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Preface

Smart Education and e-Learning (SEEL) are emerging and rapidly growing areas that represent an integration of smart objects and systems, smart technologies, smart environments, smart features or smartness levels, smart pedagogy, smart learning and teaching analytics, various branches of computer science and computer engineering, state-of-the-art smart educational software and/or hardware systems. This is the main reason that in June 2013, a group of enthusiastic and visionary scholars from all over the world arrived with the idea to organize a new professional event that would provide an excellent opportunity for faculty, scholars, Ph.D. students, administrators, and practitioners to meet well-known experts and discuss innovative ideas, findings and outcomes of research projects, and best practices in smart education and e-learning.

The main research, design and development topics in SEEL area include, but are not limited to, (1) conceptual frameworks for Smart Education (SmE) and Smart e-Learning (SeL), (2) infrastructure, main characteristics and features of Smart Universities (SmU) and Smart Classrooms (SmC), (3) SmU-wide software, hardware, security, safety, communication, collaboration and management systems, (4) SmE analytics, (5) innovative learning and teaching strategies as components of smart pedagogy, (6) SeL strategies, approaches and environments, (7) smart learner modelling, (8) assessment and quality assurance in SmE and SeL, (9) social, cultural and ethical dimensions and challenges of SmE and SeL, (10) applications of various innovative technologies–Internet of Things, cloud computing, Ambient Intelligence (AmI), smart agents, sensors, wireless sensor networks, context-awareness technology, etc.—and smart software/hardware systems in universities and classrooms, and numerous other topics. We hope that active and open discussion of those topics within SEEL professional research and academic communities will help us to (a) organize mutually beneficial partnerships, stimulate national and international research, design and development projects in SEEL area, (b) propose innovative pedagogy, teaching and learning strategies, standards and policies in SEEL, (c) identify tangible and intangible benefits of SEEL.

The inaugural international KES conference on Smart Technology-based Education and Training (STET) has been held at Chania, Crete, Greece, during 18–20 June 2014. The 2nd international KES conference on Smart Education and e-Learning took place in Sorrento, Italy, during 17–19 June 2015. This book contains the contributions presented at the 3rd international KES conference on Smart Education and e-Learning, which took place in Puerto de la Cruz, Tenerife, Spain, during 15–17 June 2016. Book chapters, a total of 56 peer-reviewed chapters, are grouped into several parts, as follows: Part I—Smart University: Conceptual Modelling, Part II—Smart Education: Research and Case Studies, Part III—Smart e-Learning, Part IV—Smart Education: Software and Hardware Systems, and Part V—Smart Technology as a Resource to Improve Education and Professional Training.

We would like to thank scholars who dedicated a lot of efforts and time to make SEEL international conference a great success: Dr. Luis Anido (Spain), Dr. Elena Barbera (Spain), Dr. Claudio da Rocha Brito (Brazil), Dr. Dumitru Burdescu (Romania), Dr. Nunzio Casalino (Italy), Prof. Melany Ciampi (Brazil), Mr. Marc Fleetham (UK), Dr. Ekaterina Prasolova-Førland (Norway), Dr. Mikhail Fominykh (Norway), Dr. Brian Garner (Australia), Prof. Natalya Gerova (Russia), Dr. Jean-Pierre Gerval (France), Dr. Karsten Henke (Germany), Dr. Alexander Ivannikov (Russia), Dr. Marina Lapenok (Russia), Dr. Aleksandra Klasnja-Milicevic (Serbia), Prof. Andrew Nafalski (Australia), Dr. Enn Õunapuu (Estonia), Dr. Elvira Popescu (Romania), Dr. Valeri Pougatchev (Jamaica), Prof. Jerzy Rutkowski (Poland), Dr. Danguole Rutkauskiene (Lithuania), Prof. Adriana Burlea Schiopoiu (Romania), Prof. Masanori Takagi (Japan), Dr. Gara Miranda Valladares (Spain), Dr. Heinz-Dietrich Wuttke (Germany), and Dr. Larisa Zaiceva (Latvia).

We are indebted to many international collaborating organizations that made SEEL international conference possible, specifically the following: KES International (UK), InterLabs Research Institute, Bradley University (USA), Institut Superieur de l'Electronique et du Numerique ISEN-Brest (France), Silesian University of Technology (Poland), and Multimedia Apps D&R Center, University of Craiova (Romania).

It is our sincere hope that this book will serve as a useful source of valuable data and information, and provide a baseline of further progress and inspiration for research projects and advanced developments in SEEL area.

