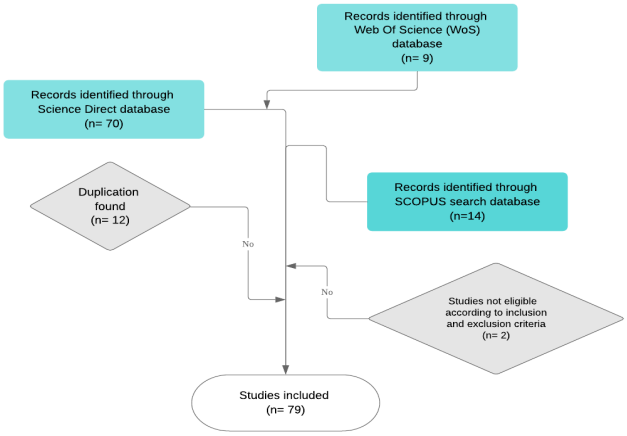


Figure 1: Inclusion and Exclusion criteria for thematic review (Zairul, 2020)

The initial search came out with 14 articles from SCOPUS, 9 from WoS and 70 articles from Science Direct. However, 12 articles were removed due to their premature results and anecdotes and 2 articles were not discussing on smart classroom patterns and trends in the higher education. Only English articles were selected for the final inclusion. Some of the articles were also found incomplete, or the full articles are not accessible, have a broken link and overlapped. Therefore, the final paper to be reviewed down to 79 articles (table 1). The articles were uploaded in the ATLAS.ti 9 as primary documents, and then each paper was grouped into 1) author; 2) issue number; 3) periodical, 4) publisher, 5) volume and 6) year of publication. In doing so, the articles can be analysed according to the year it was published and what is the discussion pattern according to the year. The total articles finalised into the final documents in the ATLAS.ti 9 is 79 documents (figure 1).

Search Documents

ID	Name	Media Type
D 61	Songkram (2017) - Virtual smart classroom to enhance 21 st century skills in learning and innovation for highe...~	Text
D 62	Songkram (2021) - Developing Students' Learning and Innovation Skills Using the Virtual Smart Classroom~	PDF
D 63	Tissenbaum (2019) - Developing a smart classroom infrastructure to support real-time student collaboration an...	Text
D 64	Tripathi (2020) - Modern Smart Classroom-Based Touch Technology Using Digital Image Processing	Text
D 65	Unggyoung (2019) - Implementation of Smart Learning in Korean Education Using the Smart Classroom Respo...	Text
D 66	Wang (2017) - A Pad-Based Multi-Device Collaborative Teaching Software Architecture for Smart Classroom~	Text
D 67	Wang (2018) - Research on the Design of College Smart Classroom Teaching Mode under the Background of ``...~	Text
D 68	Yan (2019) - Research and Application of a High-efficiency Teaching Framework Based on Smart Classroom~	Text
D 69	Zeng (2019) - Design of intelligent classroom attendance system based on face recognition~	PDF
D 70	Zhan (2020) - A Construction Framework Design of Smart Classroom in Universities Based on Pedagogy-Spac...~	Text
D 71	Zhan (2021) - Smart classroom environments affect teacher-student interaction: Evidence from a behavioural se...	Text
D 72	Zhang (2017) - Exploration of Blended Teaching Pattern based on Hstar and Smart Classroom~	Text
D 73	Zhang (2017) - Future Classroom Design of Teaching from the Perspective of Educational Technology~	Text
D 74	Zhang (2018) - Research of Smart Classroom Design based on Big Data~	Text
D 75	Zhao (2019) - Role of teaching assistants in synchronous smart classrooms	PDF
D 76	Zhou (2017) - Fostering Elementary Student's Collaborative Knowledge Building in Smart Classroom with For...~	PDF
D 77	Zhou (2018) - The influence of debating teaching on students' critical thinking development in smart classroom	Text
D 78	Deng (2019) - Smart learning environment: A case on the construction of smart classrooms in colleges and univ...	PDF
D 79	Haghighi (2021) - Automation of Recording in Smart Classrooms via Deep Learning and Bayesian Maximum a P...	PDF

Figure 2: Documents extracted from Mendeley database

The documents were then filtered further in Mendeley to ensure that the metadata for the articles used the APA format for the authors' names, including their first and last names. The publication dates were also double-checked to ensure there are no errors in the Mendeley library. Additionally, the publication dates were verified to ensure that there are no errors in the Mendeley library. While some of the articles discovered do not contain the full text, the author ensured that the abstract was captured to grasp the article's essence. During this round, a laborious process was used to ensure that all necessary information was available prior to the data being transferred to ATLAS.ti for the thematic review process (figure 2).

Results and Discussions

The results of this thematic review are divided into two parts Quantitative and Qualitative results. In the quantitative section, the report calculated descriptive statistics based on the geographical dispersal of the publications and what are the research patterns in every country (figure 3). Next, the paper discovers the country vs publication according to year (figure 4).

Here we can see how the study being developed from 2017 until recent. Subsequently, the review generates a table on what are the themes generated from each paper discovered from 2017 till 2021 (figure 5).

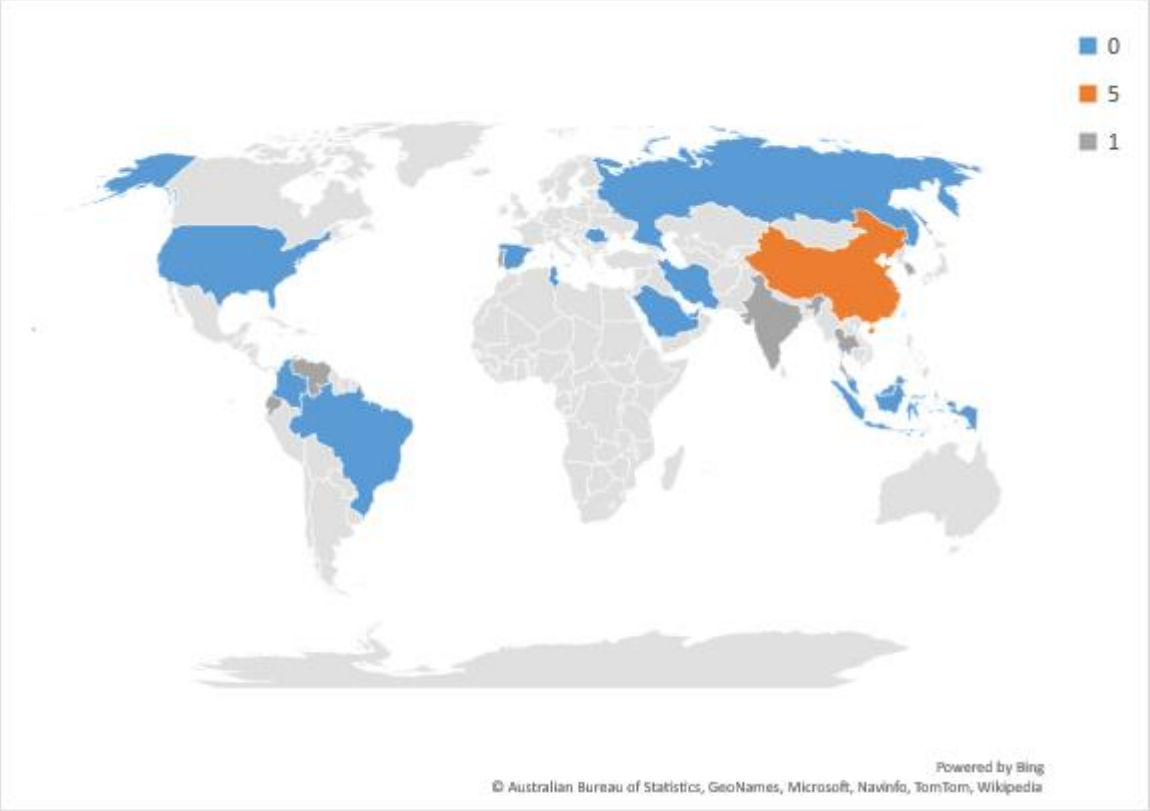


Figure 3: Geographical dispersal of studies on smart classroom

The geographical distribution of studies on smart classrooms is depicted in Figure 3. The study of smart classroom literature entails a range of studies on the topic's application, pedagogical framework, and fundamentals. The trends according to figure below shows the highest contributor from China with 43 percent of the studies from the year span of 2017 until recent year. Numerous Chinese studies focus on the technology appliances used in smart classrooms, such as the secure programmable edge network system from Nsunza et al., (2018) and data mining and learning analysis in the smart classroom (Liu et al., 2018). Several pedagogical models were introduced including the instruction model of learning by Chen et al (2018) and a study on students' cognitive learning outcome in the smart classroom (Shi et al., 2020). Subsequently, India in the 2nd place with 15 percent of contribution in the statistics. The trends from India can be seen mostly on the IoT application. For example Chauhan & Goswami, (2020) describes the metaheuristic technique based energy aware clustering protocol in the smart classroom. Several augmented reality were introduced by Selvi et al., (2020) and learning analytics by (Naidu et al., 2017).

Next, South Korea with 6 percent of the statistics contributed mainly on the energy consumption in the smart classroom through smart campus strategy (Pirahandeh & Kim, 2017). Ambient intelligence in a smart classroom was proposed to determine students' levels of engagement (Kim, 2019) and supported by a study from Radosavljevic et al (2019) from Russia . USA on the 3rd ranking with most studies focusing on developing a smart classroom infrastructure by Tissenbaum & Slotta (2019) and a framework for instructors to teach in the

smart classroom (Gerritsen et al., 2018). Several studies focusing on MOOC framework for smart classroom (Ayub et al., 2018) in Malaysia and intelligent environment by Mokhtar et al (2018) for Saudi Arabia. The statistics continued by a study from Venezuela 3 articles and Malaysia, Russia, Saudi Arabia, Spain, Thailand, and UAE with each 2 articles while the rest having 1 article for the topic (Figure 4).

