A Systematic Review on Smart Classrooms

Una revisión sistemática sobre *smart classrooms*

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Abstract

The main objective of this article is to offer an updated synthesis of research on smart classrooms in the last eleven years. The results show that research on smart classrooms increased in the last two years, led by China, India, and Korea. The main research topics in smart classrooms are related to methodological strategies and the configuration of technological equipment.

Keywords: smart classroom, artificial intelligence, technological education, learning method, innovation in education.

Resumen

El objetivo principal de este artículo es presntar una síntesis actualizada de la investigación sobre *smart classrooms* en los últimos once años. Los resultados muestran que la investigación sobre este tema aumentó en los últimos dos años, y ha sido liderada por China, India y Corea. Los principales temas de investigación están relacionados con las estrategias metodológicas y la configuración de equipos tecnológicos.

Palabras clave: *smart classrooms*, inteligencia artificial, educación tecnólogica, método de aprendizaje, innovación educativa.

Introduction

A *smart classroom* is an intelligent class that incorporates learning methods and emerging information technologies with innovative teaching and new pedagogies (Bargaoui & Bdiwi, 2014). In literature, smart classrooms have evolved from a distance education system that uses Internet as a means to transform a conventional classroom into an intelligent space (Al-Hunaiyyan, Al-Sharhan, & Alhajri, 2017). In recent years, several research papers on the implementation of smart classrooms around the world have been published. Various investigations have been carried out by addressing various aspects of intelligent classes, such as the transformation and basic configuration of a traditional classroom to an intelligent classroom (MacLeod *et al.*, 2018; Santana-Mancilla *et al.,* 2013; Alelaiwi *et al.*, 2015; and Bargaoui & Bdiwi, 2014. Other research addresses learning models and activities (Al-Hunaiyyan *et al.*, 2017, and Radosavljevic, Radosavljevic, & Jelic, 2019). However, there are still some questions about smart classrooms that need to be analysed, such as: What are the educational levels in which they are implemented the most? What research topics are being addressed in smart classrooms? What countries are at the forefront of intelligent classrooms research?

Based on the questions described above, the main objective of this paper is to provide an updated synthesis of research on smart classrooms in the last five years. In this study, the general description, the main research topics, and the educational level of implementation were reviewed.

This document is organized in three sections: Methods, which describes the methodology used in the systematic literature review in smart classrooms; Results, which presents the results obtained in the systematic review; and Conclusions, which presents the conclusions of this investigation.

Methods

This study has been undertaken as a systematic literature review based on Kitchenham (Kitchenham *et al.*, 2010). The goal of this systematic review is to offer an updated synthesis of research on smart classrooms, so the general description, the main research topics, and the educational level of implementation were reviewed. The steps of the systematic literature review method are documented below.

Research Questions

The research questions addressed in this study are:

RQ1. How much research activity in smart classrooms has been carried out in the last eleven years?

RQ2. What are the countries that lead research in smart classrooms?

RQ3. What research topics are being addressed in smart classrooms?

RQ4. What are the educational levels in which intelligent classrooms have been implemented?

RQ5. What are the challenges facing the implementation of smart classrooms?

Search Process

The search process was a manual search of specific conference proceedings and journal papers published since 2008. The selected journals and conferences are shown in Table 1. The journals and conferences were selected because they were known to include empirical studies related to smart classrooms.

Each journal, conference proceeding, and book was reviewed by two different researchers, and the papers that addressed literature on smart classrooms were identified as potentially relevant.

Table 1. Selected journals, conference proceedings, and books

Source	Acronym
Computers & Education	C&E
Computers in Human Behavior	CHB
Telematics and Informatics	TI
Procedia - Social and Behavioral Sciences	PSBS
Infrared Physics & Technology	IP&T
Proceedings of the third international conference on learning analytics and knowledge	LAK
Emerging issues in smart learning	EISL
International Conference on Blended Learning	BL
Multimedia Tools and Applications	MTA
Smart Learning Environments	SLE
Ambient Intelligence and Humanized Computing	AIHC
New Advances in Information Systems and Technologies	NAIST
2017 Tenth International Conference on Mobile Computing and Ubiquitous Network	ICMU
International Conference on Education and e-Learning Innovations	EEI
2014 International Conference on Intelligent Environments	IE
Proceedings of 2011 International Conference on Electronic & Mechanical Engineering and Information Technology	E&MEIT
2008 IEEE International Conference on Granular Computing	GC

