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Smart Education and future trends

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Abstract. Smart Education is the influence of diverse technologies (Combinatorial Optimization, Machine Learning, Big Data, data visualisation, Internet of Education Things, Learning analytics, and others) to enhance the quality of education. In other words, Smart Education is the process of optimally managing human, economic and technological resources from educational institutions and research centres. Smart Education is part of the Smart Society (a component of a Smart City). The Smart Education components are the Internet of Education Things (Wireless Sensor Networks, RFID Technology), management of the education physical, infrastructure, smart classroom, smart campus, smart learning, Learning analytics, Smart Analysis, data science, Education Impact, and Educational Policy. This paper is a guide for understanding Smart Education components by presenting a survey of the characteristics, taxonomy (Education-Hard problems and Education-Soft problems), smart education indicators, history and future trends.

Keywords: Smart Cities, Smart Education, Internet of Things, Sensors.

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1 Introduction

IBM (2010) defined a Smart City as using information and communication technology to sense, analyse, and integrate core systems' key information in running cities [75].

The components of the Smart Cities are Smart Government (Smart Open Data, Smart Infrastructure, Smart Tourism, and e-government), Smart Energy, Smart Healthcare, Smart Transportation, Smart Building, Smart Mobility, Smart Society (Smart Education), Smart Farming (Smart Production of Foods), Smart Industry, Smart Environment (Smart Water, Smart Waste, Smart Air), and Smart Life [75].

This paper is a guide for understanding Smart Education components by presenting a survey of the characteristics, taxonomy (Education-Hard problems and Education-Soft problems), smart education indicators, history and future trends. Section 2 presents Smart Education and future trends, and the last section presents the conclusions.

2 Smart Education and future trends

The Smart Society (a Smart City component) must have digital citizenship, smart education and the affinity for lifelong learning, social and ethnic diversity, flexibility, creativity, cosmopolitanism, and participation in public life [75]. In this paper, we present the concept of Smart Education and the affinity for lifelong learning.

Smart Education influences diverse technologies (Combinatorial Optimization, Machine Learning, Big Data, data visualisation, Internet of Education Things, Learning analytics, and others) to enhance education quality. We also consider smart education as the process of optimally managing human, economic, and technology resources from educational institutions and research centres.

The Education-objects could be:

- Pedagogical tools (laboratories for teaching and learning can be operated remotely, build a world or virtual learning environment, the platform for collaborative learning allowing the monitoring and acting on objects or physical environments, bodily conditions expressed by students during educational processes.
- The object of study or content of a programme (management of facilities and educational resources).
- Campus management or the physical infrastructure as windows or air conditioning, intelligent energy management of classrooms and offices, physical security and the perimeter of the facilities security, detection of earthquakes, fires, and humidity, management of visitors to the University campus, optimisation of the use of water through intelligent irrigation of gardens and green areas and the control systems of the water consumption in buildings.
- Academic administration of higher education (registration and attendance to classes and academic events of the higher education).

Smart Education in a Smart City has two kinds of problems and ways to resolve them:

- Education-Hard problems. All issues where there can be optimised (maximisation or minimisation) of the education’s resources. The Smart Education-Hard Problems are the management of the Education with Technology to optimise or monitor in real-time by the Internet of Thing Technology the physical infrastructure, aspects related to the institutions of higher education as strategies for teaching and learning, high-tech services, the interaction student-professor, and the design and development of multimedia contents for learning.
- Education-Soft problems. A fuzzy concept is used to drive specific government educational agendas and others. The Smart Education-Soft Problems are the educational problems that handle information inaccurate or incomplete, with uncertainty and ambiguity, being Ambiguous, volatile, poorly understood, and dynamic (education public policy, administration, decision-making, educational reforms).

