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Smart Education: A Review and Future Research Directions †

Adrián Carruana Martín [iD]**, Carlos Alario-Hoyos** *[iD] **and Carlos Delgado Kloos** [iD]

Department of Telematics Engineering, Universidad Carlos III de Madrid, Leganés 28911, Spain;
acarruan@inf.uc3m.es (A.C.M.); calario@it.uc3m.es (C.A.-H.); cdk@it.uc3m.es (C.D.K)

* Correspondence: calario@it.uc3m.es; Tel.: +34-91-624-8779

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Abstract: Research and development often move forward based on buzzwords. New terms are coined to summarize new developments, often with several interpretations and without a formal definition. The term *Smart Education* has been coined to represent a move forward in technology-enhanced education, but what is behind it? Does it represent something essentially different from the educational technologies used before? In this paper, we do a systematic literature review to understand how this term is used, what the technologies behind it are, and what promises are made. We conclude that although the term is fuzzy, there are indeed several developments available today that can make educational technologies much more adapted to the learner and therefore underpin the learning in a *smarter* way.

Keywords: Smart Education; Internet of Things; Machine Learning; Artificial Intelligence; Learning Analytics

1. Introduction

Information technologies continuously improve and reinvent everything around us. Take for example the simple case of the doorbell: from the *mechanical* doorbell, to the *electric* one, to the one *connected* to your smartphone via the internet to see who is ringing, and to the *smart* one with face recognition. Different technological solutions for the same basic function, but with contextual differences. For instance, we might need to consider ethical questions for the smart version, but not on the same level for the mechanical one.

Most industries and sectors are affected by the advance of information technologies. The change is gradual and sometimes subtle, but when observed with perspective, we see huge implications. The term industry 4.0 was coined in Germany to clearly distinguish different phases in industrial settings and so identify the implications. We need these artificial conceptual aids to make us a better picture in a context where we are bombarded continuously with new buzzwords [1]. The same happens in education: does a particular buzzword imply a change in paradigm with profound implications or is it just a slight incremental improvement?

The term *Smart Education* has recently shown up in the literature. Is it something radically new or just a new buzzword for old technologies? How is this concept related to other concepts such as IoT (Internet of Things) or Augmented or Virtual Reality? And how does the *smart* aspect come into play in the context of concepts like Artificial Intelligence, Machine or Deep Learning, Big Data, or similar ones? Do these keywords correlate with Smart Education? And how about the systems developed under this idea? What do they propose?

According to Zhu et al. [2], several smart education initiatives have been carried out throughout the world with important differences, but also with common factors: the use of the most advanced technologies, the personalization of teaching and learning processes, the increase of educational appealing, and creativity-centered education, in short, intelligent, personalized, and adaptive education.

This systematic literature review aims to find out how this term is used, what the implications are, and what the prospects are. The next section describes the query that was performed. Section 3 analyzes the systems developed. Section 4 discusses the implications and research opportunities. Section 5 presents the conclusion.

2. Literature Review

2.1. Search Methodology

For this literature review, the well-known Scopus database was used to search the most relevant papers on Smart Education. The following query was used:

KEY(educat* OR pedagog* OR student* OR teach* OR class*) AND ("Smart Education" OR "Smart Teaching" OR "Smart Class" OR "Smart Classroom" OR "Smart Pedagogy" OR "Smart Learning") AND ("iot" OR "sensor" OR "Internet of things" OR "augmented reality" OR "AR" OR "virtual reality" OR "VR") AND ("artificial intelligence" OR "AI" OR "learning analytics" OR "LA" OR "data mining" OR "machine learning" OR "deep learning" OR "big data")

As can be seen, this query is divided into four parts. These parts are connected with *AND* conjunctions and deal with: (1) educational context; (2) enhancement of the educational context through smart components; (3) keywords related to smart technologies; and (4) keywords related to data collection and analysis in smart environments.

This query was made on papers indexed in Scopus searching titles, abstracts and keywords in September 2019; 429 papers were obtained. From all of them, a subset with the 100 most relevant papers was created. Only 100 articles were finally selected because when advancing in the list obtained through Scopus the relevance of Smart Education declined rapidly. From these 100 articles, 44 of them had to be discarded because they did not contribute anything to Smart Education or simply were not accessible.