June 2016

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Part I
Smart University: Conceptual Modeling

Smart University Taxonomy: Features, Components, Systems

Vladimir L. Uskov, Jeffrey P. Bakken, Akshay Pandey, Urvashi Singh, Mounica Yalamanchili and Archana Penumatsa

Abstract Smart education creates unique and unprecedented opportunities for academic and training organizations in terms of higher standards and innovative approaches to (1) learning and teaching strategies—smart pedagogy, (2) unique highly technological services to local on-campus and remote/online students, (3) set-ups of innovative smart classrooms with easy local/remote student-to-faculty interaction and local/remote student-to-student collaboration, (4) design and development of Web-based rich multimedia learning content with interactive presentations, video lectures, Web-based interactive quizzes and tests, and instant knowledge assessment. This paper presents the outcomes of an ongoing research project aimed to create smart university taxonomy and identify main features, components, technologies and systems of smart universities that go well beyond those in a traditional university with predominantly face-to-face classes and learning activities.

Keywords Smart university · Smartness features · Smart university components · Systems · Smart pedagogy

1 Introduction

The "smart university" (SmU) concept and several related concepts, such as smart learning environment, smart campus, smart education, smart e-learning, smart training, and smart classrooms were introduced just several years ago; they are in permanent evolution and improvement since that time [1, 2].

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Smart education is rapidly gaining popularity among the world's best universities because modern, sophisticated smart technologies, smart systems and smart devices create unique and unprecedented opportunities for academic and training organizations in terms of higher standards and innovative approaches to (1) education, learning and teaching strategies, (2) unique services to local on-campus and remote/online students, (3) set-ups of highly technological smart classrooms with easy local/remote student-to-faculty interaction and local/remote student-to-student collaboration, (4) design and development of Web-based rich multimedia learning content with interactive presentations, video lectures, Web-based interactive quizzes and tests, instant knowledge assessment, etc. Additionally, "the analysts forecast the global smart education market to grow at a CAGR of 15.45 % during the period 2016–2020" [3]. "Markets and Markets forecasts the global smart education & learning market to grow from $105.23 Billion in 2015 to $446.85 Billion in 2020, at a Compound Annual Growth Rate (CAGR) of 24.4 %" [4].

Therefore, it is necessary to perform active research and obtain a clear understanding of what main features, components, technologies, software, hardware, pedagogy, faculty, etc. will be required by SmUs in the near future.

2 Smart University: Literature Review

Recently, various creative researchers and developers began presenting their vision of SmU concepts and principles; a brief summary of several remarkable publications on such concepts is given below.

Smart University. Tikhomirov's [5] vision is that "*Smart University* is a concept that involves a comprehensive modernization of all educational processes. … The *smart education* is able to provide a new university, where a set of ICT and faculty leads to an entirely new quality of the processes and outcomes of the educational, research, commercial and other university activities. … The concept of *Smart* in education area entails the emergence of technologies such as smart boards, smart screens and wireless Internet access from everywhere".

Smart Learning Environment. Hwang [6] presented a concept of *smart learning environments* "… that can be regarded as the technology-supported learning environments that make adaptations and provide appropriate support (e.g., guidance, feedback, hints or tools) in the right places and at the right time based on individual learners' needs, which might be determined via analyzing their learning behaviors, performance and the online and real-world contexts in which they are situated. … (1) A smart learning environment is context-aware; that is, the learner's situation or the contexts of the real-world environment in which the learner is located are sensed… (2) A smart learning environment is able to offer instant and adaptive support to learners by immediate analyses of the needs of individual learners from different perspectives… (3) A smart learning environment is able to adapt the user interface (i.e., the ways of presenting information) and the subject contents to meet the personal factors (e.g., learning styles and preferences) and learning status (e.g., learning performance) of individual learners".

Smart Education. IBM [7] defines *smart education* as follows: "A smart, multi-disciplinary student-centric education system—linked across schools, tertiary institutions and workforce training, using: (1) adaptive learning programs and learning portfolios for students, (2) collaborative technologies and digital learning resources for teachers and students, (3) computerized administration, monitoring and reporting to keep teachers in the classroom, (4) better information on our learners, (5) online learning resources for students everywhere".

Cocoli et al. [8] described *smart education* as follows: "Education in a smart environment supported by smart technologies, making use of smart tools and smart devices, can be considered smart education… . In this respect, we observe that novel technologies have been widely adopted in schools and especially in universities, which, in many cases, exploit cloud and grid computing, Next Generation Network (NGN) services and portable devices, with advanced applications in highly interactive frameworks … smart education is just the upper layer, though the most visible one, and other aspects must be considered such as: (1) communication; (2) social interaction; (3) transport; (4) management (administration and courses); (5) wellness (safety and health); (6) governance; (7) energy management; (8) data storage and delivery; (9) knowledge sharing; (10) IT infrastructure".