Source	Acronym
2018 International Conference on Advances in Computing, Communications and Informatics	ICACCI
2017 International Conference of Educational Innovation through Technology	EITT
2008 International Symposium on Knowledge Acquisition and Modeling	KAM
2014 International Conference on Web and Open Access to Learning	ICWOAL
2018 Fifth International Conference on Parallel, Distributed and Grid Computing	PDGC
2009 International Conference on Information Engineering and Computer Science	IECS

Source: own elaboration.

a. Constructing Search Terms

The following details will help in defining the search terms that were used for the research questions of this systematic review: "smart classrooms", "educational level", "smart classrooms" + "Research topic", "smart classrooms" + "challenges", "smart classrooms" + "technologies", "smart classrooms" + "educational strategy" and "intelligent classrooms".

b. Search Strategy

Search strings were built using the search terms and alternative synonyms. Boolean operators AND and OR were used in the search strings. Three databases were used to search and filter the relevant documents. The three databases are given in Table 2.

Table 2. Data sources and results for literature search

	Data source	Total results	Initial selection	Final selection
a	Science Direct	107	12	8
b	Springer	399	12	6
c	IEEE	105	12	12

Source: own elaboration.

c. Publication Selection

i. Inclusion criteria

The inclusion criteria to determine relevant literature (journal papers & conference papers) are listed below:

- Studies that report research results on the implementation of smart classrooms at one or several educational levels.

ii. Exclusion criteria

The following criteria were used to exclude literature that was not relevant to this study.

- Studies that are not relevant to the research question.
- Studies that do not describe or answer at least half of the research questions.

iii. Data Collection

The information extracted from each study was:

- The source (journal or conference) and full reference.
- Main research topic.
- The author(s) and their institution and the country where it is situated.

iv. Data Analysis

The data was tabulated to show:

- The number of papers published per year and their source (addressing RQ1).
- The number of studies in each category (addressing RQ1 and RQ2).
- The topics studied in the research (addressing RQ3).
- The affiliations of the authors and their institutions (addressing RQ2).
- The educational level in which the smart classroom was implemented (addressing RQ4).

d. Selecting Primary Sources

The selection process carried out in this study had two parts: (i) an initial selection of published articles that could satisfy search strings or selection criteria based on the reading of the title, the abstract, and the keywords and (ii) the final selection based on the list of articles initially selected when reading the full text of the document.

The selection process was performed by the principal reviewer. However, to mitigate some possible bias, a reliability test was performed between evaluators in which a secondary reviewer confirmed the result of the primary reviewer.

In this study, 26 articles were found as the final selection for this review process, which are shown in Table 3.

Table 3. Types of smart classrooms and their objectives

No.	Reference	Q2 (Country)	Q3 (Topic)	Q4 (Educational Level)	Year
1	(MacLeod *et al.*, 2018)	China	Learning environment	Higher Education	2018
2	(Sevindik, 2010)	Turkey	Learning environment	Higher Education	2010
3	(Uzelac, Gligorić, & Krčo, 2018)	Serbia	Internet of things	Higher Education	2018
4	(Aziz & Baba, 2011)	Malaysia	Teaching and learning strategies	Secondary Education	2011
5	(Santana-Mancilla *et al.*, 2013)	Mexico	Ambient intelligence	Higher Education	2013
6	(Uzelac, Gligoric, & Krco, 2015)	Serbia	Internet of things	Higher Education	2015
7	(J. Yang, Yu, & Chen, 2019)	China	Improving classroom teaching	Middle Education	2019
8	(Cheng, Sun, & Chen, 2018)	Taiwan	Learning technology	All levels of education	2018
9	(Wang, Wu, & Qi, 2018)	China	Intelligent learning environment	Media in Education	2018