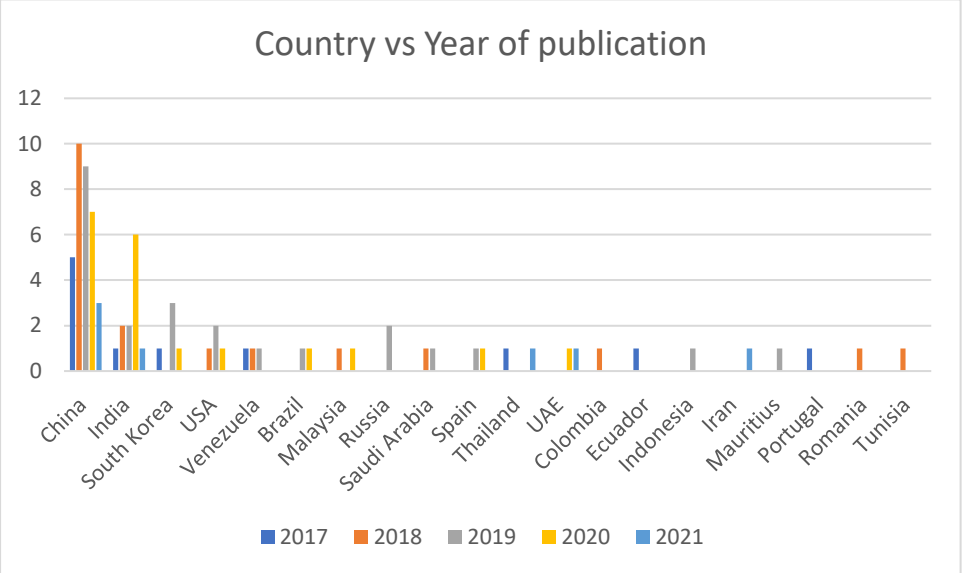


Figure 4: Country vs Publication year

In the following table (table 3), the papers were sorted by the themes established from the coding exercise in the ATLAS.ti 9. ATLAS.ti allows researchers to easily select, categorise, and thematizing the topic based on the abstract and title of the paper. A thematic review process consists of annotation in the margin expressed as codes based on social constructs and author's own interpretation of the topic discussed in the articles. Based on the sorting, 4 main themes were found: feedback, pedagogy, space and technology (Table 3).

	Feedback	Pedagogy	Space	Technology
(Abdellatif, 2019)	-	/	/	/
(Aguilar et al., 2018)	-	/	-	/
(Aguilar et al., 2020)	-	/	-	-
(Aguilar et al., 2019)	-	/	-	/
(Alassery, 2019)	-	-	-	/
(Ani et al., 2018)	-	-	/	/
(Ayub et al., 2018)	-	/	-	-
(Bautista-Perez et al., 2019)	-	-	/	-
(Bhatia & Kaur, 2020)	-	-	-	/
(Cebrian et al., 2020)	-	/	-	/
(Chamba-Eras & Aguilar, 2017)	-	-	-	/
(Chauhan & Goswami, 2020)	-	-	-	/

(Chen et al., 2017)	-	/	-	-
(Chen et al., 2018)	-	/	-	-
(Cui & Xu, 2019)	-	-	-	/
(Dai & Zhang, 2019)	-	/	-	-
(Enugala & Vuppala, 2018)	-	-	-	/
(Banu et al., 2020)	-	-	-	/
(Feng et al., 2020)	-	-	/	-
(Fischer et al., 2019)	-	-	-	/
(Gerritsen et al., 2018)	-	/	-	-
(Gupta et al., 2019)	-	-	-	/
(He, 2020)	-	-	-	/
(Huang et al., 2019)	-	-	/	/
(Huda et al., 2019)	-	-	-	/
(Ivliev, 2019)	-	/	-	-
(Jiahua et al., 2018)	-	-	/	-
(Jiang et al., 2020)	-	/	-	-
(Kim et al., 2018)	-	-	-	/
(Radosavljevic et al., 2019)	-	-	-	/
(Nikhath et al., 2021)	-	/	-	-
(Kwet & Prinsloo, 2020)	-	/	-	-
(Lee et al., 2019)	-	-	/	/
(Li et al., 2019)	-	-	-	/
(Li et al., 2020)	-	-	-	/
(Yingjie Li & Chen, 2020)	-	-	-	/
(Lin et al., 2019)	-	/	-	-
(Liu et al., 2018)	-	-	-	/
(Lu et al., 2021)	-	/	-	-
(MacLeod et al., 2018)	/	-	-	-
(Miraoui, 2018)	-	-	/	/
(Mokhtar et al., 2018)	-	-	/	/
(Nagowah et al., 2019)	-	-	-	/
(Naidu et al., 2017)	-	-	-	/

(Nsunza et al., 2018)	-	-	-	/
(Pacheco et al., 2018)	-	-	-	/
(Paudel et al., 2020)	-	-	-	/
(Paul et al., 2019)	-	-	-	/
(Phoong et al., 2020)	/	-	-	-
(Pigatto & Nunes, 2020)	-	-	-	/
(Pirahandeh & Kim, 2017)	-	-	-	/
(Popescu et al., 2018)	-	-	-	/
(Premalatha & Hari Krishnan, 2020)	-	-	-	/
(Qin, 2021)	/	-	-	-
(Radosavljevic et al., 2019)	/	-	-	/
(Sardinha et al., 2017)	-	-	/	/
(Selim et al., 2020)	/	-	-	-
(Selvi et al., 2020)	-	-	-	/
(Shi et al., 2018)	/	-	-	-
(Shi et al., 2020)	/	-	-	-
(Songkram, 2017)	/	-	/	-
(Songkram et al., 2021)	-	/	-	-
(Tissenbaum & Slotta, 2019)	-	-	/	-
(Tripathi et al., 2020)	-	-	/	/
(Unggyoung, 2019)	-	/	-	-
(Wang & Wang, 2017)	-	/	-	/
(Wang, 2018)	-	/	-	-
(Yan & Yang, 2019)	-	/	-	-
(Zeng et al., 2019)	-	-	-	/
(Zhan et al., 2020)	-	/	/	/
(Zhan et al., 2021)	/	-	-	-
(Zhang et al., 2017)	-	/	-	-
(Zhang & Zhou, 2017)	-	-	/	-
(Q. Zhang & Li, 2018)	-	-	-	/
(Zhao et al., 2019)	-	/	-	/
(Zhou & Yang, 2017)	-	/	-	-

(Zhou et al., 2018)	-	/	-	-
(Deng & Zhang, 2019)	-	-	/	-
(Haghighi et al., 2021)	-	-	/	/

Figure 5: Paper breakdown according to the themes generated

Table 3: Tabulation of themes according to year of publications

After analysing 79 papers, the data captured the intensity of theme generated from 2017 to 2021. To identify the shared, core findings across these studies, I used the thematic analysis methodology described in introduction. The methodology allowed themes to emerge from the papers, rather than being predetermined through a hypothesis or a theoretical framework. The themes emerged into 4 clusters as being mentioned in table 3 earlier and figure 6 respectively. A study could be coded as addressing more than one theme. The citations that appear here in figure 5 and figure 6 are all to one of the 79 articles included in the study. The themes that were discovered basically discussed the following characters"

- Theme on Feedback: Discuss feedback and conduct an experiment or survey to ascertain the perceptions and feedback of a group of students who have used an existing smart classroom.
- Theme on Pedagogy: Discuss the pedagogical approaches being used or experimented with in the smart classroom.
- Theme on Space: Discuss the space, design, and infrastructure requirements for a smart classroom ecosystem.
- Theme on technology: Discuss the technology that has been implemented or is being considered for use in smart classrooms worldwide.

The Sankey diagram below illustrates the study's intensity (figure 6). The more popular a theme became, the denser it became. As can be seen, the pattern of smart classroom research is heavily reliant on technology. The theme (technology) will reach its zenith in the years 2019 and 2020. Despite the global COVID-19 pandemic, none of the articles mentioned the COVID-related study.

