The Ontology of Next Generation Smart Classrooms

Vladimir L. Uskov, Jeffrey P. Bakken and Akshay Pandey

Abstract Fast proliferation of various types of smart devices, smart systems, and smart technologies provides academic institutions, students and learners with enormous opportunities in terms of new approaches to learning technologies, education, learning processes and strategies, corporate training, user's personal productivity and efficiency, and faster and better quality of services provided. This paper presents the developed ontology of Smart Classroom systems - it helps to understand and analyze current smart classroom systems, and identify features, hardware, software, services, pedagogy, teaching and learning-related activities of the next generation Smart Classroom systems.

Keywords Smart classroom · Ontology · Hardware · Software · Technology · Pedagogy · Learning and teaching activities

1 Introduction

Modern sophisticated smart devices, smart systems, and smart technologies create unique and unprecedented opportunities for academic and training organizations in terms of new approaches to education, learning and teaching strategies, services to on-campus and remote/online students, set-ups of modern classrooms and labs. The performed research clearly shows that smart education market, in general, and

V.L. Uskov (✉) · A. Pandey
Department of Computer Science and Information Systems, Bradley University, Peoria, USA
e-mail: uskov@fsmail.bradley.edu

A. Pandey
e-mail: apandey@fsmail.bradley.edu

J.P. Bakken
The Graduate School, Bradley University, Peoria, USA
e-mail: jbakken@fsmail.bradley.edu

V.L. Uskov et al. (eds.), *Smart Education and Smart e-Learning*,
Smart Innovation, Systems and Technologies 41,
DOI 10.1007/978-3-319-19875-0_1

market of software and hardware for smart classrooms and smart universities, in particular, will exponentially grow in upcoming years.

Smart Education Market in 2013-2017. "The global smart education and learning market is expected to reach $220.0 billion by 2017 at a CAGR of 20.3 % between 2012 and 2017, including (a) services segment with projected $97.9 billion by 2017 with a CAGR of 26.6 %, (b) content segment - $72.9 billion in 2017, at a CAGR of 12.1 %, (c) software segment - $37.2 billion, and (d) hardware - $12.1 billion in 2017. Companies such as Ellucian, Inc. (U.S.), Smart Technologies (U.S.), Blackboard Inc. (U.S.), Kaplan Inc. (U.S.)., Promethean World Plc (United Kingdom), Pearson PLC (United Kingdom), and Informa Plc (Switzerland) are among key players on the smart education market" [1].

Smart Classrooms' Market in 2014-2018. "The global smart classroom market will grow at a CAGR of 31.25 % over the period 2013-2018. The two key factors contributing to this market growth are interactive display instruments and 3D education. Multiple global companies are among leaders in this area, including Apple, IBM, Microsoft, and SMART Technologies Inc." [2].

Therefore, it is necessary to perform research and get clear understanding of what specific technologies, software, hardware, services, learning-related activities and strategies will be required by next generation of smart classrooms in the near future.

2 Generations of Smart Classrooms: Literature Review

The concept of smart classroom was introduced several years ago; it is in permanent evolution and improvement since that time. "Smart Classrooms represents a focus on re-orienting our school structures and business processes around individual students and their learning needs. It is a transformative strategy to transition from traditional ways of working to a digital way of working that is meaningful, engaging and connected" [3].

We may identify several generations of implementations of smart classroom concept and corresponding software/hardware solutions in academic institutions.

The first (2001-2007) generation of smart classrooms. The early smart classroom implementations were primarily focused on synchronous delivery of learning content to local (i.e. students in actual physical classroom with face-to-face learning/teaching mode) and remote/online (i.e. students, in remote locations with online mode of learning/teaching) as well as synchronous teacher-students and local student-to-remote student communications. Shie, Xie, Xu, et al. in [4] showed that "…in the Smart Classroom, teachers can use multiple natural modalities while interacting with remote students to achieve same effect as a teacher in a classroom with local students. … In this type of tele-education, multimedia education systems let teachers and students in different locations participate in the class synchronously". Additionally, Xie, Shi, Xu et al. in [5] presented that "The Smart Classroom demonstrates an intelligent classroom for teachers involved in tele-education, in which teachers could have the same experiences as in a real classroom. … The

magic of the Smart Classroom is the way teachers using the system - teachers are no longer tied up to the desktop computer, nor cumbersome keyboard and mouse".