Smart Campus. Kwok [9] defines *intelligent campus* (*i-campus*) "… a new paradigm of thinking pertaining to a holistic intelligent campus environment which encompasses at least, but not limited to, several themes of campus intelligence, such as holistic e-learning, social networking and communications for work collaboration, green and ICT sustainability with intelligent sensor management systems, protective and preventative health care, smart building management with automated security control and surveillance, and visible campus governance and reporting".

Xiao [10] envisions smart campus as follows: "*Smart campus* is the outcome of the application of integrating the cloud computing and the internet of things. …The application framework of smart campus is a combination of IoT and cloud computing based on the high performance computing and internet".

Smart Teachers. Abueyalaman [11] argues "A smart campus depends on an overarching strategy involving people, facilities, and ongoing faculty support as well as effective use of technology…. A smart campus deploys *smart teachers* and gives them smart tools and ongoing support to do their jobs while assessing their pedagogical effectiveness using smart evaluation forms".

Smart Learning Communities. Adamko et al. [12] describe features of smart learning community applications as follows: "… the requirements of the smart community applications are the following: (1) sensible—the environment is sensed by sensors; (2) connectable—networking devices bring the sensing information to the web; (3) accessible—the information is published on the web, and accessible to the users; (4) ubiquitous—the users can get access to the information through the web, but more importantly in mobile any time and any place; (5) sociable—a user can publish the information through his social network; (6) sharable—not just the data, but the object itself must be accessible and addressable; (7) visible/augmented—make the hidden information seen by retrofitting the physical environment".

Smart Classrooms. An overview of smart classrooms of the first generations and requirements for second generation smart classrooms is available [13].

3 Research Project Goal and Objectives

The performed analysis of these and multiple additional existing publications and reports relevant to (1) smart systems, (2) smart technologies, (3) smart devices, (4) smart universities, (5) smart campuses, (6) smart classrooms, and (7) smart learning environments undoubtedly shows that "smart university" as a topic should be in the center of multiple research, design and development projects in upcoming years. It is expected that, in the near future, SmU concepts, features, hardware/software solutions and technologies will have a significant role and be actively deployed by leading academic intuitions—smart universities in the world.

Project Goal. The overall goal of the ongoing multi-aspect research project is to create a taxonomy of a smart university, i.e. to identify and classify a SmU's main (1) features, (2) components (smart classrooms, technological resources—systems and technologies, human resources, financial resources, services, etc.), (3) relations (links) between components, (4) interfaces, (5) inputs, (6) outputs, and (7) limits/constraints. The premise it that to-be-developed SmU taxonomy will (1) enable us to identify and predict most effective software, hardware, pedagogy, teaching/learning activities, services, etc. for the next generation of a university—smart university, and (2) help traditional universities to understand, identify and evaluate paths for a transformation into a smart university.

Project Objectives. The objectives of this project were to identify an SmU's main (1) features, (2) components, and (3) systems that go well beyond those in a traditional university with predominantly face-to-face classes and learning activities. Due to limited space, we present a summary of up-to-date research outcomes below.

4 Research Project Outcomes

4.1 Smart University: Distinctive Features

Our vision of SmUs is based on the idea that SmUs—as a smart system—should implement and demonstrate significant maturity at various "smartness" levels or smart features, including (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organization and re-structuring (Table 1).

Table 1 SmU distinctive features (that go well beyond features of a traditional university)

SmU smartness levels	Details	Possible examples (limited to 3)
Adaptation	SmU ability to automatically modify its business functions, teaching/learning strategies, administrative, safety, physical, behavioral and other characteristics, etc. to better operate and perform its main business functions (teaching, learning, safety, management, maintenance, control, etc.)	• SmU easy adaptation to new style of learning and/or teaching (learning-by-doing, flipped classrooms, etc.) and/or courses (MOOCs, SPOCs, open education and/or life-long learning for retirees, etc.)
		• SmU easy adaptation to needs of students with disabilities (text-to-voice or voice-to-text systems, etc.)
		• SmU easy network adaptation to new technical platforms (mobile networking, tablets, mobile devices with iOS and Android operating systems, etc.)
Sensing (awareness)	SmU ability to automatically use various sensors and identify, recognize, understand and/or become aware of various events, processes, objects, phenomenon, etc. that may have impact (positive or negative) on SmU's operation, infrastructure, or well-being of its components—students, faculty, staff, resources, properties, etc.	• Various sensors of a Local Action Services (LAS) system to get data regarding power use, lights, temperature, humidity, safety, security, etc.
		• Smart card (or biometrics) readers to open doors to mediated lecture halls, computer labs, smart classrooms and activate features/software/hardware that are listed in user's profile
		• Face, voice, gesture recognition systems and corresponding devices to retrieve and process data about students' class attendance, class activities, etc.
Inferring (logical reasoning)	SmU ability to automatically make logical conclusion(s) on the basis of raw data, processed information, observations, evidence, assumptions, rules, and logic reasoning	• Student Analytics System (SAS) to create (update) a profile of each local or remote student based on his/her interaction, activities, technical skills, etc.
		• Local Action Services (LAS) campus-wide system to analyze data from multiple sensors and make conclusions (for ex: activate actuators and close/lock doors in all campus buildings and/or labs, turn off lights, etc.)
		• SAS can recommend administrators take certain pro-active measures regarding a student