2.2. Search Results

Table 1 shows the distribution of papers related to Smart Education per year. It is worth noting that there is a period of four years from the oldest (2012) [3] to the second oldest (2016) [4]. As time passes, there is a growing number of papers published on the subject, noting the papers published in 2019 refer only to the first nine months.

Most papers (46 out of 56) address the concept of IoT, including sensors, beacons, cameras and/or single-board computers such as Raspberry Pi. Of the ten papers that do not deal with IoT, six papers use their available data to analyze and extract information, considering IoT as a future improvement; the remaining ones use Virtual Reality (VR) and/or Augmented Reality (AR) [5–7]. Moreover, some papers focus on unusual technologies, such as Whiteboard/Smartboard [8–10], Kinect [8], CouchDB [11], End-edge-cloud network [12] and Qubo [13] (a tablet to display information interactively). It is worth noting that the NFC/RFID technology, which was not included in the query, appears in 11 papers, as can be seen in Table 2.

Table 1. Number of papers per year.

Year	# Papers
2012	1
2016	9
2017	11
2018	21
2019 *	14
TOTAL	56

* Only the first 9 months.

Table 2. Number of papers dealing with certain technologies.

Technologies	# Papers
IoT	46
NFC/RFID	11
AR	11
VR	8
Others	5

A paper can be in multiple rows.

Keywords for data collection and analysis were also taken into account in the query. Of these keywords, it is worth noting that the most used one is Learning Analytics, followed by Big Data, as can be seen in Table 3. This is because Learning Analytics is quite popular in educational environments in which large amounts of data are collected. It was also detected that keywords such as machine learning and deep learning are being used more and more, either individually or as a complement to the previous two.

One of the potentials of Smart Education is the large amounts of data which can be collected. Many papers have taken advantage of this to make predictions about students' behavior or to develop security measures to detect network intrusions. For this reason, some papers used more specific methods in their data collection and analysis techniques: **Decision Tree** [14–16], **Random Tree** [17], **Random Forest** [15,17,18], **Artificial Neural Network (ANN)** [15,18], **Convolution Neural Networks (CNNs)** [12,19], **Naïve Bayes** [15,20,21], **K-means Clustering** [20,22], **k-Nearest Neighbor (K-NN)** [21,23] and **others** [24–27] including Bayesian Network, Graph-based Clustering, Local Binary Patterns Histograms and Multimedia and Agents based Question Answering System (MAQAS) (see Table 4).

Some papers deal with Learning Analytics or Big Data but they do not explain the techniques used for data collection and analysis, or simply address the topic of Smart Education in a theoretical way [6,28–32]. Others focus on technology, either for the display of information [10,13], the communication between devices [9], to calculate the position of people [33–35] or the implementation of AR and VR in education [36–40].

Table 3. Number of papers mentioning relevant keywords for data collection and analysis.

Keywords	# Papers
Learning Analytics	19
Big Data	18
Machine Learning	16
Data Mining	10
Deep Learning	5
Others	2

A paper can be in multiple rows.

Table 4. Number of papers detailing methods for data collection and analysis.

Methods	# Papers
Decision Tree	3
Random Forest	3
Naïve Bayes	3
ANN	2
CNNs	2
K-means Clustering	2
K-NN	2
Random Tree	1
Others	4

A paper can be in multiple rows.

Another relevant information is the educational level addressed in the papers. It was observed that most papers focus on Higher Education, with only two papers focusing on Primary/Secondary Education. It is worth noting that a large number of papers do not mention the educational level in which they carry out their studies, as can be seen in Table 5.

A topic that is interesting in Smart Education is the localization where the study takes place, i.e., face-to-face (on-site) or online education. Although a large number of papers focus on both (20 out of 56), face-to-face education is the most addressed localization with 26 papers while online education is only addressed in three papers. As with the educational level, several papers do not specify the localization in which they carry out their studies (see Table 6).

Table 5. Number of papers per educational level.