V. Uskov and A. Uskov in [6] described a synchronous teaching of local students and remote/online students using the Internet-2 technology with 2-way full-scale synchronous high definition video, high quality audio, real-time 2-way discussions between local and remote students, active participation of remote students (who were as far as 2,400 miles away from actual physical classroom) in classroom activities, their questions and feedback.

The second (2008 - current) generation of smart classrooms. The second generation of smart classroom implementations is mainly based on active use of mobile technology, user/student/learner mobile devices and automatic communications between then and smart classroom environment.

Yau et al. [7] proposed Smart Classroom solution based on Reconfigurable Context-Sensitive Middleware (RCSM), connected situation aware PDA (i.e. with awareness about location, light, noise, and mobility) for each student, pervasive computing technology and collaborative learning.

O'Driscoll et al. in [8] described their version of Context Aware Smart Classroom (CASC). "It is a classroom that responds to lecturers and student groups based on preset policies and the lecture timetable. The pervasive nature of personal mobile devices permits the investigation of developing low-cost location and identification systems that support development of a smart classroom. The smart classroom CASC uses a central scheduling system to determine the teaching activity".

Huang et al. in [9] proposed "… a SMART model of smart classroom which characterized by showing, manageable, accessible, interactive and testing. … A smart classroom relates to the optimization of teaching content presentation, convenient access of learning resources, deeply interactivity of teaching and learning, contextual awareness and detection, classroom layout and management, etc.".

Pishva and Nishantha in [10] define a smart classroom as an intelligent classroom for teachers involved in distant education that enables teachers to use a real classroom type teaching approach to teach distant students. "Smart classrooms integrate voice-recognition, computer-vision, and other technologies, collectively referred to as intelligent agents, to provide a tele-education experience similar to a traditional classroom experience" [10].

Glogoric, Uzelac and Krco [11] addressed the potential of using Internet-of-Things (IoT) technology to build a smart classroom. "Combining the IoT technology with social and behavioral analysis, an ordinary classroom can be transformed into a smart classroom that actively listens and analyzes voices, conversations, movements, behavior, etc., in order to reach a conclusion about the lecturers' presentation and listeners' satisfaction" [11].

Slotta, Tissenbaum and Lui described an infrastructure for smart classrooms called the Scalable Architecture for Interactive Learning (SAIL) that "employs learning analytic techniques to allow students' physical interactions and spatial positioning within the room to play a strong role in scripting and orchestration" [12].

Koutraki, Efthymiou, and Grigoris developed a real-time, context-aware system, applied in a smart classroom domain, which aims to assist its users after recognizing

any occurring activity. The developed system "…assists instructors and students in a smart classroom, in order to avoid spending time in such minor issues and stay focused on the teaching process" [13].

The Samsung Smart School solution has three core components: (1) the interactive management solution, (2) the learning management system, and (3) the student information system. Its multiple unique features and functions are targeted at smart school impact on education and benefits, including (1) increased interactivity, (2) personalized learning, (3) efficient classroom management, and (4) better student monitoring [14].

3 Research Project Goal and Objectives

The performed analysis of these and multiple additional publications and reports relevant to (1) smart classrooms, (2) smart technologies, (3) smart systems, (4) smart devices and meters, (5) smart universities, (6) smart environments, (7) smart cities, (8) ambient intelligence, (9) Internet-of-Things, and (10) smart educational systems undoubtedly shows that (a) smart classrooms, (b) smart labs, and (c) smart universities will be essential topics of multiple research, design and development projects in upcoming 5…10 years. It is expected that in near future smart classroom concept and hardware/software solutions will have a significant role and be actively deployed by leading academic intuitions – smart universities - in the world.

Based on our vision of smart classroom, smart university and up-to-date obtained research outcomes, we believe that the next generation of Smart Classroom systems should significantly emphasize not only software/hardware features but also "smart" features and functionality of smart systems (Table 1) [15, 16].

Table 1 Classification of levels of "smartness" of a smart system [15, 16]

Smartness levels (i.e. ability to …)	Details
Adapt	Ability to modify physical or behavioral characteristics to fit the environment or better survive in it
Sense	Ability to identify, recognize, understand and/or become aware of phenomenon, event, object, impact, etc.
Infer	Ability to make logical conclusion(s) on the basis of raw data, processed information, observations, evidence, assumptions, rules, and logic reasoning
Learn	Ability to acquire new or modify existing knowledge, experience, behavior to improve performance, effectiveness, skills, etc.
Anticipate	Ability of thinking or reasoning to predict what is going to happen or what to do next
Self-organize	Ability of a system to change its internal structure (components), self-regenerate and self-sustain in purposeful (non-random) manner under appropriate conditions but without an external agent/entity

Therefore, next generation of smart classrooms should pay more attention to implementation of "smartness" maturity levels or "intelligence" levels, and abilities of various smart technologies.