(continued)

Table 1 (continued)

SmU smartness levels	Details	Possible examples (limited to 3)
Self-learning	SmU ability to automatically obtain, acquire or formulate new or modify existing knowledge, experience, or behavior to improve its operation, business functions, performance, effectiveness, etc. (A note: Self-description, self-discovery and self-optimization features are a part of self-learning)	• Learning from active use of innovative software/hardware systems—Web-lecturing systems, class recording systems, flipped class systems, etc.
		• Learning from anonymous Opinion Mining System (OMS)
		• Learning from different types of classes—MOOCs, blended, online, SPOCs, etc.
Anticipation	SmU ability to automatically think or reason to predict what is going to happen, how to address that event, or what to do next	• Campus-wide Safety System (CSS) to anticipate, recognize and act accordingly in case of various events on campus
		• Enrollment Management System to predict, anticipate, and control variations on student enrollment
		• University-wide Risk Management System (snow days, tornado, electricity outage, etc.)
Self-organization and configuration, re-structuring, and recovery	SmU ability automatically 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. (A note: Self-protection, self-matchmaking, and self-healing are a part of self-organization)	• Automatic configuration of systems, performance parameters, sensors, actuators and features in a smart classroom in accordance with instructor's profile
		• Streaming server automatic closedown and recovery in case of temp electrical outage
		• Automatic re-configuration of wireless sensor network (WSN) because nodes may join or leave spontaneously (i.e. evolving network typology), university-wide cloud computing (with multiple clients and services), etc.

4.2 *Smart University: Distinctive Main Components*

SmUs may have numerous components of a traditional university; however, it must have multiple additional components to implement and maintain SmU distinctive features that are described in Table 1. Based on our vision of SmUs and outcomes of our research, the SmU main distinctive components should include at least those that are described in Table 2 below.

Table 2 SmU main components and main distinctive sub-components (that go well beyond components of a traditional university)

SmU components	SmU distinctive sub-components (that go well beyond those in a traditional university)
Software systems	• Web-lecturing systems (with video capturing and computer screen capturing functions) for learning content development pre-class activities • Smart classroom in-class activities recording systems • Smart cameraman software systems • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and sharing learning content/documents • Collaborative Web-based audio/video one-to-one and many-to-many communication systems • Systems to host, join, form and evaluate group discussions (including both local and remote students) • Systems to replay automatically recorded class activities and lectures for post-class review and activities (by both local and remote students) • Repositories of digital learning content and online (Web) resources, learning portals • Smart learning analytics and smart teaching analytics systems • Speaker/instructor motion tracking systems • Speech/voice recognition systems • Speech-to-text systems • Text-to-voice synthesis systems • Face recognition systems • Emotion recognition systems • Gesture (activity) recognition systems • Context (situation) awareness systems • Automatic translation systems (from/to English language) • Intelligent cyber-physical systems (for safety and security) • Various smart software agents • Power/light/HVAC consumption monitoring system(s)
Technology	• Internet-of-Things technology • Cloud computing technology • Web-lecturing technology • Collaborative and communication technologies • Ambient intelligence technology • Smart agents technology • Smart data visualization technology • Augmented and virtual reality technology • Computer gaming (serious gaming) technology • Remote (virtual) labs • 3D visualization technology • Wireless sensor networking technology • RFID (radio frequency identification) technology • Location awareness technologies (indoor and outdoor) • Sensor technology (motion, temperature, light, humidity, etc.)
Hardware/equipment	• Panoramic video cameras • Ceiling-mounted projectors (in some cases, 3D projectors) • SMART boards and/or interactive white boards • Smart pointing devices • Controlled and self-activated microphones and speakers • Interconnected big screen monitors or TVs ("smart learning cave") • Interconnected laptops or desktop computers • Smart card readers • Biometric-based access control devices • Robotic controllers and actuators

(continued)

Table 2 (continued)