The Technology Components of Smart Education are (Figure 1):

- Internet of Education Things (IoEdT). IoEdT is a digital interconnect of not computational and computational Education-Objects using sensors and RFID technology with the Internet. IoEdT is related to the processes and activities of educational, research, administrative and other aspects related to the institutions of higher education as strategies for teaching and learning (smart learning), high-tech services (smart campus), the interaction student-professor (smart classroom), and the design and development of multimedia contents for learning (smart education). Wireless Sensor Networks. A Wireless Sensor Network (WSN) is a distributed network of multiple devices or sensors that monitor the education objects characteristics.
- Smart Classroom. A smart classroom integrates in an unobtrusive manner, sensor technology, communication technology, and artificial intelligence, among others, into the classroom to improve the learning process [11,12].
- Smart Campus. The smart campus is the educational institutions or universities that use technology to manage transport, waste, water, electricity, maintenance facilities, gardens and parks, even, the mobility of people and the parking of cars, the management integral of activities of the campus, and thus find the sustainability and efficiency of the university or educational institution. Management of the Education Physical infrastructure is the planning, organisation, direction and control of the material and technological resources (windows or air conditioning, intelligent energy management of classrooms and offices, physical security and the perimeter of the facilities security, detection of earthquakes, fires, and humidity, management of visitors to the University campus, optimisation of the use of water through intelligent irrigation of gardens and green areas and the control systems of the water consumption in buildings) of educational institutions.
- Smart Learning or Learning analytics (LA). LA is the collection, analysis, and use of the data accumulated about learning processes. LA uses statistical techniques, machine-learning approaches, and data visualisation techniques to provide knowledge that will help to optimise student performance, highlight students’ problems (identify the students’ problems and needs), Monitor efforts and progress of the students, analyse the evaluation process, discover the learning styles of the students, determine reforms on the learning processes, Monitor the learning process in the smart classroom, improve pedagogical strategies, and tune-up educational platforms [11].
- Data Science. Data Science analyses the behaviour of the data obtained from sensors and educational-object, extracting value from stored data, and formulating predictions through the patterns observed to serve for decision-making of Smart Education.
- Education Impact. The Education Impact is the desertion, illiteracy, and others.

- Educational Policy. Educational policies are agreements or laws (educational regulations and agreements) governmental related to education.

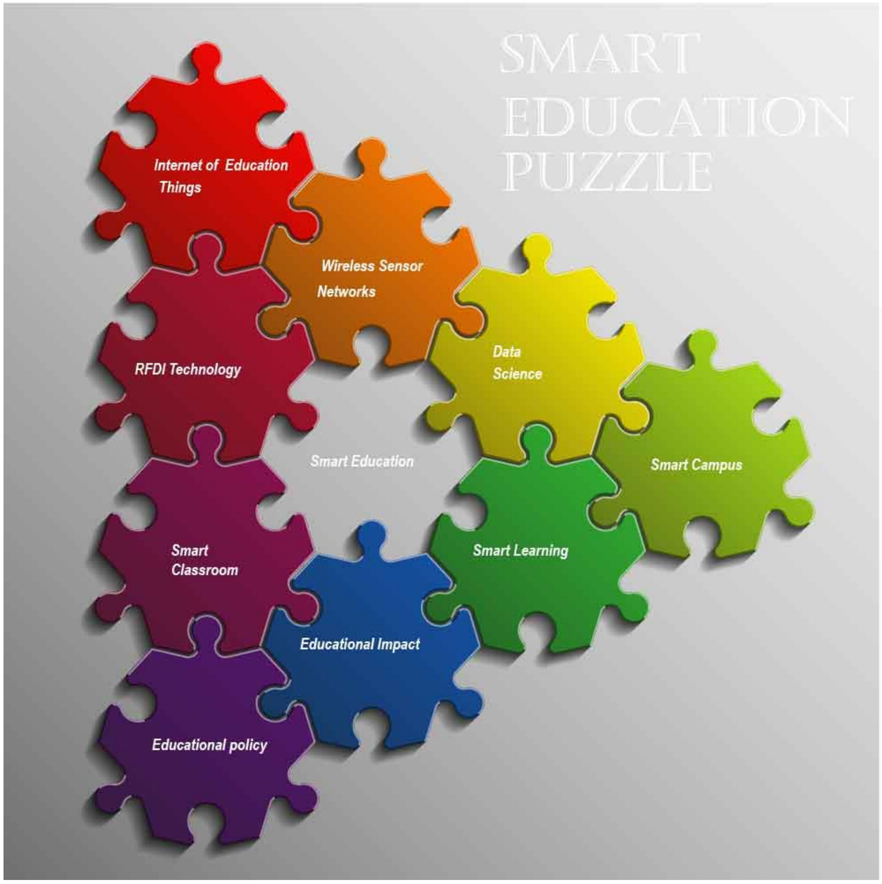

Figure 1. Components of Smart Education.