The goals of performed research were to identify smart classroom's components, features, interfaces, inputs, outputs, limits/constraints, and develop ontology of Smart Classroom systems. The premise it that such taxonomy will enable us to identify and predict most effective hardware, software, services, pedagogy, teaching/learning activities for the next generation of Smart Classroom systems.

4 Research Outcomes: Smart Classrooms' Ontology

The proposed ontology of next generation Smart Classroom system is presented below in a tabular form. It is based on Systems Thinking approach that uses the following general descriptors: (1) goals, (2) components, (3) environment, (4) constraints/limits, (5) links (relations) between interrelated components, (6) interfaces between components and system-environment types of relations, (7) inputs, (8) outputs, and (9) boundary between Smart Classroom system and environment. Due to space limits of this paper, we present research outcomes for only the first four descriptors.

4.1 Goal and Objectives of the Next Generation Smart Classroom Systems

The main goal of next generation Smart Classroom systems is to demonstrate significant maturity at various "smartness" levels, including (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organizations and restructuring (Table 1). The specific objectives of the next generation Smart Classroom systems are given in Table 2.

Table 2 Goals and objectives of the next generation Smart Classroom systems

Scope	Goals and objectives (main functions of the system)
	Goals
	• Goal 1: Next generation Smart Classroom systems must demonstrate significant maturity on various "smartness" levels, including (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organizations and restructuring (Table 1)
	• Goal 2: Next generation Smart Classroom systems must have corresponding modern hardware (Table 3), software (Table 4), provide various services and activities to facilitate really smart teaching and learning strategies (Table 5), and deploy a great variety of learning strategies and pedagogies (Table 6)

(continued)

Table 2 (continued)

Scope	Goals and objectives (main functions of the system)
	Objectives
Common	• Facilitate learning through collaboration and interaction with students both remotely and locally using various types of interconnected wireless devices
	• Facilitate collaborative learning between local and remote students regardless students' native languages
	• Seamlessly connect several distant smart classrooms to share lectures and information via networking
	• Seamless connect various types of users' mobile smart devices and technical platforms; provide scalability and timely update of software systems and applications used by various users
	• Go well beyond the conventional static HTML-based presentation on the Web page or PPT slide show to multiple HD screens-based interactive learning experience (i.e. provide "smart learning cave" effect)
	• Automatically record all class activities and provide students with post-class review activities, for example, to review/learn content at student's own pace and comfort level
	• Accommodate, adapt and implement newest and emerging technologies and innovative trends, for example, computer vision, face recognition, speech recognition, noise cancellation, gesture recognition, etc.
	• Provide voice recognition, quality and fats automatic translation from English language to other languages, and visa versa
	• Provide ambient intelligence features, specifically, to adjust features like light intensity, temperature, humidity, safety, odor, etc. to suit and comfort local students in order to facilitate learning environment
Specific to instructor	• Allow instructor to communicate and express himself/herself naturally as in a traditional classroom without having significant experience in computer, information, and communication technologies and Web services
	• Allow teachers to host, join, form and evaluate group discussions on mobile devices and laptops for both local (in traditional classroom) and remote (online) students who present learning outcomes
	• Empower instructor with voice recognition, face recognition, gestures and smart pointing devices and boards to navigate, edit and display information on smart boards
	• Provide instructor with various analytical and recommender systems to maintain high quality and effective learning and teaching processes
	• Allow instructor to move freely and naturally without the need of a human cameraman to keep switching panoramic camera angles and views to display and present information to remote students (or, to use a smart cameraman component)
Specific to local student	• Provide students with quality automatic translation features (for example, from Spanish to English, or from English to Chinese)
Specific to remote student	• Provide a regular face-to-face learning like experience to online/remote students logging into a session in a smart classroom or smart lab
	• Provide students with quality automatic translation features (for example, from Spanish to English, or from English to Chinese)
	• Provide remote student with access to automatically recorded class activities for post-class review, for example, to review/learn content at student's own pace and comfort level

4.2 Components of Next Generation Smart Classroom Systems

Next generation Smart Classroom system's components include but are not limited to (a) hardware components, devices or equipment, (b) software systems, applications, and emerging technologies, (c) various activities related to learning and teaching, and (d) types of learning or pedagogy to used. Table 3 below contains detailed information about main hardware components, Table 4 – software components, Table 5 – learning activities related to learning and teaching, and Table 6 – types of learning and/or pedagogy to be used in next generation Smart Classroom systems.