SmU components	SmU distinctive sub-components (that go well beyond those in a traditional university)
Smart curricula	• Adaptive programs of study—major and minor programs, concentration and certificate programs with variable structures adaptable to types of students/learners, smart pedagogy, etc. • Adaptive courses, lessons and learning modules with variable components and structure suitable for various types of teaching—face-to-face, blended, online, types of students/learners, smart pedagogy, etc.
Students, learners, faculty	• Students and/or learners with blended or flexible learning • Fully remote (or fully online) students and/or learners • Life-long learners (retirees) in open education • Students with disabilities • Smart faculty (smart instructors)
Smart pedagogy	Active utilization and, if needed, adaptable combination of the following innovative types of pedagogy (teaching strategies): • Learning-by-doing (including active use of virtual labs) • Collaborative learning • e-Books • Learning analytics • Adaptive teaching • Student-generated learning content • Serious games- and gamification-based learning • Flipped classroom • Project-based learning • Bring-Your-Own-Device • Smart robots (robotics) based learning
Smart classrooms	Smart classrooms with corresponding technologies, software hardware systems, and smart pedagogy for smart education

4.3 Smart University: Distinctive Software Systems

As a part of this research project, for several classes of selected software systems, in Table 2 we

(1) analyzed about 10–15 existing systems usually—including both open source and commercial systems—by means of (a) review of system's functions and features, (b) review of system's demo version, (c) installation and testing of the systems, and (d) review of users and analysts' feedback,

(2) identified a list of main functions of those systems—functions to be required by SmUs, and (3) evaluated and ranked those systems. A brief summary of our research outcomes for selected classes of software systems for SmUs is presented in Table 3 below. A detailed list of references to all analyzed and mentioned below systems is available at Towards Smart University project web site at Bradley University at [14].

Table 3 Selected classes of software systems to be used by SmUs [14]

Class of systems	Open-source systems	Commercial systems	Our choice (1-best)
In-class activities recording systems	• Opencast	• Panopto	1—Opencast
	• ClassX	• Echo360 Lect. Cap.	1—Panopto
	• Kaltura	• Camtasia Studio	2—Kaltura
	• openEyA	• Mediasite Lecture C.	2—Mediasite
	• Lecture Record.x2	• Tegrity	3—ClassX
	• VSDC Video Ed.	• Valt	3—Echo360 L.C.
	• CamStudio	• Adobe Presenter 11	
	• SameView	• YuLa Lecture/Room C.	
Instructor-to-remote students audio/video conferencing systems (one-to-many, many-to-many)	• Skype	• WebEx Meeting Center	1—Hangouts
	• BigBlueButton	• TurboMeeting	1—BlackBoard C.
	• Open meetings	• Adobe Connect	2—BigBlueButton
	• DimDim	• Citrix	2—Adobe connect
	• Mconf	• Netop Vision ME	3—Skype
	• BlueJeans	• AB Tutor	3—GlobalMeet
	• Jitsi	• SoftLink	
	• Hangouts	• LAN School	
	• JoinMe	• GoToMeeting	
	• MeetingBurner	• GlobalMeet	
	• WebHuddle	• AnyMeeting	
	• Zoom	• BlackBoard Collabor.	
Web lecturing systems for pre-class learning content development activities	• InterLabs	• Camtasia Studio	1—CamStudio
	• ActivePresenter	• Adobe Presenter 11	1—Camtasia Stud.
	• Jing	• Movavi Studio V7	2—Ezvid Scr.Rec.
	• Webinaria	• CamVerse 1.95	2—Adobe Pres 11
	• Rylstim	• WM Recorder Bundle	3—Screen-O-Mat.
	• IceCream screen rec.	• Debut Video Capture	3—Movavi Stud.
	• CamStudio	• Fraps3.5.99	
	• Screen-O-Matic	• Snagit 12	
	• Flash Back Exp. Rec.	• 1AVCapture	
	• Ezvid Screen Rec.	• ScreenPresso	
Instructor motion tracking systems	• Motion	• Qualisys	1—Motion
	• Genious Vis. NVR	• Bosh Security	1—Bosh Security
	• iSpy	• Honeywell Mot.Sens.	2—Voodoo C.T.
	• OptiTrack	• Camera Viewer Pro	2—Qualisys
	• Zoneminder	• Netcam Studio	3—OptiTrack
	• Voodoo Camera Tr.		3—Netcam Studio

(continued)

Table 3 (continued)