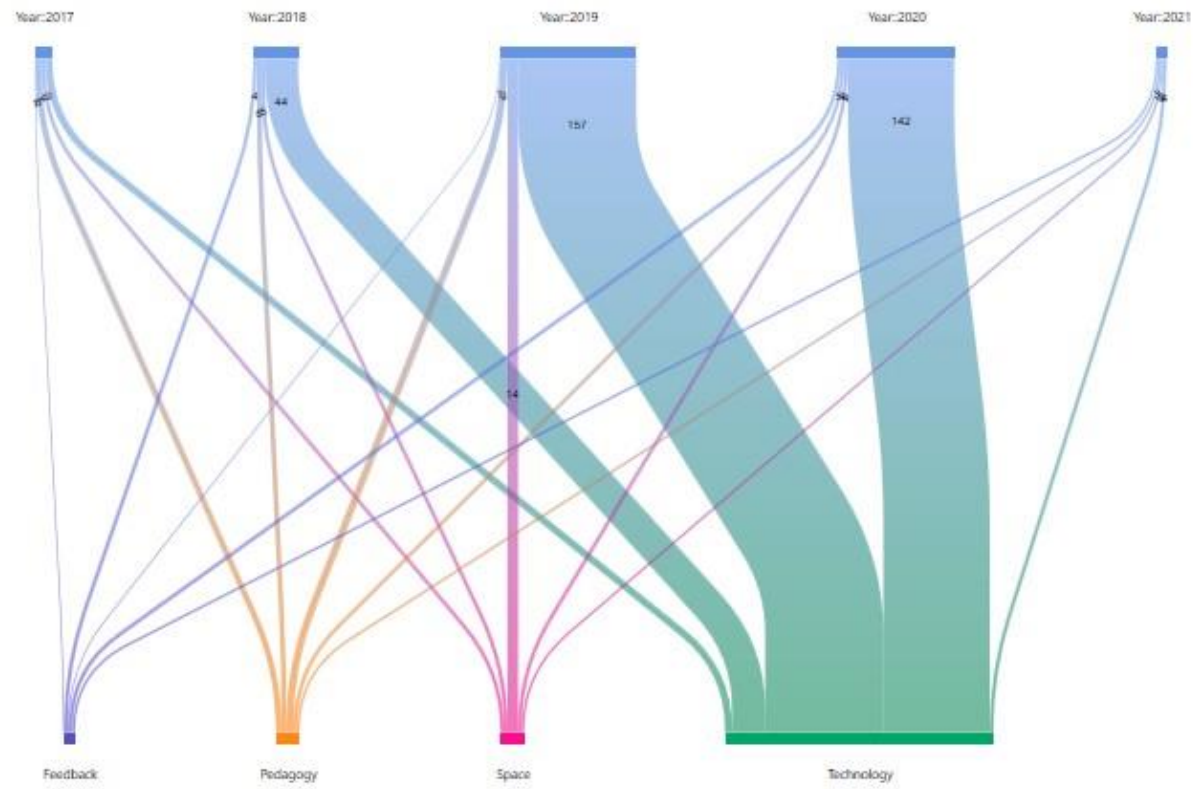


Figure 6: Sankey diagram to show the intensity of research theme

What is the focus of the literature on smart classrooms from 2017 to 2021?

The initial coding resulted in 16 initial codes in the first round. The coding process with ATLAS.ti is like qualitative coding because it supports code-based approaches. ATLAS.ti aides in the analysis and prioritisation of non-linear and non-thematic association tracking. Its emphasis on in-context navigation and retrieval. Data segments are compared, similar discussion and solution were analysed to find the right matching theme. Collecting, coding and analysing data were occurred concurrently. So that the themes shall be reflected in a genuine context. Numerous papers highlighted multiple themes in their publications, which resulted in a homogeneous outcome for the study. The following section will describe and discuss the results of the thematic analysis. Additionally, the themes can be construed as theoretical contexts, disciplines, or areas of investigation (Boyatzis, 1998).

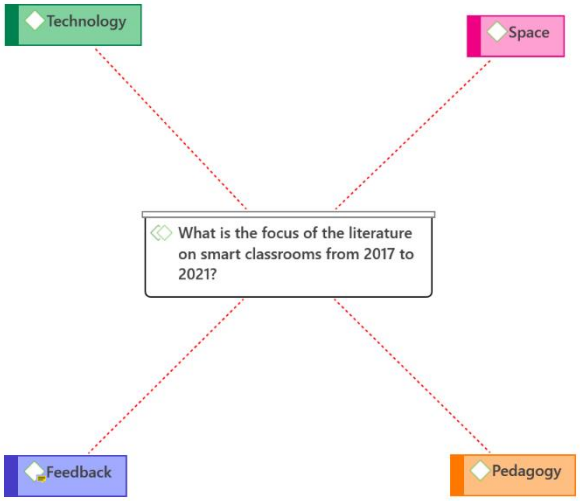


Figure 7: Overall network and how the themes answering the research question

Theme 1 (Pedagogy)

Pedagogical innovations in the smart classroom will enhance the autonomic learning in the smart classroom. A comprehensive mobile learning (m-learning) model is presented in the context of a smart classroom environment as part of a holistic approach to implementing an effective Technology Enhanced Learning (TEL) environment (Al-Hunaiyyan et al., 2017). This is also supported by (Li et al., 2020) that to optimize classroom environments to improve student's learning experience, the present study investigated smart classroom from both pedagogical and technological perspective by a large scale survey considering the five dimensions of resources, environment, enhancement, management, and presentation. According to Abdellatif, (2019), it is important to have a central management system that manages all modules used in the classroom. This notion was supported by Ayub et al (2018) on the designing and developing a MOOC course as smart future classroom in VLE (virtual learning environment). Further, a study has proposed a platform for advanced mathematics based on the internet+. Chen et al (2017) posit that the mutual integration of online and offline learning extends interactive learning between teachers and students, and between students and students, beyond the classroom, fully mobilising learners' initiative and significantly improving their learning interest and quality of learning. Several other pedagogical approach make similar attempt on financial accounting course by Dai & Zhang (2019) and developing students' learning and innovation skills using the virtual smart classroom (Songkram, 2017).

In the US, several approaches and regulations were introduced to provide examples of how technology can enhance pedagogical process among teachers (Kwet & Prinsloo, 2020). Kwet & Prinsloo (2020) further introduces the notion of smart technology in the cities, campus and classroom and further recommend towards best pedagogy to fit the context. In South Korea, a response system was developed to enables students to use a keypad in order to respond to questions posted in the classroom by the teacher using digital presentation (Unggyoung, 2019). Another holistic attempt made by Zhan et al (2020) to establish a framework of smart classroom based on Pedagogy-space and technology. Several studies readdressed the understanding of higher order thinking skills (HoTS) in the smart classroom environment (Lu et al., 2021) and the development of higher-order through a teaching model based on APT (Assessment, Pedagogy, Technology model in the smart classroom (Zhou et al., 2018). Nevertheless, through integrating technology into learning strategies, 21st century students

can develop a variety of abilities through intelligent pedagogy offered in a smart classroom. By collaborating on generative learning (virtual classes) and classroom-based teaching (physical classes), advanced research can be applied.

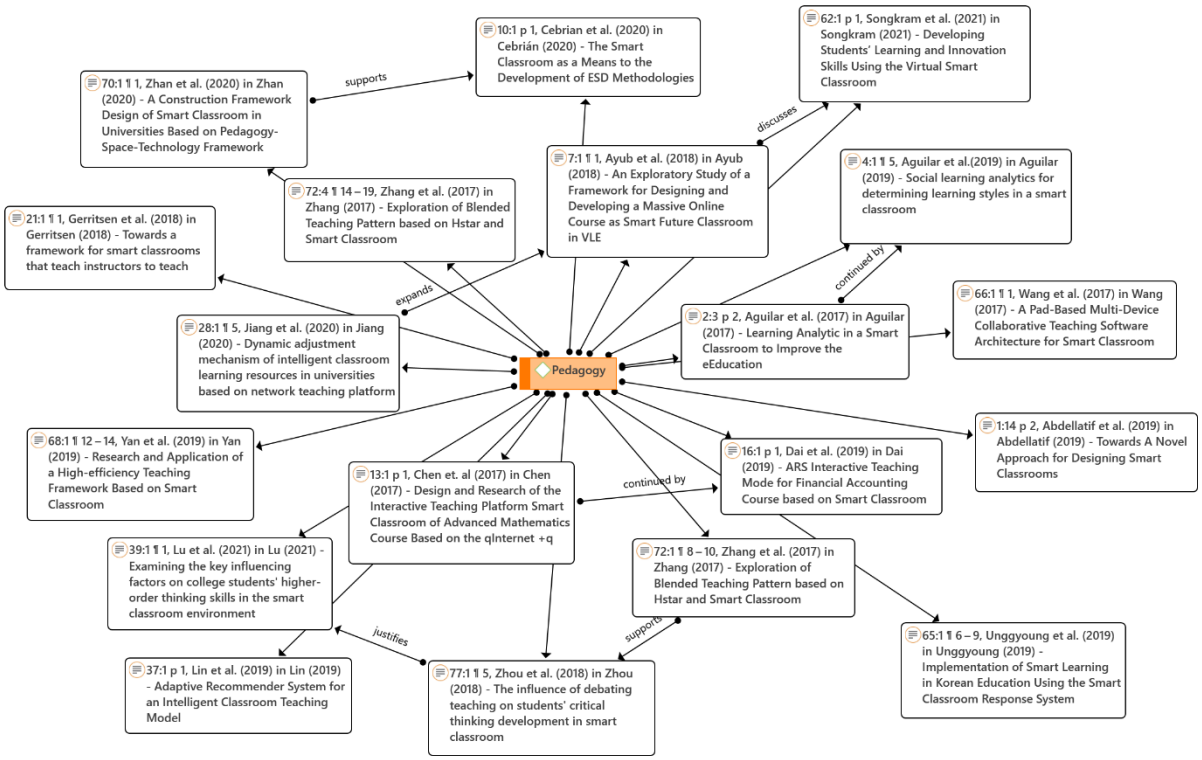


Figure 8: Pedagogy network theme

Theme 2 (Technology)

Higher education institutions, or HEIs, are frequently early adopters of new technology. This is simply because they service a larger clientele, namely students. However, as previously stated, the complexity of the Internet of Things (IoT), combined with the organization's requirements for a particular application, makes it difficult for decision makers to select the appropriate architecture, technology, components, and suppliers (Abdellatif, 2019). Thanks to internet, all classrooms are connected to internet in today's world. This means that classroom objects (projectors, windows, books, and doors, for example) can be transformed into smart objects by adding sensors, RFID, NFC, or BLE Beacons and imparting sufficient intelligence to enable actuator operation and even decision making (Abdellatif, 2019). Scholars divide an intelligent classroom into seven modules: (1) Infrastructure (desks, chairs, and lighting), (2) Network sensors (Radio Frequency Identification (RFID), (3) Human Recognition System (HRS), (4) Augmented reality (networked video conferencing and wearable computing), (5) Real-time recording (course recording and broadcasting systems), (6) Ubiquity technology (cloud services and mobile terminals), and (7) a central management system that manages all of the above (Songkram et al., 2019). However, the majority of the articles found did not discuss how to choose the most appropriate and affordable technology. Several scholars suggested digital students attendance that can facilitate checking absenteism (Alassery, 2019), roll caller system (SCRCS) to track student;s attendance as decribed by (Abdellatif, 2019). Enugala & Vuppala (2018) proposed smart chair system that will automatically check whether the chair is occupied or not by using multiple sensing technologies and smart attendance system using retina detection. Some even go the extend

of introduing Artificial Intelligence to predict student's attendance (Banu et al., 2020). However, there is also a drawback when applying this kind of technology, one described the student tries to do proxy for attendance by scanning RFID card for himself and his friends (Enugala & Vuppala, 2018).