Table 3 Proposed hardware components of next generation Smart Classroom systems

Scope	Hardware/equipment details
Common	• Array of video cameras installed to capture main classroom activities, movements, discussions, expressions, gestures, etc.
	• Ceiling-mounted projector(s) with 1 or 2 big size screen to display main activities in actual classroom; in some cases – 3D projectors
	• Student boards (big screen displays or TV) to display images of remote/online students from different locations
	• One or many (depending on class size, number of remote students, learning needs and workload) hidden computer systems to actually run the software and components of the Smart Classroom system
	• Bluetooth and Internet enabled devices like cell phones, smart phones, PDAs and laptops to facilitate communication and information/data/notes exchange
	• Network equipment (for example, Wi-Fi routers, zig bee transceivers, infrared, RFID readers and tags) to facilitate authorization and other forms of inter- device secure and reliable communication
	• Access to the Internet (mobile Web)
	• Wireless sensor network
	• Sensors (location detection, voice detection, motion sensors, thermal sensors, humidity, sensors for facial and voice recognition, etc.)
	• Robotic controllers and actuators to perform functions like intensity control, temperature control, movement, etc.
	• Devices: context aware devices, virtual mouse, biometric based login devices, automated zoom-in devices
	• Controlled and self-activated microphones(s) for instructor and students
	• Various type of speakers
	• Various types of lights
Specific to instructor	• Instructor's tablet PC (to write formulas, equations, run PPT presentations, video and audio clips, etc. in real time)
	• Big size smart board (to write formulas, equations, etc. in real time)
	• Document camera (connected to projector)
Specific to local student	• Array of mobile devices: smart interconnected mobile devices - smart phones, PDAs, laptops, smart headphones, etc.
	• (In some cases only): 3D goggles
Specific to remote student	• Desktop or tablet PC or laptop with connected or built-in microphone, speakers
	• Access to the broadband Internet

Bradley University contracted the Crestron company (http://www.crestron.com) to set-up multimedia top-quality Web-lecturing and capturing equipment for several classrooms including smart boards, HD video cameras, projectors, document camera, computer systems and software for instructor, microphones, speakers, etc. – this is the first step towards Smart Classroom establishment. A total cost of a full set-up (equipment + installation) of one classroom of this type is about $40,000 (as of May 2015).

Table 4 Proposed software components of next generation Smart Classroom systems

Scope	Software details
Common	• Agent-based systems to enable various types of communication between devices in the Smart Classroom system
	• Learning management system (LMS) or access to university wide LMS
	• Advanced software for rich multimedia streaming, control and processing
	• Software systems to address needs of special students, for example, visually impaired students (speech and gesture based writing/editing/navigation and accessibility tools to facilitate reading and understanding)
	• Smart cameraman software (for panoramic cameras)
	• Recognition software: face, voice, gesture
	• Motion or hand motion stabilizing software
	• Noise cancellation software
	• Security system for a secure log-in and log-out of registered student
	• Implementation of Internet-of-Things technology
	• Implementation of elements of various emerging technologies (for example, Smart Environments, Ambient Intelligence, Smart Agents)
Specific to instructor	• Smart drawing tools (for example, Laser2cursor) for drawing on smart boards, navigating and giving remote students floor to speak
	• Situation and/or context aware analytical system (that may generate hints and/or recommendations to instructor)
	• Analytical systems to analyze and rank class performance and outcomes
	• Systems to analyze presence, attendance, etc.
Specific to local student	• Smart notebook/laptop/tablet PC software
	• Main office software applications
	• Same view and smart view software
Specific to remote student	• Remote client programs to facilitate remote learning
	• Main office software applications
	• Same view and smart view software

Table 5 Types of activities related to learning/teaching to be actively used in the next generation of Smart Classroom systems