No.	Reference	Q2 (Country)	Q3 (Topic)	Q4 (Educational Level)	Year
10	(Li, Kong, & Chen, 2015)	China	Intelligent learning environment	Media in Education	2015
11	(Shi, Peng, Wang, & Yang, 2018)	China	Intelligent learning environment	Higher Education	2018
12	(Pirahandeh & Kim, 2017)	Korea	Ambient intelligence	Higher Education	2017
13	(J. Yang, Pan, Zhou, & Huang, 2018)	China	Intelligent learning environment	Higher Education	2018
14	(Kim, 2019)	Korea	Internet of things Ambient intelligence Assessment of students' engagement levels	Higher Education	2019
15	(Songkram, 2017)	Thailand	Virtual learning environment	Higher Education	2017
16	(Dekdouk, 2012)	Argelia, Oran	Intelligent learning environment	All educational levels	2012
17	(Song, Zhong, Li, Du, & Nie, 2014)	China	Ambient intelligence	Higher Education	2014
18	(S. Yang & Chen, 2011)	China	Intelligent learning environment	Higher Education	2011
19	(Chen Di, Zhao Gang, & Xu Juhong, 2008)	China	Virtual learning environment	Higher Education	2008
20	(Ani, Krishna, Akhil, & Arun, 2018)	India	Internet of things	Higher Education	2018
21	(Zhou & Yang, 2017)	China	Intelligent learning environment	Elementary Education	2017
22	(Di, Gang, & Juhong, 2008)	China	Intelligent learning environment	Higher Education	2008
23	(Bargaoui & Bdiwi, 2014)	Tunisia	Intelligent learning environment	Higher Education	2014
24	(Yan & Yang, 2019)	China	Intelligent Learning Environment	Higher Education	2019
25	(Enugala & Vuppala, 2018)	India	Internet of things	Higher Education	2018
26	(Chen, Xu, & Tan, 2009)	China	Intelligent learning environment	Higher Education	2009

Source: own elaboration.

e. Range of Research Papers

The literature review performed in the present study covers published research from 2008 to 2019.

Results

a. How much research activity in smart classrooms has been carried out in the last eleven years?

In the last two years, the publication of papers related to smart classrooms has more than doubled (Figure 1). This means smart classrooms are an issue that has gained the interest of the international scientific community.
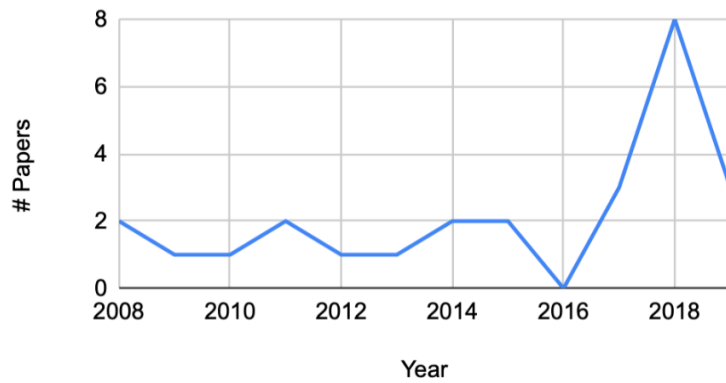
Figure 1. Published papers by year

> Source: own elaboration.

b. What are the countries that lead research in smart classrooms?

In general, the set of studies is dominated by Chinese researchers who have participated in 12 of the studies (Figure 2).
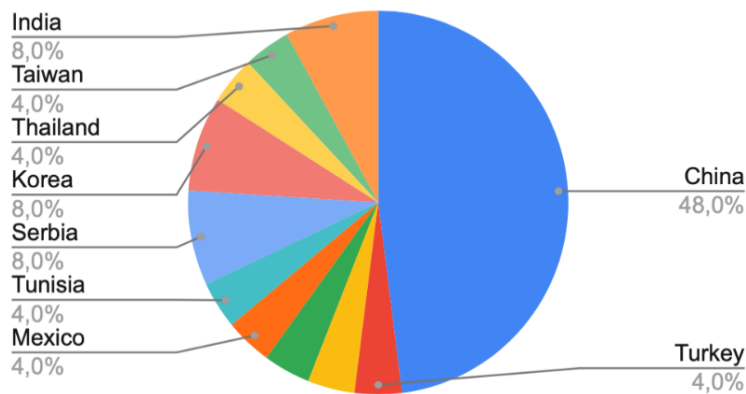

Figure 2. Published papers by country

> Source: own elaboration.