Educational Level	# Papers
All	11
Higher Education	27
Primary/Secondary Education	4
Not specified	14

Table 6. Number of papers per localization.

Localization	# Papers
On-site	26
Online	6
Both	20
Not specified	4

3. Developed Systems

Smart education is an emerging concept that many related papers discuss from a theoretical point of view with possible applications. Nevertheless, some other papers were able to perform preliminary tests and obtain some results. There are four main objectives to develop a system to support Smart Education: (1) identification, (2) data management, (3) showing information and (4) creating virtual environments.

Regarding systems developed for identification purposes, the paper by Nsunza et al. [12] performed intrusion detection with a CNNs for cloud-based architectures. In this paper, the authors demonstrated that their system was able to identify intrusions with 82.83% of accuracy. Another paper on identification is that of Liu et al. [19] who defined a Smart Classroom model in which smartphones, microphones and wearable sensors were used to identify students' physiological responses; at the same time, CNNs were used to recommend activities. The results showed an improvement in students' grades. Elhoseny et al. [18] defined a framework that analyzes and identifies the activities of people

through wearable sensors or smartphones and also predicts what their next activity will be. For this prediction, they ran a large number of tests with different datasets and algorithms (Random Forest, Artificial Neural Network, etc.). This system aims to facilitate the administration and delivery of instructions in smart environments. Besides, Soltanpoor et al. [41] defined a system for the identification of student qualities to predict the probability of passing the student. These authors performed a couple of tests in which the results were not conclusive and therefore more research in this line is still needed. Finally, Savov et al. [25] designed a system for the identification of emotions with cameras and microphones. After testing with 448 samples, was able to correctly identify 78.2% of them.

Regarding data management, the paper by Arora et al. [8] stands out. Its main objective is to reduce the time teachers need to dedicate to support students. For this, they used a multi-touch sensor to collect students' fingerprints when entering the classroom. After implementing the system, they asked the students and most of them (97%) positively assessed the system. Dutta et al. [42] defined an architecture for the evaluation and improvement of the classroom environment, from air quality to the amount of noise. After performing some tests, they observed that their measurements allowed to reduce noise and pollution. Pacheco et al. [43] defined an intelligent lighting system controlled with the smartphone to which they added functionalities to control the door and a multimedia projector. To evaluate the system the response latency was analyzed, obtaining promising results. Another paper is the one by Fernandez-Soriano et al. [16] in which they introduced a system to determine if the students are going to pass or not. After a first pilot, they conclude that the results were not entirely reliable due to limitations with the set of study. The last paper on data management is that of Shidaganti et al. [44]; they designed a framework to transform administrative data and created a knowledge base. For the evaluation, they measured the execution times of the framework to carry out the transformation process but did not compare it with any other system.

Regarding showing information two related papers were found. The first is that of Shapsough et al. [11]; they created a standards-based evaluation system that uses tablets and smartphones to perform evaluations and allows real-time reporting. For the evaluation, they analyzed the throughput according to the number of students and observed that with more than 20 students the performance of the evaluation system decreased. The second paper is that of Uzelac et al. [17] in which a real-time system was developed to assess the reading quality of students. For this, the authors considered the characteristics of the teacher's voice and environmental values, such as temperature or ambient noise. The system obtained 78.8% of accuracy in the tests.

Regarding virtual environments, the paper by Verma et al. [24] is a good example. They defined a system for students to interact with each other and objects related to the course. With RFID and GPS sensors they obtained the position of both students and objects and analyzed the activities the authors performed. With this data, they evaluated the students' performance in the course. Another paper is the one by Fahim et al. [45] in which a system was defined to make learning more attractive and solve the problem of scarcity of educational materials. This system allowed the teacher to create a scenario which could be visualized from students' smartphones with an NFC card. All students found it fun to use and most of them (86.66%) felt more independent. Khalid et al. [7] defined a virtual environment to observe and interact with a human body. Most students positively assessed the use of this virtual environment. The last paper on virtual environments is that of Aguilar et al. [21], who defined a framework to introduce augmented reality in education, recommend teaching resources and predict student performance. For this purpose, cameras and other sensors were used for data collection. For the recommendation and prediction, they used the methods of Naïves Bayes and K-NN.