Scope	Activities (to …)
Common	• Communicate with other classmates as well as local and remote student project team members (a sub-group of students)
	• Share student team project documents on the Web or portal
	• Communicate with students in other smart classrooms at different locations
	• View learning content in a preferred language
	• Collect immediate feedback from students in terms of interest and likeability of an activity, session, or an overall subject and teacher
	• Recognize and classify the movement of any students in class
	• Automatically collect data from sensors and run analytics on students in terms of behavior, performance, interest, participation, etc.
	• Help special students, for example, visually impaired students (speech and gesture based writing/editing/navigation and accessibility tools to facilitate reading and understanding)
	• Adjust automatically classroom environment (lights, AC, temperature, humidity, etc.) or by voice commands
	• Agent-based systems to enable various types of communication between devices in the Smart Classroom system
Specific to instructor	• Give voice commands to the system to perform specific actions or to follow designated Web links
	• Initiate a classroom session with voice/facial/gesture commands
	• Give a floor to a remote student
	• Recognize each and every individual and his position/location in or outside physical classroom
	• Ability to suggest changes to the system
Specific to local student	• Learn and discuss presented learning content using reach multimedia and various communications tools and devices; participate in all class activities
	• Discuss presented learning content and assignments with remote students in real-time and using preferred language by each student
Specific to remote student	• Learn and discuss presented learning content synchronously with local students
	• Complete in-classroom assignments in real time and submit corresponding documents from remote locations synchronously with local students
	• Vote in a student team (with local and remote students) regarding an issue synchronously with local students
	• Ask teacher a question in real time during class session
	• Present in front of the local students from a remote area
	• Discuss and annotate any learning materials in real time

Table 6 Types of pedagogy to be used in the next generation of Smart Classroom systems

Scope	Types of pedagogy or learning
Common	• Smart classroom pedagogy (or, smart technology based teaching)
	• Learning-by-doing
	• Collaborative learning
	• Project-based learning
	• Advanced technology-based learning
	• e-Learning pedagogy
	• Games-based learning and pedagogy
	• Flipped classroom pedagogy

4.3 Environment and Constraints/Limits of the Next Generation Smart Classroom Systems

Various academic (schools, colleges, universities) and training (centers, businesses) organizations will primarily serve as the environment for the next generation Smart Classroom systems. Several examples of identified constraints for those organizations are presented in Table 7.

Table 7 Expected limits/constraints of the next generation Smart Classroom systems

Scope	Types of visible limits/constraints (several examples)
Common	• Limit on number of local and remote students in smart classroom
	• A combination of various sophisticated (cutting-edge) hardware and software systems and services may cause incompatibility problems
	• System can get "confused" by multiple voice-activated modules
	• Storage space (backdoor room) with servers, equipment, security, maintenance, etc. may be an issue both technologically and financially
Technology-related	• Technology constraints; potential problems with technology update, upgrade and maintenance at academic institutions
	• Too many interlinked devices, software systems, data exchange protocols used, etc.; as result, those devices and/or modules may lead to unexpected significant complexity and consequent failures of the entire system
	• Internet bandwidth constraints, especially for remote students in geographically isolated locations
	• Smart board technology is not yet as good and natural as unparalleled "white board-and-marker" or "chalk-and-board" methodology
Financial	• Financial constraints due to costs of high tech hardware, software, services, servers, maintenance, etc.
Student/learner-related	• Limit on number of hours a person can spend in front of computer screen or a mobile device
	• Absence of modern laptop, smart phone, software can be a constraint both financially and emotionally
	• Technological knowhow may be a constraint for older, not technology savvy students; a set of constraints will occur for disabled students
	• Non-social ("quite") student/learner issues

5 Conclusions. Future Steps

The performed research, identified evolution and development tendencies and obtained research findings and outcomes enabled us to make the following conclusions:

(1) Smart education market and market of software and hardware for smart classrooms will exponentially grow in upcoming years.
(2) Smart classrooms and smart universities will be essential topics of multiple research, design and development projects in upcoming 5…10 years.
(3) Leading academic intuitions in the will deploy smart classroom concept and hardware/software solutions in the near future.
(4) Next generation of Smart Classroom systems should pay more attention to implementation of "smartness" maturity levels and abilities of smart technologies.
(5) The proposed and developed ontology of Smart Classroom systems (components, functions, interfaces, inputs, outputs, limits/constraints, etc.) enabled us to identify and predict hardware, software, services, teaching/learning activities for the next generation Smart Classroom systems (Tables 2, 3, 4, 5, 6, 7).