While discussing technology in the smart classroom, the discussion on IoT is inevitable. For example, The Internet of Things (IoT) technology, combined with fog-cloud computing, has enabled the education industry to provide efficient services (Bhatia & Kaur, 2020). Specifically, IoT technology is integrated into the classroom to collect data on students and teachers in order to determine students' academic progress (Bhatia & Kaur, 2020). Moreover, smart Classrooms are educational spaces that incorporate technology in a variety of ways, from the incorporation of digital devices and learning software to the inclusion of sensor networks that assist in tracking classroom processes, collecting data, and providing insights to aid in decision-making for better and faster learning, as well as to provide more convenient teaching and learning conditions for educators and students (Cebrian et al., 2020). Thus, it appears clear that technology must be adapted to pedagogical aspects, responding to educational needs rather than being included as a novel but disconnected solution.

Augmented Reality (AR) has been a popular topic in the technology for smart classroom. Several papers described the application of AR in the smart classroom as multi-agent systems (Chamba-Eras & Aguilar, 2017). The implementation of augmented reality in the classroom has had a positive effect on students' motivation, learning curve, and memorization. (Chamba-Eras & Aguilar, 2017). Recently, The most recent advancements in augmented reality include how this technology can be used to create immersive scenarios that make learning more interactive and relevant to the student (Cebrian et al., 2020). Another experiment made by Cui & Xu (2019) reported an experiment on consumer behaviour and successfully constructed a virtual reality experimental design of a consumption-accompanying environment, which was used in the exploration of experimental economics and management education. Nonetheless, additional research is required to promote AR and the outcomes of its implementation across multiple disciplines of study.

Several study talks about RFID application in the smart classroom to detect classroom's ambient environment (Bhatia & Kaur, 2020), to tag sensor to control attendance (Cebrián et al., 2020), RFID-enabled Smart Attendance (Enugala & Vuppala, 2018) and smart bench in a smart classroom accessed through RFID system (Banu et al., 2020). Hence, RFID can offer a lot of potential to enhance smart classroom in the future. Another aspect that being discussed by several researchers in their paper is the advent of cloud system for classroom management. Smart classrooms are regarded as cloud classrooms, in which objects are manipulated via a cloud-based system (Abdellatif, 2019). Using a cloud system based on Near Field Communication (NFC) technology for time attendance was discussed in the paper by (Alassery, 2019). Further, Bhatia & Kaur (2020) proposed IoT-fog-cloud computing and QGT collaborations provide a novel method for collecting, processing, and making real-time decisions based on ubiquitous data. However, Cui & Xu (2019) argue that the cloud platform in a smart classroom serves the opposite purpose of effectively utilising the smart classroom's potential and enhancing the level of laboratory data operation. Nevertheless, cloud platform mostly associated with internet and big data. A management role in higher education should develop their own cloud system rather than relying on an independent operator to ensure data security.

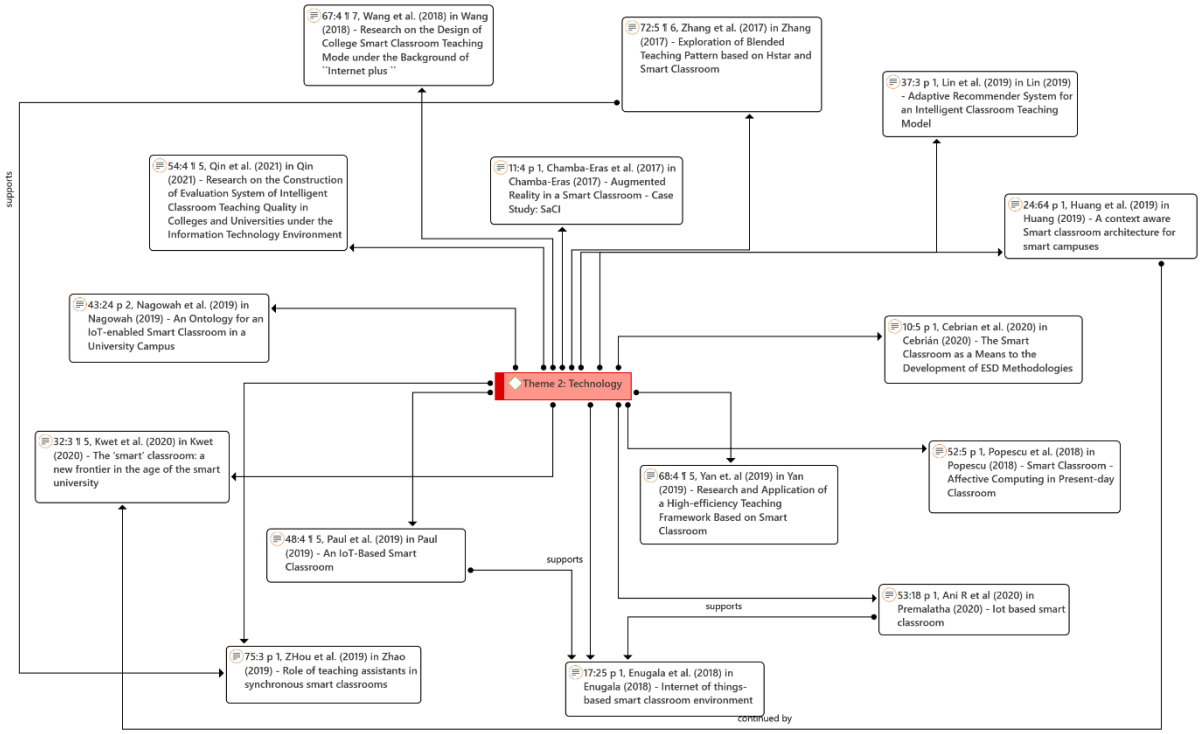


Figure 9: Technology network theme

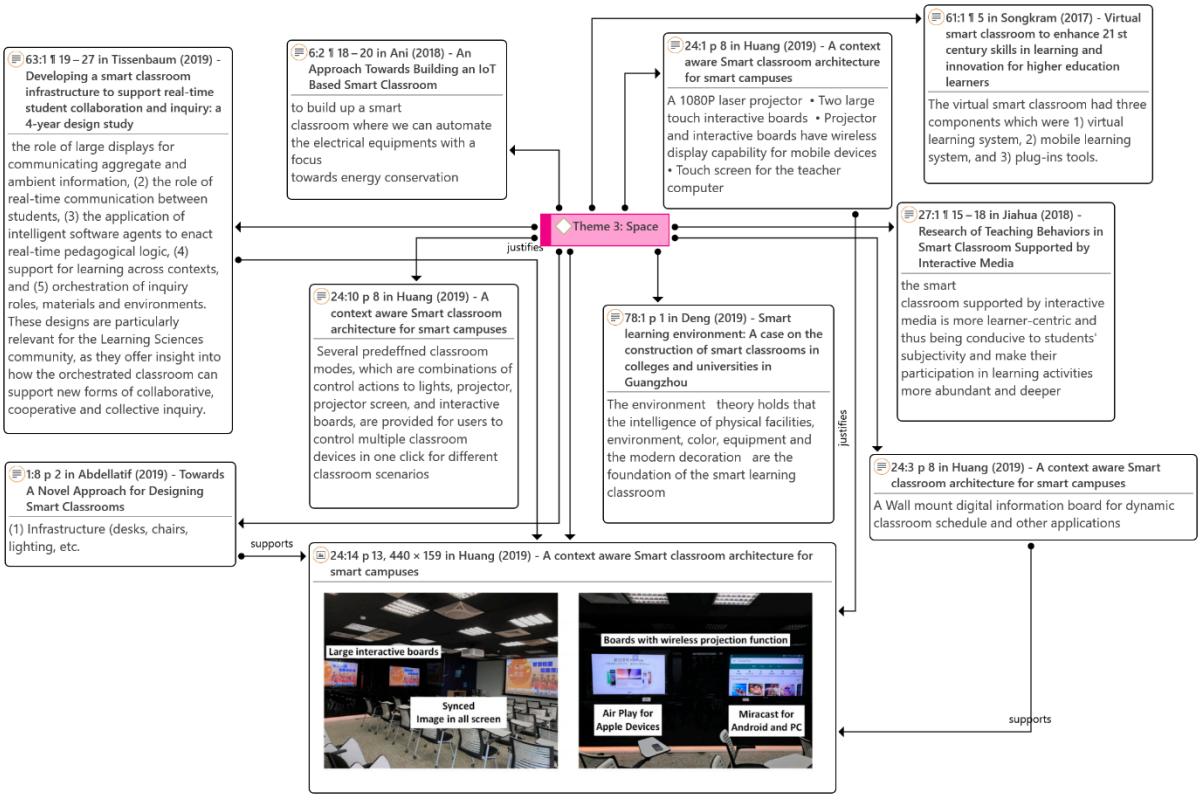
Theme 3 (Space)

A well-designed smart classroom is necessary to maximise teaching effectiveness using appropriate technology. In South Korea, a study by Lee et al (2019) exploring on the design attributes of renovating standardized classroom in the classroom. This change is critical because it has the potential to increase students' active participation and interaction (Tripathi et al., 2020) and supported by a construction of framework design of smart classroom in universities based on pedagogy-Space-Technology framework (Zhan et al., 2020). According to Songkram et al., (2021), it is important to invest in a infrastructure such as desks, chair and lighting in the classroom. Further, to build a smart classroom, preservation of energy should be one's goal (Ani et al., 2018).