In table 1 are the Smart Education Indicators. The Smart Education Indicators serve to determine if it has the necessary elements to be considered intelligent education within a smart city.

Table 1. Indicators of a Smart Education.

Indicators of the Smart Education	
Smart Learning	Educational technology (PowerPoint Presentation), Learning Management System LMS Platform (moodle, blackboard), Chat Room, E-Mail, Internet Connection, Multimedia Technology, Online Activity (online teaching, online discussion, online information searching), Video Conference.
Smart Classroom	Students face recognition, a digital archive of courses, Instant messages to teachers, voice recognition, virtual reality learning, class activity database, interactive whiteboard system, Automatic learning assessment systems, Virtual classroom, Distance education, Mobile Learning, Social and Ethnic diversity in the Smart Classroom.
Smart Campus	Social and Ethnic diversity in the Smart Campus, Management of the Education Physical Infrastructure (Air conditioning, intelligent energy management of classrooms and offices, physical security and the perimeter of the facilities security, detection of earthquakes, fires, and humidity, management of visitors to the University campus, optimisation of the use of water through

	intelligent irrigation of gardens and green areas and the control systems of the water consumption in buildings).
Highly trained human capital formation	The affinity for lifelong learning, Citizen science, Open Science, important scientific infrastructure, Flexibility, Creativity, Cosmopolitanism and Participation in public life, technology and innovation system, knowledge work and personal learning environments, homeschooling.

There are several works on Education-hard problems (Timetabling Scheduling Problem, University Timetabling, High School Timetabling, Examination Timetabling, Student Sectioning, School timetabling problem, and others).

Wren (1996) [96] proposed the timetabling Scheduling Problem (TSP) as allocation with selected resources constraints to being placed in space-time. The timetabling Scheduling Problem is a classical np-hard problem, where the main goal is to assign rooms or timeslots to create a timetable (figure 2). The main constraints are divided into two ways: a) Hard constraints (One resource person or room must not be assigned into two simultaneous events, All available courses must be scheduled, same period events can be assigned at the same timeslot if both events are the same type, but with different assistant groups, Each room has an availability schedule, Each event must be assigned to the instructor designated for the kind of event, Some events must be strictly assigned to specific instructors, Each room has a specific capacity and must be assigned to a specific group of assistants, And so on), b) Soft constraints (Every instructor has his/her availability schedule and preferred periods, All instructors have a limit of weekly work-hours, An event can be divided into more than one noncontiguous periods, The travel time of instructors and assistants between events must be minimised, And so on).

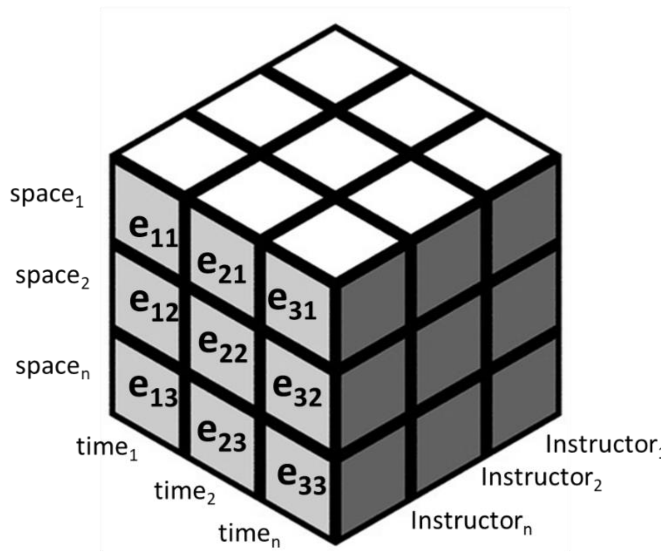

Figure 2. Timetabling Scheduling Problem representation.