Class of systems	Open-source systems	Commercial systems	Our choice (1-best)
Speech/voice recognition systems	• HDecode	• Dragon Natur.Sp.	1—Jasper
	• JULIUS	• IBM ViaVoice	1—Dragon N.S.
	• KALDI	• LH Voice Express	2—CSLU TK
	• CMU Sphinx	• Briana	2—Naunce Rec.
	• SHoUT Toolkit	• Kurzweil 3000	3—CMU Sphinx
	• SIMON	• IVR with SR	3—ViaTalk
	• eSpeak	• Tazti	
	• Jasper	• Speechlogger	
	• EmacSpeak	• iSpeech Translator	
	• MARF	• Rubidium	
	• IVONA	• ViaTalk	
	• CSLU Toolkit	• ClapCommander	
	• iListen	• Naunce Recognizer	
Gesture recognition systems	• OpenGesture	• GestureTek	1—GRT
	• GRT	• Cognitec	1—Myo
	• GR Engine	• Omek	2—HandVu
	• iGesture	• PointGrab	2—GestureTek
	• HandVu	• SoftKinetic	3—iGesture
	• LinHand	• Myo	3—Rithmio
	• GestureWorks	• Rithmio	
Face recognition systems	• OpenBR	• Cognitec FaceVACS	1- OpenBR
	• OpenCV	• EmoVu	1—FaceVACS
	• Skybiometry	• Kairos	2—FaceMark
	• FaceMark	• Eyeface	2—EmoVu
	• Libface	• Rekognition	3—Liccv
	• Libccv	• Face++	3—Kairos
Collaborative learning systems	• Cynapse	• Mikogo	1—Cynapse
	• Voki	• Socrative	1—Socrative
	• Storybirds	• Weebly	2—Sakai
	• Moodle	• Edmodo	2—ClassDojo
	• Sakai	• ClassDojo	3—Moodle
Context/situation awareness systems		• SARA	1—Qognify
		• Magitti	2—Magitti
		• Qognify	3—SARA

5 Conclusions

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

(1) Leading academic intuitions all over the world are investigating ways to transform the traditional university into a smart university and benefit from the

advantages of a smart university. Smart University concepts, principles, technologies, systems, and pedagogy will be essential parts of multiple research, design and development projects in upcoming years.

(2) It is necessary to create a taxonomy of a smart university, i.e. to identify and classify SmU main (1) features, (2) components (smart classrooms, technological resources—systems and technologies, human resources, financial resources, services, etc.), (3) relations (links) between components, (4) interfaces, (5) inputs, (6) outputs, and (7) limits/constraints. The premise it that to-be-developed SmU taxonomy will (1) enable us to identify and predict most effective software, hardware, pedagogy, teaching/learning activities, services, etc. for the next generation of a university—smart university, and (2) help traditional universities to understand, identify and evaluate paths for a transformation into a smart university.

(3) Our vision of SmUs is based on the idea that SmUs—as a smart system—should implement and demonstrate significant maturity at various "smartness" levels or distinctive smart features, including (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organization and re-structuring—the corresponding research outcomes are presented in Table 1.

(4) Based on our vision of SmUs, the identified SmU main components are presented in Table 2, and multiple analyzed and ranked software systems of selected classes to be used by SmU in Table 3.

Based on obtained research findings and outcomes, and developed SmU features, components and systems, the future steps in this research project are to (a) implement, test, validate, and analyze various identified software and hardware systems, technologies and smart pedagogy in smart classroom environment, (b) perform summative and formative evaluations of local and remote students and gather sufficient data on the quality of SmU main components—hardware, software, technologies, services, etc.).

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Smart Universities, Smart Classrooms and Students with Disabilities

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Abstract To better educate in-classroom and remote students we will need to approach education and how we teach various types of students differently. In addition, students these days are more technological than ever and are demanding new and innovative ways to learn. One of the most promising approaches is based on design and development of smart universities and smart classrooms. This paper presents the up-to-date outcomes of research project that is aimed on analysis of students with disabilities and how they might benefit from smart software and hardware systems, and smart technology.

Keywords Smart university · Smart classroom · Learning disabilities · Visual impairments · Hearing impairments · Speech and language disabilities · Smart system

1 Introduction

Smart universities (SmU) and smart classrooms (SmC) can create multiple opportunities for students to learn material in a variety of ways. In addition, they can give access to materials in a variety of ways. Although not designed or even

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conceptualized to benefit students with disabilities, this concept would definitely have an impact on the learning and access to material for students with disabilities.

1.1 Smart Classrooms: Literature Review

Pishva and Nishantha define a SmC 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" [1].

Glogoric, Uzelac and Krco addressed the potential of using Internet-of-Things (IoT) technology to build a SmC. "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" [2].

Slotta, Tissenbaum and Lui described an infrastructure for SmC 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" [3].

Koutraki, Efthymiou, and Grigoris developed a real-time, context-aware system, applied in a SmC 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" [4].

Given all the research available that focus on SmC, no literature was located that dealt with analysis of possible impact of SmCs concepts, features and functionality on students with disabilities.

1.2 Smart Universities: Literature Review

Primary focus of smart universities is in the education area, but they also drive the change in other aspects such as management, safety, and environmental protection. The availability of newer and newer technology reflects on how the relevant processes should be performed in the current fast changing digital era. This leads to the adoption of a variety of smart solutions in university environments to enhance the quality of life and to improve the performances of both teachers and students. Nevertheless, we argue that being smart is not enough for a modern university. In fact, all universities should become smarter in order to optimize learning. By "smarter university" we mean a place where knowledge is shared between employees, teachers, students, and all stakeholders in a seamless way [5].