In the analysis by continent, it was found that Asia produces most of the research in smart classrooms, while only 4% of the studies had Latin American authors (Figure 3).
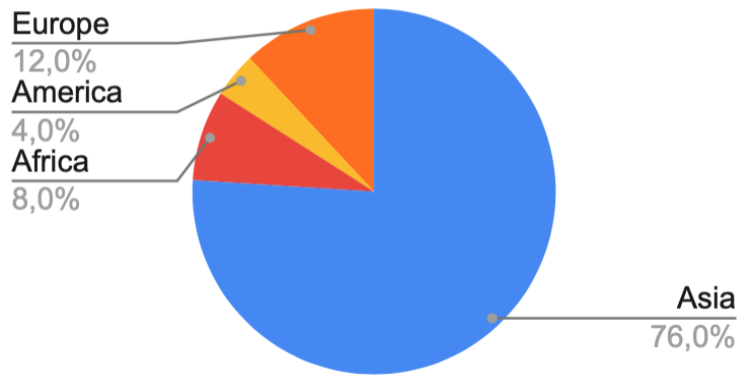
Figure 3. Published papers by continent

Source: own elaboration.

c. What research topics are being addressed in smart classrooms?

The main research topics in smart classrooms are (i) teaching and learning strategies and (ii) software and technological equipment.

i. Teaching and learning strategies

The review found that the two research topics in teaching and learning strategies are the appropriate use of technological tools and the monitoring of student progress. The proper use of the internet and technological tools by students and teachers is a recurring theme in research on smart classrooms. The studies carried out are based on surveys and validation of instruments with pre- and post-tests, where the methods used by the teachers are evaluated. In the studies analysed, it is observed that the monitoring of students' progress in achieving learning objectives is done through the development of machine learning algorithms.

ii. Software and technological equipment

The must-have set of smart classroom equipment is as follows: Learning Management System, interactive control center, class pad, interactive displays, classroom control system, response pad, on-demand collaboration, on-demand visual learning, classroom capture and interactive whiteboards.

d. What are the educational levels in which intelligent classrooms have been implemented?

Figure 4 shows that 92.3% of the investigations carried out in smart classrooms have been applied only at a single educational level. 73.1% of the research has been carried out in higher education. Higher education is therefore the most studied educational level, while elementary education is the level where less research has been done with only 3.8% of studies. It was found that 2 investigations report results of the application of intelligent classrooms integrally in the three main educational levels.
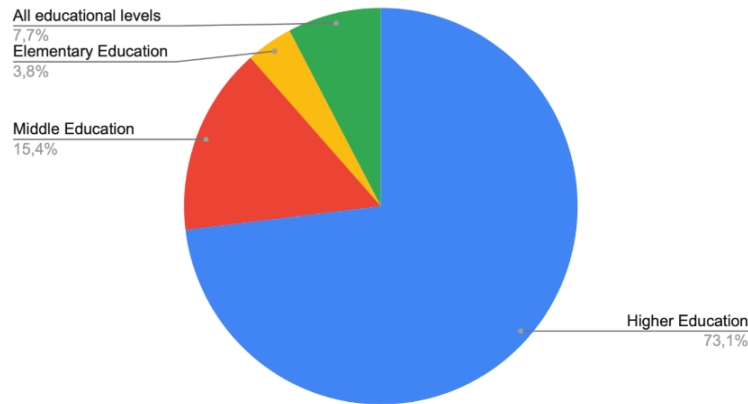
Figure 4. Implementation of smart classrooms at educational levels

Source: own elaboration.

e. What are the challenges facing the implementation of smart classrooms?

When the challenges of the reviewed research are analysed, recurring themes such as device integration, quality and access to educational resources, design of learning activities, and high cost of assembly can be found. In terms of device integration, the main challenge is to seamlessly integrate mobile devices with different characteristics. In this sense, the adjective "transparent" refers to plug-and-play integration without prior configuration in the device. To address this challenge, some proposals focus on the use of the Internet of Things and others recommend the study of context-sensitive adaptive methods to identify the configuration of the device that is integrated into the smart classroom.