The TSP has several variants where there are some related to school scheduling problems. The characteristics of each variant depend on the main objective, e.g., Wren (1996) [96] emphasises TSP oriented to minimise the total cost of resources; Carter (2001) oriented the TSP to decide when events will occur, and so on. Educational timetabling can be presented as the main education planning problems:

- University Timetabling. McCollum (2006) [2,5] proposed the university timetabling as a university course divided into sections, and designation of times, students and rooms. University timetabling is oriented to assign lectures to school rooms and timeslots to create high education timetables for students and teachers.
- High School Timetabling. Pillay (2013) [69] defined the High School Timetabling problem, where the aimed objective is to allocate classes, teachers and rooms into timeslots to satisfy the restrictions.
- Examination Timetabling. Qu et al. (2009) presented a study of Examination Timetabling, where this problem aims to schedule the exams for students with limited resources.
- Student Sectioning. This kind of problem consists of assigning students to sections of courses based on individual requests for each student.

- School timetabling problem (STP). Carter et al. (1997) [31,32] define this kind of problem as a subtype of course timetabling. The aim consists on to allocate the classes, teachers and spaces tuples into timetable slots to satisfy the constraints (hard and soft) of the instance. Based on Abramson (1991) [8,9], the students are grouped into classes prioritising the timetable construction process.

The School timetabling problem has been solved using different methodologies. The Methods used to solve the STP are: Simulated annealing: Abramson (1991) [8] used Simulated annealing where the atoms are the timetable's elements; Melicio et al. (2006) proposed a THOR timetabling tool. Evolutionary algorithms: Abramson et al. (1991) [9] used Genetic Algorithms; Beligiannis et al. (2008) used an adaptive evolutionary algorithm; Caldiera et al. (1997) used Genetic Algorithm; Filho et al. (2001) used a constructive genetic algorithm; Nurmi et al. (2008) used a Genetic Algorithm; Raghavjee et al. (2008) used a Genetic Algorithm; Wilke et al. (2002) used a Genetic Algorithm. Tabu Search: Bello et al. (2008) used Tabu Search into Graph Coloring Schema; Jacobsen et al. (2006) used Tabu Search into Graph Coloring Schema; Santos et al. (2005) used Tabu Search into an initial solution based on a constructive algorithm. Integer programming: Birbas et al. (1997) used integer programming; Santos et al. (2008) used integer programming with Fenchel cuts. Constraint programming: Valouxis et al. (2003) used constraint programming in local search. GRASP: Moura et al. (2010) used GRASP with path-relinking. Tiling algorithms: Kingston (2004) and Kingston (2006) used a tiling algorithm with hillclimbing and an alternating path algorithm; Kingston (2008) used a bipartite matching model. Hybrid approaches: Alvarez-Valdes et al. (1996) used parallel heuristic algorithm, Tabu search, graph theory and FloydWarshall algorithm; De Haan et al. (2007) used a branch-and-bound algorithm, dynamic priority rules, graph colouring first-fit heuristic and Tabu Search; Schaerf (1991) used RNA and Tabu Search; Birbas et al. (2009) used the shift assignment problem with integer programming.

Examination Timetabling has been solved using different methodologies of artificial intelligence and operational research, mainly: Hyper-heuristic [23,24,25,26,2,3,4,5,6,7,16,69,70,71], Adaptative methods [18], Graph-based [23,24,25,26].

University Timetabling has been solved with methodologies of artificial intelligence: Swarm-based algorithm (Fong et al. 2015), Graph Coloring [30,31,32], Simulated annealing [41,88,89,90], Tabu Search [1,2,53,62,63,64,37], Neighborhood Search [5,6], Local search [28], Genetic Algorithm [3,4], Ant Colony [43,81,82], Honey Bee [76,77], Artificial Bee Colony [16,17].