Aqeel-ur-Rehman et al. in [6] present the outcomes of their research on one feature of future SmU—sensing with RFID (Radio frequency identification) technology; it should benefit students and faculty with identification, tracking, smart lecture room, smart lab, room security, smart attendance taking, etc.

Lane and Finsel emphasize an importance of big data movement and how it could help to build smarter universities. "Now is the time to examine how the Big Data movement could help build smarter universities—in situations that can use the huge amounts of data they generate to improve the student learning experience, enhance the research enterprise, support effective community outreach, and advance the campus's infrastructure. While much of the cutting-edge research being done with Big Data is happening at colleges and universities, higher education has yet to turn the digital mirror on itself to innovate the academic enterprise" [7]. Big data analytics systems will strongly support inferring feature of a SmU.

Al Shimmary et al. analyzed advantages of using RFID and WSN technology in development of SmU. "The developed prototype shows how evolving technologies of RFID and WSN can add in improving student's attendance method and power conservation" [8]. RFID, WSN as well as Internet-of-Things technology are expected to be significant parts of a SmU and strongly support sending characteristics of smart universities.

Doulai in [9] presents a developed system for a smart campus. This system "… offers an integrated series of educational tools that facilitate students' communication and collaboration along with a number of facilities for students' study aids and classroom management. The application of two technologies, namely dynamic web-based instruction and real-time streaming, in providing support for "smart and flexible campus" education is demonstrated. It is shown that the usage of technology-enabled methods in university campuses results in a model that works equally well for distance students and learners in virtual campuses".

Yu et al. argue that "… with the development of wireless communication and pervasive computing technology, smart campuses are built to benefit the faculty and students, manage the available resources and enhance user experience with proactive services. A smart campus ranges from a smart classroom, which benefits the teaching process within a classroom, to an intelligent campus that provides lots of proactive services in a campus-wide environment" [10]. The authors described 3 particular systems–Wher2Study, I-Sensing, and BlueShare—that provide sensing, adaptation, and inferring smart features of a SmU.

1.3 Research Project Goal and Objectives

The performed analysis of these and multiple additional publications and reports relevant to (1) SmU, (2) SmC, (3) smart learning environments (SmLE), (4) smart technologies, and (5) smart systems undoubtedly shows that (a) SmU, (b) SmC,

(c) smart pedagogy, and (d) smart faculty topics will be essential themes of multiple research, design and development projects in the upcoming 5–10 years. It is expected that in the near future SmC concepts and hardware/software solutions will have a significant role and be actively deployed by leading academic intuitions—smart universities—in the world.

Unfortunately, all analyzed publications are lacking a systematic approach to "smartness levels" of a smart educational system (i.e., school, college, university). Additionally, all analyzed publications are focused on traditional students/learners; however, we could not find publications on detailed analysis of "SmU, SmC and students with disabilities".

The goal of ongoing research project at the InterLabs Research Institute at Bradley University (Peoria, IL, U.S.A.) is to perform a detailed analysis and identify potential benefits of SmU and SmC components, features, systems, and technology for special type of students—students with various types of disabilities.

The objectives of this particular research project include but are not limited to:

(1) identification of smartness levels in a smart educational system;
(2) identification of characteristics of students with various types of disabilities;
(3) identification of software and hardware systems and technology to aid students with disabilities in highly technological SmCs.

The up-to-date outcomes of this research project are presented below.

2 Smart University and Students with Disabilities: Analysis Phase

SmU and SmC can create multiple opportunities for students to learn material in a variety of ways. In addition, they can give access to materials in a variety of ways. Although not designed or even conceptualized to benefit students with disabilities, this concept would definitely have an impact on the learning and access to material for students with disabilities.

2.1 Smart Educational System: Smartness Levels

Based on our vision of a SmU and up-to-date obtained research outcomes, we believe that a SmU should significantly emphasize not only software/hardware/technology features but also "smart" features and functionality of smart systems (Table 1) [11].

In order for SmU and SMC to be effective and efficient for various types of students and learners there are certain smartness levels (Table 1) that should be addressed. These levels or features should guide designers and developers of SmC,

Table 1 Classification of levels of "smartness" of a smart system [11]

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

smart labs, smart libraries, smart offices, etc. In doing so, we can then identify the most effective hardware, software, pedagogy and learning activities for all students, including students with disabilities…

2.2 Characteristics of Students with Disabilities

Types of students with disabilities that SmU and SmC can impact include students with (1) learning disabilities, (2) speech or language impairments, (3) visual impairments and (4) hearing impairments. Brief characteristics of each designated type of disability are given below.