Subsequently in a study by Bautista-Perez et al (2019), proposed that a smart classroom should be adaptable, flexible, and have multi-functional spaces, and that all chairs should be swivel to accommodate various modes of learning (Huang et al., 2019). Huang et al (2019) further describes that a smart classroom should have the following features:

- A 1080P laser projector
- Two large touch interactive boards
- Projector and interactive boards have wireless display capability for mobile devices
- Touch screen for the teacher computer
- A dynamic classroom schedule and other applications can be displayed on a wall-mounted digital information board.
- All student chairs are swivel tablet chairs designed for various types of lecturing and group discussion.
- All light sets can be controlled individually
- Several predefined classroom modes, which are combinations of control actions for the lights, projector, projector screen, and interactive boards, are provided to enable

users to control multiple classroom devices with a single click for a variety of classroom scenarios.



In addition, in a research on teaching behaviours in smart classroom Jiahua et al (2018) described that a smart classroom, aided by interactive media, is more learner-centric, fostering students' subjectivity and increasing their participation in learning activities. Additionally, one study describes six fundamental configurations for the various tasks required in the future classroom, including exploration, collaboration, meeting, lecturing, lounging, and presentation (Mokhtar et al., 2018). Nevertheless, an innovative interior design of the smart classroom will promote inclusiveness among students in learning (Sardinha et al., 2017) and active participation and promote active learning (Tripathi et al., 2020). Subsequently, several characteristics of a smart classroom have been established, including pan-network and seamless access, multi-screen display and facilitation of collaboration, classroom record and conducive to self-study, virtual and augmented reality integration and resource expansion, intelligent control, and a people-oriented design concept. (A. Zhang & Zhou, 2017). According to the environment theory, the intelligence of physical facilities, the environment, colour, equipment, and modern decoration all contribute to the smart learning classroom's foundation (Deng & Zhang, 2019). To support this, another study from Yang et al., (2021) experimented on the student's preferences of seating arrangement and found that in (English as foreign language)EFL blended learning classrooms, semicircles generated more student involvement in activities than rows and columns. Students maintained effective communication and focused attention and assessed the semi-circular seating classroom setting to be more compassionate, lively, convenient, and inclusive, resulting in a preference for semicircles and improved performance in class activities. Nonetheless, there is no further discussion of what the ideal spaces should look like in terms of size and a proper design brief to assist in developing the ideal space for a smart classroom for higher education. More discussion should include a more integrated approach in designing an ideal spaces for future classroom ecosystem.

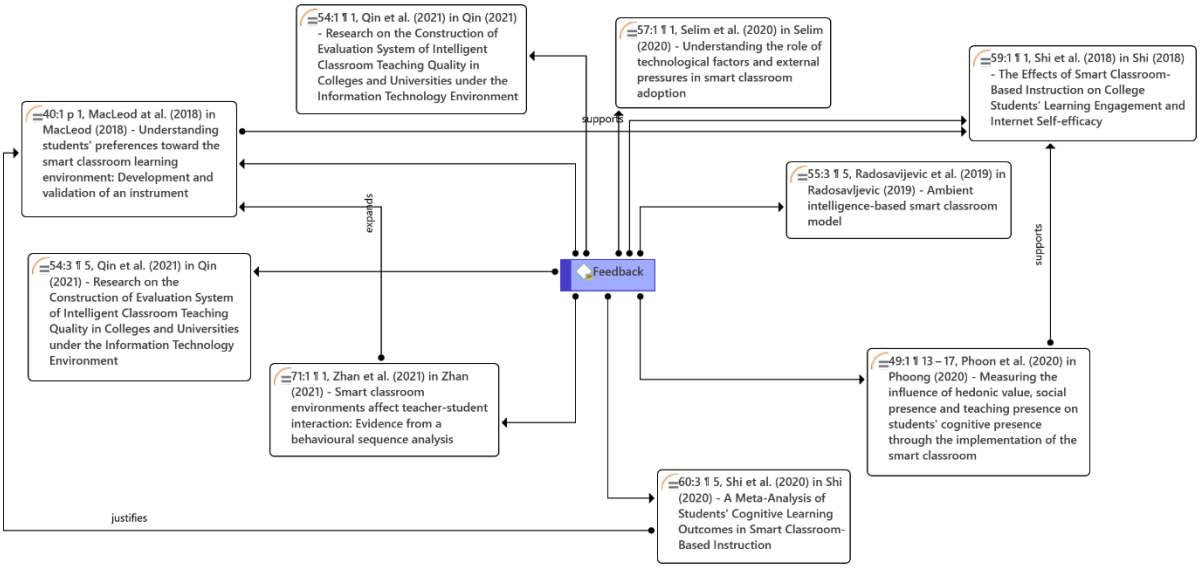
Theme 4 (Feedback)

More intelligent classroom teaching mode has been developed because of the close integration of modern information technology and university education. Numerous papers discussed its characteristics, benefits, feedback, and effect on the students who occupy it. MacLeod et al (2018) developing an instrument to measure the validity and reliability in a higher education context. They discover that there were no gender differences in preferences, and the instrument was found to be a valid and reliable tool for assessing college students' preferences for a smart classroom learning environment. The study assesses students' preferences for a smart classroom environment using eight criteria, including student negotiation, inquiry learning, reflective thinking, ease of use, perceived usefulness, multiple sources, connectedness, and functional design (MacLeod et al., 2018).

Subsequently, in a study by Phoong et al (2020) students in smart classrooms reported greater cognitive presence and comprehension compared to their counterparts in conventional classrooms. Multiple regression analysis was used to determine the relationship between cognitive presence and teaching, social presence, and hedonic value. Recently, another study examined the teaching quality in the smart classroom environment by studying the characteristics, process, and teaching effect (Qin, 2021). Another study investigates how the environment of the smart classroom affects students' performance in order to provide students with an adequate learning strategy. The study proves that ambient in the smart classroom is important to produce desired results among students (Radosavljevic et al., 2019). The author, however, did not go into detail about the acquired ambience necessary to promote a sound strategy in the smart classroom.

Even though smart classroom adoption is increasing in higher education globally, the factors influencing smart classroom adoption have not been adequately explored. Therefore, Selim et al (2020) posited that they proposed the first study using innovation diffusion theory to understand the smart classroom adoption in the higher education. The findings indicate that innovation diffusion theory and external pressures provide an adequate model for comprehending the adoption of smart classrooms (Selim et al., 2020). In another study, a quasi-experiment was conducted between smart classrooms and conventional classrooms on a sample of 96 freshmen at one of China's universities. The experiment revealed that students who received instruction in a smart classroom had a significantly higher level of learning engagement and internet self-efficacy than students who received instruction in a traditional classroom, indicating that when used in conjunction with an appropriate instructional approach, using smart classrooms can increase students' learning engagement and internet self-efficacy (Shi et al., 2018).

Several previous studies demonstrated that numerous experiments and surveys were conducted with students, teachers, and stakeholders to ascertain the smart classroom's efficiency toward its users. It can be assured that the moving toward smart classroom create positivity in the outcome of all stakeholders. However, universities must provide training to assist teachers in developing their technological, pedagogical, and content knowledge, familiarising themselves with smart classroom infrastructure, and providing technical support during class. Additionally, students must be exposed to technology without burning a hole in their pockets for unnecessary gadgets. At the end of the day, technology should assist users, not add to their burdens.



Discussion and Future Studies

Smart classrooms can significantly assist university's lecturers in focusing on the learning needs of their students and ensuring a positive learning experience. Creating and implementing a smart classroom, on the other hand, is not an easy task. As an information technology system involves security and safety issues, smart classrooms must adhere to all university requirements. These requirements are different from one organization to another. Undoubtedly, IoT (Internet of Things) is a dynamic innovation with a significant impact on today's world that has the potential to simplify and automate human life especially for the education in the higher education. Higher education institution (HEI's) should be the role model to transform the future of education in the country. A smart classroom must be effective and efficient, providing the optimal environment for teaching and learning (Al-Sharhan, 2016), and must be simple to use in order to avoid users becoming discouraged due to technical difficulties. A smart classroom must also be engaging and motivating; this is dependent not only on the system, but also on how users behave and interact, as well as on their willingness to maximise space utilisation (Cebrian et al., 2020). Furthermore, to rethink and redesign learning spaces for smart classroom, it is essential to develop a comprehensive strategy including the way to teach (pedagogy), what type of technology required (technology) and in what type of ambient (space). This includes designing learning spaces that maximise resource efficiency, creating optimal environmental conditions, utilising innovative ICT, and adapting furniture to engage students in the true meaning of a smart classroom holistically.