Based on obtained research findings and outcomes, and developed ontology of the next generation Smart Classroom systems, the future steps in this research project are to (a) implement, test, validate, and analyze various identified learning strategies and pedagogies in smart classroom environment, (b) perform summative and formative evaluations of local and remote students and get sufficient data on quality of Smart Classroom main components - hardware, software, technologies, services, etc.), and (c) design and develop software systems for advanced Smart Classroom systems.

References

1. Smart Education and Learning Market. http://www.marketsandmarkets.com/Market-Reports/smart-digital-education-market-571.html (2013)
2. Global Smart Classroom Market 2014-2018 Report, http://www.researchandmarkets.com/research/2n7vrr/global_smart (2014)
3. e-Learning For Smart Classrooms, Smart Classroom Bytes journal, http://education.qld.gov.au/smartclassrooms/documents/strategy/pdf/scbyte-elearning.pdf (2008)
4. Shi, Y., Xie, W., Xu, G., Shi, R., Chen, E., Mao, Y., Liu, F. The smart classroom: merging technologies for seamless tele-education. In: Proceedings 4th International Conference on Multimodal Interfaces (ICMI 2002), pp. 429–434. IEEE CS Press (2002)
5. Xie, W., et al.: Smart Classroom - an intelligent environment for tele-education, In: Shum, H.-Y., Liao, M., Chang, S.-F. (eds.) PCM 2001, LNCS 2195, pp. 662–668 (2001)
6. Uskov, V.L., Uskov, A.V.: Streaming media-based education: outcomes and findings of a four-year research and teaching project. Int. J. Adv. Technol. Learn. **2**(2), 45–57 (2005). ISSN:1710-2251

7. Yau, S., Gupta, S., Karim, F. et al.: Smart classroom: enhancing collaborative learning using pervasive computing technology. In: Proceedings of 2003 ASEE Conference. http://www.public.asu.edu/~bwang/publications/SmartClassroom-2003.pdf
8. O'Driscoll, C. et al.: Deploying a context aware smart classroom. In: Proceedings of the Arrow@DIR Conference, Dublin, Ireland. http://arrow.dit.ie/engschececon/53/ (2008)
9. Huang, R., Hub, Y., Yang, J., Xiao, G. The Functions of smart classroom in smart learning age. In: Proceedings 20th International Conference on Computers in Education ICCE. Nanyang Technological University, Singapore (2012)
10. Pishva, D., Nishantha, G.G.D.: Smart classrooms for distance education and their adoption to multiple classroom architecture. J. Netw. **3**(5), 54–64 (2008)
11. Gligorić, N., Uzelac, A., Krco, S.: Smart classroom: real-time feedback on lecture quality. In: Proceedings 2012 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), Lugano, Switzerland, 19–23 March 2012, pp. 391–394 (2012). doi:10.1109/PerComW.2012.6197517
12. Slotta, J., Tissenbaum, M., Lui, M.: Orchestrating of complex inquiry: three roles for learning analytics in a smart classroom infrastructure. In: Proceedings of the Third International Conference on Learning Analytics and Knowledge LAK'13, pp, 270–274. New York, NY (2013). doi:10.1145/2460296.2460352
13. Koutraki, M., Maria, Efthymiou, V., Grigoris, A.: S-CRETA: smart classroom real-time assistance. In: Ambient Intelligence - Software and Applications, Advances in Intelligent and Soft Computing, vol. 153, pp 67–74. Springer, Berlin (2012)
14. The Next-Generation Classroom: Smart, Interactive and Connected Learning. http://www.samsung.com/es/business-images/resource/white-paper/2012/11/EBT15_1210_Samsung_Smart_School_WP-0.pdf (2012)
15. Derzko, W.: Smart Technologies. http://archives.ocediscovery.com/discovery2007/presentations/Session3WalterDrezkoFINAL.pdf (2007)
16. Uskov, A., Sekar, B.: Smart gamification and smart serious games. In: Sharma, D., Jain, L., Favorskaya, M., Howlett, R. (eds.) Fusion of Smart, Multimedia and Computer Gaming Technologies, Intelligent Systems Reference Library, vol. 84, pp. 7–36, Springer, Berlin (2015). doi 10.1007/978-3-319-14645-4_2, ISBN: 978-3-319-14644-7