Another important challenge is the quality and access to educational resources. Numerous questions arise from this challenge, such as, for example, what quality standards should the content used in a smart classroom have? Who should provide the content? What is the role of artificial intelligence in educational resources?

On the other hand, a major challenge is the high cost of setting up a smart classroom. In this sense, proposals such as dividing the general budget for the virtual classroom into small projects that are easily financed arise.

Other less common but no less important challenges are reducing energy consumption and adapting government policies. Energy consumption becomes relevant as awareness of caring for the environment is made, as well as for reducing expenses such as electricity. This is because in countries such as China or India it is important to save energy in remote areas and large cities, in the latter case due to the high cost of public services. Finally, in terms of government policies, the challenge is that in some countries there is a concern that government policies in education are lagging behind the real-time dynamics in the smart classroom, which may delay innovation in the smart classrooms.

Conclusions

This paper described the results of a systematic review of the literature published about smart classrooms in the 2008 to 2019 period. The method followed in the systematic review was the one proposed by

Kitchenham *et al.* (2010), which has been used in several reviews published in areas related to technology and systems.

The study was addressed by four questions, where question RQ1 gave the answer that publications related to smart classrooms have increased in the last two years. This reflects that smart classrooms are a research topic that has gained interest among the international scientific community.

Question RQ2 makes it clear that the Asian countries China, India, and Korea are the ones leading the research related to smart classrooms. These countries produce more than half of the publications in the area.

Regarding question RQ3, it was found that the two main research topics in smart classrooms are related to methodological strategies and the configuration of technological equipment. Finally, question RQ4 showed that 73.1% of the investigations were carried out in higher education, while it was evidenced that primary education is the educational level in which less research has been carried out.

References

Alelaiwi, A., Alghamdi, A., Shorfuzzaman, M., Rawashdeh, M., Hossain, M. S., & Muhammad, G. (2015). Enhanced engineering education using smart class environment. *Computers in Human Behavior*, *51*, 852-856. https://doi.org/10.1016/j.chb.2014.11.061

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

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)*, 2098-2102. https://doi.org/10.1109/ICACCI.2018.8554869

Aziz, Z., & Baba, S. (2011). Instructional leadership enhanced creativity in smart classroom activities. *Procedia - Social and Behavioral Sciences*, *15*, 1566-1572. https://doi.org/10.1016/j.sbspro.2011.03.332

Bargaoui, H., & Bdiwi, R. (2014). Smart classroom: Design of a gateway for ubiquitous classroom. *2014 International Conference on Web and Open Access to Learning (ICWOAL)*, 1-4. https://doi.org/10.1109/ICWOAL.2014.7009206

Chen, D., Xu, J., & Tan, D. (2009). The Application of Multigen Vega in the Blending-Reality Smart Classroom. *2009 International Conference on Information Engineering and Computer Science*, 1-3. https://doi.org/10.1109/ICIECS.2009.5363437

Chen Di, Zhao Gang, & Xu Juhong. (2008). A new system for interactive demonstration in distance education — The research and design of the smart classroom based on blending reality. *2008 IEEE International Conference on Granular Computing*, 121-124. https://doi.org/10.1109/GRC.2008.4664659

Cheng, Y.-W., Sun, P.-C., & Chen, N.-S. (2018). The essential applications of educational robot: Requirement analysis from the perspectives of experts, researchers and instructors. *Computers & Education, 126*, 399-416. https://doi.org/10.1016/j.compedu.2018.07.020

Dekdouk, A. (2012). Integrating mobile and ubiquitous computing in a smart classroom to increase learning effectiveness. *International Conference on Education and E-Learning Innovations*, 1-5. https://doi.org/10.1109/ICEELI.2012.6360684

Di, C., Gang, Z., & Juhong, X. (2008). An Introduction to the Technology of Blending-Reality Smart Classroom. *2008 International Symposium on Knowledge Acquisition and Modeling*, 516-519. https://doi.org/10.1109/KAM.2008.172

Enugala, V. P. R., & Vuppala, S. (2018). Internet of Things – based Smart Classroom Environment. 6.