Contributions and Benefits of Study

The study will contribute to the body of knowledge regarding smart classroom literature and may provide some direction for future research on smart classroom. The study aims to assist stakeholders in higher education in making decisions about the direction of their universities' smart classroom infrastructure.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Abdellatif, I. (2019). Towards A Novel Approach for Designing Smart Classrooms. *2019 IEEE 2nd International Conference on Information and Computer Technologies (ICICT)*, 280–284. https://doi.org/10.1109/INFOCT.2019.8711355

Aguilar, J., Buendia, O., Pinto, A., & Gutierrez, J. (2019). Social learning analytics for determining learning styles in a smart classroom. *Interactive Learning Environments*, 1–17. https://doi.org/10.1080/10494820.2019.1651745

Aguilar, Jose, Altamiranda, J., & Diaz, F. (2020). Specification of a Managing Agent of Emergent Serious Games for a Smart Classroom. *IEEE Latin America Transactions*. https://doi.org/10.1109/TLA.2020.9049461

Aguilar, Jose, Sanchez, M., Cordero, J., Valdiviezo-Diaz, P., Barba-Guaman, L., & Chamba-Eras, L. (2018). Learning analytics tasks as services in smart classrooms. *Universal Access in the Information Society*, *17*(4), 693–709. https://doi.org/10.1007/s10209-017-0525-0

Al-Hunaiyyan, A., Al-Sharhan, S., & Alhajri, R. (2017). A New Mobile Learning Model in the Context of the Smart Classrooms Environment: A Holistic Approach. *International Journal of Interactive Mobile Technologies (IJIM)*, *11*(3), 39. https://doi.org/10.3991/ijim.v11i3.6186

Al-Sharhan, S. (2016). Smart classrooms in the context of technology-enhanced learning (TEL) environments: A holistic approach. In *Transforming Education in the Gulf Region: Emerging Learning Technologies and Innovative Pedagogy for the 21st Century*. https://doi.org/10.4324/9781315621586

Alassery, F. (2019). A Smart Classroom of Wireless Sensor Networks for Students Time Attendance System. *2019 9TH IEEE INTEGRATED STEM EDUCATION CONFERENCE (ISEC)*, 324–331. https://doi.org/10.1109/ISECon.2019.8881998

Almarabeh, T., Majdalawi, Y. K., & Mohammad, H. (2016). Internet Usage, Challenges, and Attitudes among University Students: Case Study of the University of Jordan. *Journal of Software Engineering and Applications*, *09*(12), 577–587. https://doi.org/10.4236/jsea.2016.912039

Ani, R., Krishna, S., Akhil, H., & Arun, U. (2018). An Approach Towards Building an IoT Based Smart Classroom. *2018 INTERNATIONAL CONFERENCE ON ADVANCES IN COMPUTING, COMMUNICATIONS AND INFORMATICS (ICACCI)*, *9*(2), 2098–2102. https://doi.org/10.1109/ICACCI.2018.8554869

Ayub, E., Wei, G. W., Luaran, J. E., & Leong, L. C. (2018). An Exploratory Study of a Framework for Designing and Developing a Massive Online Course as Smart Future Classroom in VLE. *ICEBT 2018: PROCEEDINGS OF THE 2018 2ND INTERNATIONAL CONFERENCE ON E-EDUCATION, E-BUSINESS AND E-TECHNOLOGY*, 57–62. https://doi.org/10.1145/3241748.3241778

Bautista-Perez, G., Escofet-Roig, A., & Lopez-Cossta, M. (2019). Smart Classroom Project: Learning spaces design based on research. *PRAXIS-COLOMBIA*, *15*(2), 15–22.

Bhatia, M., & Kaur, A. (2020). Quantum computing inspired framework of student performance assessment in smart classroom. *Transactions on Emerging Telecommunications Technologies*. https://doi.org/10.1002/ett.4094

Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development. In *Transforming Qualitative Information Thematic Analysis and Code*

Development.

Carvalho, M. M., Fleury, A., & Lopes, A. P. (2013). An overview of the literature on technology roadmapping (TRM): Contributions and trends. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2012.11.008

Cebrian, G., Palau, R., Mogas, J., Cebrian, G., Palau, R., & Mogas, J. (2020). The Smart Classroom as a Means to the Development of ESD Methodologies. *SUSTAINABILITY*, *12*(7), 2005–2014. https://doi.org/10.3390/su12073010

Chamba-Eras, L., & Aguilar, J. (2017). Augmented Reality in a Smart Classroom - Case Study: SaCI. *Revista Iberoamericana de Tecnologias Del Aprendizaje*. https://doi.org/10.1109/RITA.2017.2776419

Chauhan, J., & Goswami, P. (2020). An integrated metaheuristic technique based energy aware clustering protocol for Internet of Things based smart classroom. *Modern Physics Letters B*, *34*(22), 2050360. https://doi.org/10.1142/S0217984920503601

Chen, J., Zhou, Z., Xu, X., & Gu, X. (2018). Design and Effectiveness of Instruction model for learning, assessment and utilization in Smart Classroom. In Yang, JC and Chang, M and Wong, LH and Rodrigo, MMT (Ed.), *26TH INTERNATIONAL CONFERENCE ON COMPUTERS IN EDUCATION (ICCE 2018)* , 521–523.

Chen, L., Zhang, H., Cao, J., Bao, J., & Cheng, S. (2017). Design and Research of the Interactive Teaching Platform Smart Classroom of Advanced Mathematics Course Based on the qInternet +q. In Xiao, X and Xue, H and Khan, SAR (Ed.), *3rd International Conference on Social Science and Higher Education (ICSSHE-17)* (Vol. 99, pp. 97–100). https://doi.org/10.2991/icsshe-17.2017.25

Clarke, V., & Braun, V. (2013). Teaching thematic analysis : Overcoming challenges and developing strategies for effective learning Associate Professor in Sexuality Studies Department of Psychology Faculty of Health and Life Sciences University of the West of England Coldharbour Lane Br. *University of the West of England*, *26*, 120–123.

Cui, C., & Xu, Y. (2019). Digital Virtual Simulation Experiment Design of Consumer Behavior in Smart Classroom Scenario. In Xiao, X and Hauer, T and Khan, SAR (Ed.), *PROCEEDINGS OF THE 2019 5TH INTERNATIONAL CONFERENCE ON SOCIAL SCIENCE AND HIGHER EDUCATION (ICSSHE 2019)* (Vol. 336, pp. 907–910).

Dai, S., & Zhang, L. (2019). ARS Interactive Teaching Mode for Financial Accounting Course based on Smart Classroom. *INTERNATIONAL JOURNAL OF EMERGING TECHNOLOGIES IN LEARNING*, *14*(3), 38–50. https://doi.org/10.3991/ijet.v14i03.10104

Deng, X., & Zhang, R. (2019). Smart Learning Environment: A Case on the Construction of Smart Classrooms in Colleges and Universities in Guangzhou. *2019 International Symposium on Educational Technology (ISET)*, 262–264. https://doi.org/10.1109/ISET.2019.00062

Enugala, V. P. R., & Vuppala, S. (2018). Internet of things-based smart classroom environment. *PDGC 2018 - 2018 5th International Conference on Parallel, Distributed and Grid Computing*, 193–198. https://doi.org/10.1109/PDGC.2018.8745883

Faritha Banu, J., Revathi, R., Suganya, M., & Gladiss Merlin, N. R. (2020). IoT based Cloud integrated smart classroom for smart and a sustainable campus. *Procedia Computer Science*, *172*(2019), 77–81. https://doi.org/10.1016/j.procs.2020.05.012

Feng, N., Yang, H. H., Gong, D., & Dai, J. (2020). Exploring Students' Preferences Toward the Smart Classroom Learning Environment and Academic Performance. *Proceedings - 2020 International Symposium on Educational Technology, ISET 2020*. https://doi.org/10.1109/ISET49818.2020.00016

Fischer, I. A., Pereira, E. P., Lopes, V., & Medina, R. D. (2019). Improving efficiency and availability in Smart Classroom environments. In Zhu, H and Wang, J and Zhou, M (Ed.), *PROCEEDINGS OF THE 2019 IEEE 16TH INTERNATIONAL CONFERENCE ON NETWORKING, SENSING AND CONTROL (ICNSC 2019)* (pp. 52–56).

Gerritsen, D., Zimmerman, J., & Ogan, A. (2018). Towards a framework for smart classrooms that teach instructors to teach. *Proceedings of International Conference of the Learning Sciences, ICLS* .