4. Research Opportunities

Smart Education is generating new challenges and opportunities for researchers [46]. A factor that almost all related papers take advantage of is data collection. With connected devices, it is much easier to collect large amounts of data [33]. At the same time, these large amounts of data. For example, data collected from tablets or wearable sensors can be shown on smart boards to inform teachers [11] and

students [8]. If the devices used in everyday life are integrated into educational settings [38], education could be more attractive to students [9,47]. Another concept which can be combined with technologies present in Smart Education [48], such as AR or VR is Gamification [24,36,48,49].

Nevertheless, new technologies entail also new challenges. Some problems are very specific [4] and affect only a low percentage of people, such as disability, but others are more general [50], such as adaptation to new technologies. Another challenge that emerges is the communication between devices and systems [18], particularly to the saturation of the network or concerning security problems [12]. Another related problem is the lack of standardization in communications [51,52], which generates conflicts when implementing third-party technologies [53]. The last of the challenges refers to the number of students. A large scalability of the systems developed means the need for devices for everyone and connections capable of supporting that load [3].

In a newly created area as it is Smart Education, there are few papers which discuss research opportunities. One of the key topics that should be taken into account is the technological changes [54,55], and how these affect students and teachers. Other factors to take into account are the external factors [4] which may condition the research on Smart Education. At the same time, the habits and opinions of society must be taken into account [39]. The context in which the research is carried out must also be taken into account when developing Smart Education initiatives [34], since depending on the country [56] and its socioeconomic context, more or less support may be available to implement Smart Education initiatives. Current technological and social limits are a decisive factor for the future [57], because they define the new goals to be pursued.

According to the papers analyzed, the challenges on Smart Education which need more research are:

- **Connectivity**. Several Smart Education systems tested the speed of their communications and discovered that there is a great reduction in performance as more devices connect. This entails a problem since the trend is having more and more students per classroom. A possible improvement could be to create a specific a protocol for mixed communications (AR and VR with RFID or other sensors). A protocol like that could respond more quickly and/or introduce more elements into the systems.
- **Security**. The collection of personal data of students, teachers or even management personnel are very common in Smart Education environments. More research is therefore needed regarding the ethical aspects of data collection, including privacy and secure data management, among others.
- **Prediction systems**. Another relevant research line to be developed is the prediction of events before they occur, such as students dropping out or failing a course. In this way, it would be possible to take corrective measures and/or increase resources, resources with the aim to improve teachers an students' performance.
- **Data visualization**. Although several papers already focus on data visualization techniques and dashboards, there is still a long way to go to deal with the large amount of data generated in Smart Education environments, display them correctly and make this data easier to understand for students and teachers. This research topic is important in order to combine existing administrative data with data collected from Smart Education environments.

5. Conclusions

This paper has analyzed the current state of Smart Education. A study of the evolution of the published papers on Smart Education, their technologies, keywords and methods of data collection and analysis, educational level and localization was carried out. The systems developed in these papers were also been reviewed and their quality and viability evaluated. In the end, research opportunities and the most important fields to improve were identified.

Smart Education is an increasingly important concept, as more and more research papers address this topic. Besides, the most relevant systems that have been implemented so far are giving promising results from users and performance. Therefore, it may be concluded that Smart Education might be

useful in the future of education. Nevertheless, there are still few papers working on Smart Education, and most of them approach this topic from a theoretical perspective. Much remains to be researched since there is no formal widespread definition of Smart Education, although several common factors have been observed throughout this systematic literature review.

Finally, this study is somehow limited in the sense that covered only a small set of papers although there seems to be not many more relevant papers currently on Smart Education since it is a relatively new concept. Also, Some research opportunities which were detected include connectivity, especially in connectivity and scalability of the developed systems, so that the number of students does not represent a problem. Security also represents a research opportunity as Smart Education works with personal data of teachers and students. Prediction systems can focus on detecting problems before they arise, such as the lack of students' motivation or the need for more resources. Data visualization techniques should also be improved so that teachers and students can fully exploit all the new information that is given to them.

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