High School timetabling can be presented as the main education planning problems: Neighborhood [22,48,84], Hyper-heuristics [54], Integer programming [55,15,39,40,80] Max Sat [36], Parallel metaheuristics [86,21,79,59,8,9].

There are several works on Management of the Education and Physical Infrastructure (Campus management or the physical infrastructure as windows or air conditioning, intelligent energy management of classrooms and offices, physical security and the perimeter of the facilities security, detection of earthquakes, fires, and humidity, management of visitors to the University campus, optimisation of the use of water through intelligent irrigation of gardens and green areas and the control systems of the water consumption in buildings):

Information and Communication Technology (ICT) is the backbone and infrastructure for schools in organising the education processes. ICT-Based School Management System (SMS-ICT) is proposed to manage school institutions' information. SMS-ICT is oriented to facilitate the processes related to learning. Gaffar (2011) proposed some principles for the basic structure of the SMS-ICT: Athletic structure, High response capacity, Boundaryless, Professionalism and efficiency, High-capacity building, Synergy, Values-based, High leadership capacity, and Cost-effective.

Gaffar (2011) and Cooper et al. (2005) proposed the outcomes based on the application of the SMT - ICT: Structured Information on all subjects, Extracurricular programs to be managed, Overall self-managed development activities to support their interests, talents, and creativity of students, System acceptance of new students (conventional and online), Student profiles, Profile educators, Educational facilities and infrastructure, Main activities like a performance of school principals and performance evaluation of principals, Policies, strategic planning, and program annual school activities, Funds to the program of activities, financial management and accountability, and Evaluation systems.

Everard et al. (2004) [44] proposed the SMS-ICT change academic faculty's viewpoint in schools as a common requirement and have a high priority. Through ICT- the SMS data entry process that was originally performed repeatedly has become more organised and should not be repeated. This enables the management process at the school.

Blau and Presser (2013) [20] presented the School Management Systems as an important tool to increase effective e-leadership and data-based decision making. SMS optimise the flow of information between stakeholders. In this case, the authors focus the research on the e-leaderships through the Mashov SMS on increasing the effectiveness. The SMS includes the next aspects: Making data-based decisions, Monitoring curriculum implementation, learning performance, Interaction with teachers, students and parents, and improving the school climate.

Egido-Galvez (2016) [42] mentioned that the implementation of SMS had been increased in these years. In this research, the author analyses the efficiency's increase for schools. The results showed that SMS has a positive impact on improving schools and a positive climate.

De Smet et al. (2012) [34] presented a large-scale study to understand the learning management systems (LMS) in secondary school. The results showed that Internal ICT support directly affects the informational use of the LMS and on a subjective norm.

Carballo-Santaolalla et al. (2017) [29] mentioned the use of Quality Management Systems (QMS) into educational organisations to define the improvement plan to evaluate the internal process. Rubin et al. (2010) [74] presented the effects on interaction and learned structures through the Learning Management Systems (LMS) to online courses. LMS support active engagement, meaningful connections, easy communication, and formative feedback, provide open-ended feedback and place course elements.

There are various types of affinity for lifelong learning: homeschooling (home education), adult education, continuing education, knowledge work and personal learning environments. Learning can be through massive open online courses (MOOC), assistive technology, the Web and workplace learning. Performing exercises for the brain lessens mental decline allowing lower expenditures for treatments related to Alzheimer's disease and degenerative diseases of the brain. There are several works on educational learning systems:

The Massive Open Online Courses (MOOC) is a solution for a high demand for people with training needs and a weak relationship between the tutor and participant. This can be improved with an architectural approach to monitoring and evaluating the quality of the course [52]. The MOOCs' level is related to prestige, public or private status, age, size or region. The prestige to be the most relevant [66]. MOOCs' use poses that any person regardless of the social or cultural status or location can access this type of training and must have access to the Internet, digital and technological knowledge, self-learning, and knowledge management [46]. MOOCs in Latin America education is analysed through publications from 2014 to 2017, Spain the highest and the lowest, Chile, Bolivia, Colombia, and Costa Rica [38].