Gupta, S. K., Ashwin, T. S., & Guddeti, R. M. R. (2019). Students' affective content analysis in smart classroom environment using deep learning techniques. *Multimedia Tools and Applications*, *78*(18), 25321–25348. https://doi.org/10.1007/s11042-019-7651-z

Haghighi, M. S., Sheikhjafari, A., Jolfaei, A., Farivar, F., & Ahmadzadeh, S. (2021). Automation of Recording in Smart Classrooms via Deep Learning and Bayesian Maximum a Posteriori Estimation of Instructor's Pose. *IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS*, *17*(4), 2813–2820. https://doi.org/10.1109/TII.2020.3011688

He, G. (2020). Schema Interaction Visual Teaching Based on Smart Classroom Environment in Art Course. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(17), 252. https://doi.org/10.3991/ijet.v15i17.16441

Huang, L.-S. S., Su, J.-Y. Y., & Pao, T.-L. L. (2019). A Context Aware Smart Classroom Architecture for Smart Campuses. *APPLIED SCIENCES-BASEL*, *9*(9). https://doi.org/10.3390/app9091837

Huang, L.-S., Su, J.-Y., & Pao, T.-L. (2019). A Context Aware Smart Classroom Architecture for Smart Campuses. *APPLIED SCIENCES-BASEL*, *9*(9). https://doi.org/10.3390/app9091837

Huang, L. S., Su, J. Y., & Pao, T. L. (2019). A context aware Smart classroom architecture for smart campuses. *Applied Sciences (Switzerland)*. https://doi.org/10.3390/app9091837

Huda, Y., Rukun, K., Faiza, D., & Jaya, P. (2019). Live Webcast System Design for Smart Classroom Learning in Electronic Engineering Department. *Journal of Physics: Conference Series*, *1387*(1). https://doi.org/10.1088/1742-6596/1387/1/012025

Ivliev, I. V. (2019). Model for assessment the dynamic capcapabilities of the university personnel using future classroom toolkit. *PROCEEDINGS OF THE 1ST INTERNATIONAL SCIENTIFIC CONFERENCE MODERN MANAGEMENT TRENDS AND THE DIGITAL ECONOMY: FROM REGIONAL DEVELOPMENT TO GLOBAL ECONOMIC GROWTH (MTDE 2019)*, *81*(Mtde), 626–629. https://doi.org/10.2991/mtde-19.2019.125

Jiahua, Z., Hezhen, B., Hongli, Y., Xiuhong, Z., & Hong, C. (2018). Research of Teaching Behaviors in Smart Classroom Supported by Interactive Media. In Xiao, X and Hauer, T and Khan, SAR (Ed.), *PROCEEDINGS OF THE 2018 4TH INTERNATIONAL CONFERENCE ON SOCIAL SCIENCE AND HIGHER EDUCATION (ICSSHE 2018)* (Vol. 181, pp. 806–812).

Jiang, L.-L., Xu, R., & Liu, H.-L. (2020). Dynamic adjustment mechanism of intelligent classroom learning resources in universities based on network teaching platform. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, *339*, 181–192. https://doi.org/10.1007/978-3-030-63952-5_16

Kim, P. W. (2019). Ambient intelligence in a smart classroom for assessing students' engagement levels. *JOURNAL OF AMBIENT INTELLIGENCE AND HUMANIZED COMPUTING*, *10*(10, SI), 3847–3852. https://doi.org/10.1007/s12652-018-1077-8

Kim, Y., Soyata, T., & Behnagh, R. F. (2018). Towards Emotionally Aware AI Smart Classroom: Current Issues and Directions for Engineering and Education. *IEEE Access*, *6*, 5308–5331. https://doi.org/10.1109/ACCESS.2018.2791861

Nikhath, K. A., Nagini, S., Vasavi, R., & Vasundra, S. (2021). SCP Design of Situated Cognitive

Processing Model to Assist Learning-Centric Approach for Higher Education in Smart Classrooms. In *Advances in Intelligent Systems and Computing* (pp. 653–661). https://doi.org/10.1007/978-981-15-5400-1_63

Kwet, M., & Prinsloo, P. (2020). The 'smart' classroom: a new frontier in the age of the smart university. *Teaching in Higher Education*, *25*(4), 510–526. https://doi.org/10.1080/13562517.2020.1734922

Lee, K. S., Kim, H. J., & Kang, J. (2019). From Uniformity to Sustainable Diversity: Exploring the Design Attributes of Renovating Standardized Classrooms in Korea. *SUSTAINABILITY*, *11*(20). https://doi.org/10.3390/su11205669

Li, J., Shi, D., Tumnark, P., & Xu, H. (2020). A system for real-time intervention in negative emotional contagion in a smart classroom deployed under edge computing service infrastructure. *PEER-TO-PEER NETWORKING AND APPLICATIONS*, *13*(5, SI), 1706–1719. https://doi.org/10.1007/s12083-019-00863-8

Li, X., Wang, M., Zeng, W., & Lu, W. (2019). A Students' Action Recognition Database In Smart Classroom. *14TH INTERNATIONAL CONFERENCE ON COMPUTER SCIENCE AND EDUCATION (ICCSE 2019)*, 523–527.

Li, Yanhong, Yang, H. H., & MacLeod, J. (2019). Preferences toward the constructivist smart classroom learning environment: examining pre-service teachers' connectedness. *Interactive Learning Environments*, *27*(3), 349–362. https://doi.org/10.1080/10494820.2018.1474232

Li, Yingjie, & Chen, L. (2020). Improved LSTM data analysis system for IoT-based smart classroom. *JOURNAL OF INTELLIGENT & FUZZY SYSTEMS*, *39*(4), 5141–5148. https://doi.org/10.3233/JIFS-179999

Lin, H., Xie, S., Xiao, Z., Deng, X., Yue, H., & Cai, K. (2019). Adaptive Recommender System for an Intelligent Classroom Teaching Model. *INTERNATIONAL JOURNAL OF EMERGING TECHNOLOGIES IN LEARNING*, *14*(5), 51–63. https://doi.org/10.3991/ijet.v14i05.10251

Liu, B., Li, X., Wang, Y., Wang, H., & Xu, F. (2018). The System Framework of Data Mining and Learning Analysis for Smart Classroom. In Nishimori, T and Li, Z and Liu, JC and Liu, L and Zhang, H and Yin, C (Ed.), *2018 INTERNATIONAL JOINT CONFERENCE ON INFORMATION, MEDIA AND ENGINEERING (ICIME)* (pp. 331–336). https://doi.org/10.1109/ICIME.2018.00077

Lu, K., Yang, H. H., Shi, Y., & Wang, X. (2021). Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment. *INTERNATIONAL JOURNAL OF EDUCATIONAL TECHNOLOGY IN HIGHER EDUCATION*, *18*(1), 1–13. https://doi.org/10.1186/s41239-020-00238-7

MacLeod, J., Yang, H. H., Zhu, S., & Li, Y. (2018). Understanding students' preferences toward the smart classroom learning environment: Development and validation of an instrument. *COMPUTERS \& EDUCATION*, *122*, 80–91. https://doi.org/10.1016/j.compedu.2018.03.015

Miraoui, M. (2018). A Context-aware Smart Classroom for Enhanced Learning Environment. *INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS*, *11*(1), 1–8. https://doi.org/10.21307/ijssis-2018-007

Zairul, M. (2021). A thematic Review on Industrialised Building System (IBS) Publications from 2015-2019: Analysis of Patterns and Trends for Future Studies of IBS in Malaysia. *Pertanika Journal of Social Sciences and Humanities*, *29*(1), 635–652. https://doi.org/10.47836/pjssh.29.1.35

Mokhtar, T. H., Oteafy, A., Taha, A.-E., Nasser, N., & Mansour, S. E. (2018). iCE: An intelligent

classroom environment to enhance education in higher educational institutions. *Communications in Computer and Information Science*, *852*, 85–93. https://doi.org/10.1007/978-3-319-92285-0_13

Nagowah, S. D., ben Sta, H., & Gobin-Rahimbux, B. A. (2019). An Ontology for an IoT-enabled Smart Classroom in a University Campus. *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, 626–631. https://doi.org/10.1109/ICCIKE47802.2019.9004369

Naidu, V. R., Singh, B., Hasan, R., & Al Hadrami, G. (2017). LEARNING ANALYTICS FOR SMART CLASSROOM IN HIGHER EDUCATION. In Uslu, F (Ed.), *4TH INTERNATIONAL CONFERENCE ON EDUCATION, SOCIAL SCIENCES AND HUMANITIES (SOCIOINT 2017)* (pp. 525–530).

Nsunza, W. W., Tetteh, A.-Q. R., & Hei, X. (2018). Accelerating a Secure Programmable Edge Network System for Smart Classroom. In Wang, G and Han, Q and Bhuiyan, MZA and Ma, X and Loulergue, F and Li, P and Roveri, M and Chen, L (Ed.), *2018 IEEE SMARTWORLD, UBIQUITOUS INTELLIGENCE & COMPUTING, ADVANCED & TRUSTED COMPUTING, SCALABLE COMPUTING & COMMUNICATIONS, CLOUD & BIG DATA COMPUTING, INTERNET OF PEOPLE AND SMART CITY INNOVATION (SMARTWORLD/SCALCOM/UIC/ATC/CBDCOM/IOP/SCI)* (pp. 1384–1389). https://doi.org/10.1109/SmartWorld.2018.00240

Pacheco, A., Cano, P., Flores, E., Trujillo, E., & Marquez, P. (2018). A Smart Classroom based on Deep Learning and Osmotic IoT Computing. In LozanoGarzon, CA (Ed.), *2018 CONGRESO INTERNACIONAL DE INNOVACION Y TENDENCIAS EN INGENIERIA (CONIITI)*.

Paudel, P., Kim, S., Park, S., & Choi, K.-H. H. (2020). A context-aware iot and deep-learning-based smart classroom for controlling demand and supply of power load. *Electronics (Switzerland)*, *9*(6), 1–12. https://doi.org/10.3390/electronics9061039

Paul, C., Ganesh, A., & Sunitha, C. (2019). An IoT-Based Smart Classroom. In Smys, S and Bestak, R and Chen, JIZ and Kotuliak, I (Ed.), *INTERNATIONAL CONFERENCE ON COMPUTER NETWORKS AND COMMUNICATION TECHNOLOGIES (ICCNCT 2018)* (Vol. 15, pp. 9–14). https://doi.org/10.1007/978-981-10-8681-6_2

Phoong, S. W., Phoong, S. Y., Moghavvemi, S., & Sulaiman, A. (2020). Measuring the influence of hedonic value, social presence and teaching presence on students' cognitive presence through the implementation of the smart classroom. *INTERNATIONAL JOURNAL OF LEARNING TECHNOLOGY*, *15*(2), 130–149. https://doi.org/10.1504/IJLT.2020.109571

Pigatto, L. de S., & Nunes, F. B. (2020). Attendance control system for a Smart Classroom based on Internet of Things. *REVISTA EDUCAONLINE*, *14*(3), 1–15.