Kim, P. W. (2019). Ambient intelligence in a smart classroom for assessing students' engagement levels. *Journal of Ambient Intelligence and Humanized Computing, 10*(10), 3847-3852. https://doi.org/10.1007/s12652-018-1077-8

Kitchenham, B., Pretorius, R., Budgen, D., Pearl Brereton, O., Turner, M., Niazi, M., & Linkman, S. (2010). Systematic literature reviews in software engineering – A tertiary study. *Information and Software Technology, 52*(8), 792-805. https://doi.org/10.1016/j.infsof.2010.03.006

Li, B. P., Kong, S. C., & Chen, G. (2015). A Study on the Development of the Smart Classroom Scale. In G. Chen, V. Kumar, Kinshuk, R. Huang, & S. C. Kong (Eds.), *Emerging Issues in Smart Learning* (pp. 45-52). Berlin, Heidelberg: Springer Berlin Heidelberg.

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

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

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

Santana-Mancilla, P. C., Echeverría, M. A. M., Santos, J. C. R., Castellanos, J. A. N., & Díaz, A. P. S. (2013). Towards Smart Education: Ambient Intelligence in the Mexican Classrooms. *Procedia - Social and Behavioral Sciences, 106*, 3141-3148. https://doi.org/10.1016/j.sbspro.2013.12.363

Sevindik, T. (2010). Future's learning environments in health education: The effects of smart classrooms on the academic achievements of the students at health college. *Telematics and Informatics, 27*(3), 314-322. https://doi.org/10.1016/j.tele.2009.08.001

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. In S. K. S. Cheung, L. Kwok, K. Kubota, L.-K. Lee, & J. Tokito (Eds.), *Blended Learning. Enhancing Learning Success* (pp. 263-274). Cham: Springer International Publishing.

Song, S., Zhong, X., Li, H., Du, J., & Nie, F. (2014). Smart Classroom: From Conceptualization to Construction. *2014 International Conference on Intelligent Environments*, 330-332. https://doi.org/10.1109/IE.2014.56

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

Uzelac, A., Gligoric, N., & Krco, S. (2015). A comprehensive study of parameters in physical environment that impact students' focus during lecture using Internet of Things. *Computers in Human Behavior, 53*, 427-434. https://doi.org/10.1016/j.chb.2015.07.023

Uzelac, A., Gligorić, N., & Krčo, S. (2018). System for recognizing lecture quality based on analysis of physical parameters. *Telematics and Informatics, 35*(3), 579-594. https://doi.org/10.1016/j.tele.2017.06.014

Wang, Q., Wu, W., & Qi, Y. (2018). A Learning Analytic Model for Smart Classroom. In L. H. U & H. Xie (Eds.), *Web and Big Data* (pp. 219-229). Cham: Springer International Publishing.

Yan, H., & Yang, B. (2019). Research and Application of a High-efficiency Teaching Framework Based on Smart Classroom. *2019 14th International Conference on Computer Science & Education (ICCSE)*, 483-487. https://doi.org/10.1109/ICCSE.2019.8845425

Yang, J., Pan, H., Zhou, W., & Huang, R. (2018). Evaluation of smart classroom from the perspective of infusing technology into pedagogy. *Smart Learning Environments, 5*(1), 20. https://doi.org/10.1186/s40561-018-0070-1

Yang, J., Yu, H., & Chen, N. (2019). Using blended synchronous classroom approach to promote learning performance in rural area. *Computers & Education, 141*, 103619. https://doi.org/10.1016/j.compedu.2019.103619

Yang, S., & Chen, L. (2011). A face and eye detection based feedback system for smart classroom. *Proceedings of 2011 International Conference on Electronic & Mechanical Engineering and Information Technology*, 571-574. https://doi.org/10.1109/EMEIT.2011.6023166

Zhou, P., & Yang, Q. (2017). Fostering Elementary Students' Collaborative Knowledge Building in Smart Classroom with Formative Evaluation. *2017 International Conference of Educational Innovation through Technology (EITT)*, 116-117. https://doi.org/10.1109/EITT.2017.35