Smartphones can support students with intellectual disabilities education and development activities, emotional and behavioural [97]. The use and acceptance of smart lenses can support learning and communication in children with autism spectrum disorders. Touch screens support educational skills (subjects such as geometry, the mathematics that requires good vision) and rehabilitation of children or young people who have different visual disabilities. Augmented reality supports special education by recognising Brazilian people's signs with deafness language [33]. The use of tablets and mobile applications improves students' socio-adaptive behaviour in public high schools with autism spectrum disorders – ASD (Fage et al., 2018).

There are various works about Big Data applied to education: Williamson (2018) [93] develop a data infrastructure that combines network organisations, software, standards, analysis and visualisation of data under the concept of an intelligent university is developed for higher education in the UK. Whang, Hu and Zhou (2018) [92] carried out a follow-up of students' emotional tendencies who completed tasks, commented, and participated in forums on MOOC platforms to propose teaching personalised through a semantic analysis model. Magal-Royo and García Laborda (2017) [61] propose establishing guidelines for data extraction to evaluate languages as a second language test. Tong and Li (2018) [91] analysed the factors that influence the demand for MOOCS in countries belonging to the OECD with tools such as Google Trends and Baidu Index.

Several works on IoT are applied to education (Smart Campus, Smart Classrooms): Luo (2018) [58] presents the smart campus planning problems and current research based on Wireless Sensors. Adeyemi et al. (2018) [10] performed a robust data exploration on daily Internet data traffic generated in a smart university campus for twelve consecutive months of 2017. MacLeod et al. (2018) [62] present the rationale for developing an instrument that measures students' preferences toward the smart classroom learning environment. Moreover, the data was purposely collected from 462 college students enrolled in at least one smart classroom. Aguilar et al. (2018) [11,12,13] propose the concept of Autonomic Cycle of Learning Analysis Tasks (a set of tasks of learning analysis, whose objective is to improve the learning process) and study the application of the autonomic cycle in a smart classroom (smartboard) and virtual learning environments. Byrne et al. (2017) [27] propose An IoT and Wearable Technology Hackathon for Promoting Careers in Computer Science.

An infrastructure about IoT in Education was presented for agricultural education by Gunasekera et al. (2018) [51] where the idea is to have a rapid building of multiple IoT applications at the university including many sensors by using a software-centric solution, in this way the people can access to the historical data from the sensors. In addition to this idea, it was proposed to use a web-based visualisation, so comparing the alternatives for software visualisation and IoT platforms is shown. Finally, it was developed IoT4SSAE is the preferred platform and as future work, it will be possible to have a SCADA system for agriculture.

For medical education a learning platform was designed by Ali et al. (2017) [14], they implement case-based learning (CBL) as a medium to educate about medical cases; the main idea in that paper was to have an interactive CBL between the students and the expert knowledge, this IoT application has the following layers: data perception, data aggregation, access technologies, cloud security, presentation, application and service and the business layer. The application was made at the University of Tasmania.

A different case is when the IoT is learning at the school as a tool for students, in (Szydlo et al., 2018) [87] where the communication protocols and embedded systems were presented to the students to develop IoT anywhere, thus, in the course presented to students they work in group and one of them implements the server for the IoT application, as future work it was planned to have 3D printed models of factories to have data acquisition.

A survey about IoT in education was shown by Gul et al. (2017) [49] where it was mentioned that both the teaching-learning process and educational infrastructure are opportunities for the IoT, so the impact of this technology in education was presented, in this way, the smart campus is an interesting application in universities having Internet in the classrooms, laboratories, notes sharing applications and mobile devices, there were mentioned some advantages in the use of IoT, but some problems as privacy and security must be resolved.

3 Conclusions

Smart Education influences diverse technologies (Combinatorial Optimization, Machine Learning, Big Data, data visualisation, Internet of Education Things, Learning analytics, and others) to enhance education quality. We also consider smart education as the process of optimally managing human, economic, and technology resources from educational institutions and research centres. How education is taught should be improved with the use of technologies like the Internet of Education Things.

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