Pirahandeh, M., & Kim, D.-H. (2017). Energy-aware and intelligent storage features for multimedia devices in smart classroom. *MULTIMEDIA TOOLS AND APPLICATIONS*, *76*(1), 1139–1157. https://doi.org/10.1007/s11042-015-3019-1

Popescu, R., Popescu, D., Roibu, H., & Popescu, L.-C. (2018). Smart Classroom - Affective Computing in Present-day Classroom. In Thorbergsson, H and Gudmundoosn, K and Andersen, K and Thorsteinsson, S (Ed.), *2018 28TH EAEEIE ANNUAL CONFERENCE (EAEEIE)*.

Premalatha, B., & Krishnan, H. J. (2020). Iot based smart classroom. *International Journal of Scientific and Technology Research*.

Qin, L. (2021). Research on the Construction of Evaluation System of Intelligent Classroom Teaching Quality in Colleges and Universities under the Information Technology Environment. *Journal of Physics: Conference Series*, *1744*(3), 032164. https://doi.org/10.1088/1742-6596/1744/3/032164

Radosavljevic, V., Radosavljevic, S., & Jelic, G. (2019). Ambient intelligence-based smart classroom model. *Interactive Learning Environments*, 1–15. https://doi.org/10.1080/10494820.2019.1652836

Sardinha, L., Almeida, A. M. P., & Barbas, M. P. (2017). DIGITAL FUTURE CLASSROOM: THE PHYSICAL SPACE AND THE INCLUSION OF THE NEET/REFUGEE POPULATION - CONCEPTUAL AND THEORETICAL FRAMEWORKS AND METHODOLOGY. In Chova, LG and Martinez, AL and Torres, IC (Ed.), *INTED2017: 11TH INTERNATIONAL TECHNOLOGY, EDUCATION AND DEVELOPMENT CONFERENCE* (pp. 2396–2405).

Selim, H. M., Eid, R., & Agag, G. (2020). Understanding the role of technological factors and external pressures in smart classroom adoption. *Education and Training*, *62*(6), 631–644. https://doi.org/10.1108/ET-03-2020-0049

Selvi, K. K., Prasannah, S. S. R., Youdhika, A., Ramprabhu, R., & Benny, R. T. (2020). An Overview of Smart Classroom using the Augmented Reality Technology. *2020 6TH INTERNATIONAL CONFERENCE ON ADVANCED COMPUTING AND COMMUNICATION SYSTEMS (ICACCS)*, 566–570.

Shi, Y., Peng, C., Wang, S., & Yang, H. H. (2018). The Effects of Smart Classroom-Based Instruction on College Students' Learning Engagement and Internet Self-efficacy. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-94505-7_21

Shi, Y., Yang, H., Zhang, J., Pu, Q., & Yang, H. H. (2020). A Meta-Analysis of Students' Cognitive Learning Outcomes in Smart Classroom-Based Instruction. *2020 International Symposium on Educational Technology (ISET)*, 8–12. https://doi.org/10.1109/ISET49818.2020.00012

Songkram, N. (2017). Virtual smart classroom to enhance 21 st century skills in learning and innovation for higher education learners. *2017 Tenth International Conference on Mobile Computing and Ubiquitous Network (ICMU)*, 1–4. https://doi.org/10.23919/ICMU.2017.8330109

Songkram, N., Chootongchai, S., Khlaisang, J., & Koraneekij, P. (2019). Education 3.0 system to enhance twenty-first century skills for higher education learners in Thailand. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2019.1592197

Songkram, N. N. N. N. N. N., Songkram, N. N. N. N. N. N., Chootongchai, S., & Samanakupt, T. (2021). Developing Students' Learning and Innovation Skills Using the Virtual Smart Classroom. *International Journal of Emerging Technologies in Learning*, *16*(4), 34–51. https://doi.org/10.3991/ijet.v16i04.15221

Tissenbaum, M., & Slotta, J. D. (2019). Developing a smart classroom infrastructure to support real-time student collaboration and inquiry: a 4-year design study. *INSTRUCTIONAL SCIENCE*, *47*(4), 423–462. https://doi.org/10.1007/s11251-019-09486-1

Tripathi, S., Jana, J., Samanta, J., & Barui, S. (2020). Modern Smart Classroom-Based Touch Technology Using Digital Image Processing. *Lecture Notes in Electrical Engineering*. https://doi.org/10.1007/978-981-15-0829-5_50

Unggyoung, K. (2019). Implementation of Smart Learning in Korean Education Using the Smart Classroom Response System. *JOURNAL OF THE INTERNATIONAL NETWORK FOR KOREAN LANGUAGE AND CULTURE*, *16*(2), 93–119. https://doi.org/10.15652/ink.2019.16.2.093

Wang, X.-C., & Wang, X.-H. (2017). A Pad-Based Multi-Device Collaborative Teaching Software Architecture for Smart Classroom. In Patnaik, S (Ed.), *PROCEEDINGS OF THE 2017 INTERNATIONAL CONFERENCE ON WIRELESS COMMUNICATIONS, NETWORKING AND APPLICATIONS (WCNA2017)* (pp. 205–209). https://doi.org/10.1145/3180496.3180633

Wang, Y. (2018). Research on the Design of College Smart Classroom Teaching Mode under the Background of ``Internet plus ``. In Jing, W and Ning, X and Huiyu, Z (Ed.), *PROCEEDINGS OF THE 8TH INTERNATIONAL CONFERENCE ON MANAGEMENT AND COMPUTER SCIENCE (ICMCS 2018)* (Vol. 77, pp. 587–591).

Yan, H., & Yang, B. (2019). Research and Application of a High-efficiency Teaching Framework Based on Smart Classroom. *14TH INTERNATIONAL CONFERENCE ON COMPUTER SCIENCE AND EDUCATION (ICCSE 2019)*, 483–487.

Yang, X., Zhou, X., & Hu, J. (2021). Students' preferences for seating arrangements and their engagement in cooperative learning activities in college English blended learning classrooms in higher education. *Higher Education Research and Development*, *0*(0), 1–16. https://doi.org/10.1080/07294360.2021.1901667

Zairul, M. (2020). A THEMATIC REVIEW ON STUDENT-CENTRED LEARNING IN THE STUDIO EDUCATION. *Journal of Critical Reviews*, *7*(02), 504–511. https://doi.org/10.31838/jcr.07.02.95

Zeng, W., Meng, Q., & Li, R. (2019). Design of intelligent classroom attendance system based on face recognition. *Proceedings of 2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference, ITNEC 2019*, 611–615. https://doi.org/10.1109/ITNEC.2019.8729496

Zhan, H., Liu, Z., Lu, F., Ma, X., Zhang, S., & Chen, Y. (2020). A Construction Framework Design of Smart Classroom in Universities Based on Pedagogy-Space-Technology Framework. In *Lecture Notes in Electrical Engineering* (pp. 1647–1654). https://doi.org/10.1007/978-981-15-5959-4_200

Zhan, Z., Wu, Q., Lin, Z., & Cai, J. (2021). Smart classroom environments affect teacher-student interaction: Evidence from a behavioural sequence analysis. *AUSTRALASIAN JOURNAL OF EDUCATIONAL TECHNOLOGY*, *37*(2, SI), 96–109. https://doi.org/10.14742/ajet.6523

Zhang, A., & Zhou, T. (2017). Future Classroom Design of Teaching from the Perspective of Educational Technology. In Liu, J and Nishimura, S and Zhang, H and Jin, Q (Ed.), *2017 6TH INTERNATIONAL CONFERENCE OF EDUCATIONAL INNOVATION THROUGH TECHNOLOGY (EITT)* (Vols. 2018-March, pp. 203–206). https://doi.org/10.1109/EITT.2017.56

Zhang, Q., & Li, J. (2018). Research of Smart Classroom Design based on Big Data. In Zheng, Z (Ed.), *2018 3RD INTERNATIONAL CONFERENCE ON EDUCATION & EDUCATION RESEARCH (EDUER 2018)* (pp. 189–192). https://doi.org/10.25236/eduer.18.041

Zhang, Z., Cao, T., Shu, J., Zhi, M., Liu, H., & Li, Z. (2017). Exploration of Blended Teaching Pattern based on Hstar and Smart Classroom. In Wang, FL and Au, O and Ng, KK and Shang, J and Kwan, R (Ed.), *2017 INTERNATIONAL SYMPOSIUM ON EDUCATIONAL TECHNOLOGY (ISET 2017)* (pp. 3–7). https://doi.org/10.1109/ISET.2017.10

Zhao, S., Yang, H. H., & Li, Y. (2019). Role of teaching assistants in synchronous smart classrooms. *Proceedings - 2019 8th International Conference of Educational Innovation through Technology, EITT 2019*, 110–114. https://doi.org/10.1109/EITT.2019.00029

Zhou, P., Wang, Q., Zhang, Y., & Yang, Q. (2018). The influence of debating teaching on students' critical thinking development in smart classroom. *Proceedings - 2018 7th International Conference of Educational Innovation through Technology, EITT 2018*. https://doi.org/10.1109/EITT.2018.00018

Zhou, P., & Yang, Q. (2017). Fostering Elementary Student's Collaborative Knowledge Building in Smart Classroom with Formative Evaluation. In Liu, J and Nishimura, S and Zhang, H and Jin, Q (Ed.), *2017 6TH INTERNATIONAL CONFERENCE OF EDUCATIONAL INNOVATION*

THROUGH TECHNOLOGY (EITT) (Vols. 2018-March, pp. 116–117). https://doi.org/10.1109/EITT.2017.35