Learning Disabilities [12, 13]. Learning disabilities are associated with many different problems that include difficulties in listening, reasoning, memory, attention, selecting and focusing on relevant stimuli, and the perception and processing of visual and/or auditory information. These perceptual and cognitive processing difficulties are assumed to be the underlying reason why students with learning disabilities experience one or more of the following characteristics: reading problems, deficits in written language, and underachievement in math. Not all students with learning disabilities will exhibit these characteristics, and many students who demonstrate these same behaviors are quite successful in the classroom. These students are a diverse group of individuals, exhibiting potential difficulties in many different areas. For example, one child with a learning disability may experience significant reading problems, while another may experience no reading problems whatsoever, but has significant difficulties with written expression. Learning disabilities may also be mild, moderate, or severe which complicates instruction for these students in the classroom even further.

Speech or Language Impairments [14, 15]. The characteristics of speech or language impairments will vary depending upon the type of impairment involved. There may also be a combination of several problems. Students could have difficulties with articulation (difficulty making certain sounds), fluency (something is disrupting the rhythmic and forward flow of speech), or voice (problems with the pitch, loudness, resonance, or quality of the voice). Students may also have difficulties with language. Language has to do with meanings, rather than sounds. A language disorder refers to an impaired ability to understand and/or use words in context [14]. A child may have an expressive language disorder (difficulty in expressing ideas or needs), a receptive language disorder (difficulty in understanding what others are saying), or a mixed language disorder (which involves both). Some characteristics of language disorders include: (1) improper use of words and their meanings, (2) inability to express ideas, (3) inappropriate grammatical patterns, (4) reduced vocabulary, and (5) inability to follow directions. Children may hear or see a word but not be able to understand its meaning. They may also have trouble getting others to understand what they are trying to communicate.

Visual Impairments [14, 16, 17]. Total blindness is the inability to tell light from dark, or the total inability to see. Visual impairment or low vision is a severe reduction in vision that cannot be corrected with standard glasses or contact lenses and reduces a person's ability to function at certain or all tasks. Legal blindness (which is actually a severe visual impairment) refers to a best-corrected central vision of 20/200 or worse in the better eye or a visual acuity of better than 20/200 but with a visual field no greater than 20° (e.g., side vision that is so reduced that it appears as if the person is looking through a tunnel) [16]. Being able to see gives us tremendous access to learning about the world around us. That's because so much learning typically occurs visually. When vision loss goes undetected, children are delayed in developing a wide range of skills. While they can do virtually all the activities and tasks that sighted children take for granted, children who are visually impaired often need to learn to do them in a different way or using different tools or materials. Central to their learning will be touching, listening, smelling, tasting, moving, and using whatever vision they have [17].

Hearing Impairments [18, 19]. The term "hearing impaired" refers to any person with any type or degree of hearing loss. The term may be used with qualifying adjectives such as "mild," "moderate," "severe," and "profound" to denote the degree of impairment. "Deaf" refers to a hearing-impaired person in whom the auditory sense is sufficiently damaged to preclude the auditory development and comprehension of speech and language with or without sound amplification. "Hard of hearing" is used to define a hearing-impaired person in whom the sense of hearing, although defective, is functional with or without a hearing aid and whose speech and language, although deviant, will be developed through an auditory base. The major challenge faced by students with hearing impairments is communication. Hearing-impaired students vary widely in their communication skills. Age of onset plays a crucial role in the development of language. Persons with prelingual hearing loss (present at birth or occurring before the acquisition of language and the development of speech patterns) are more functionally disabled than those who lose some degree of hearing after the development of language and speech. Many students with hearing impairments can and do speak. Most deaf students have normal speech organs and have learned to use them through speech therapy. Some deaf students cannot monitor or automatically control the tone and volume of their speech, so their speech may be initially difficult to understand. Understanding improves as one becomes more familiar with the deaf student's speech pattern.

3 Smart University and Students with Disabilities: Design Phase

3.1 Considerations for Students with Disabilities

The implementation of a SmC model could potentially have a huge impact on the learning of students with disabilities in general and more specifically students with learning disabilities, speech and language impairments, visual impairments, and hearing impairments. Many of the smart features of SmC are the exact areas where students with these disabilities have documented weaknesses. Most noted are deficiencies with learning, inferring, and self-organizing. Thus, the SmC should be considered when working with students with all of these disabilities [20].

Although we cannot create an exhaustive list of software and hardware technologies that should be incorporated into a SmC, we can suggest some things to consider. One must realize that one technology will not necessarily work or be effective with all students with disabilities, but when choosing software one must choose the software that will benefit the most students. As students enter your classrooms with more specific needs then those can be dealt with at that time. For example, some examples of objectives, hardware, and software of a SmC [21] that could be beneficial to students with disabilities are presented in Table 2 below.

3.2 Students with Disabilities and SMART Boards

Given the difficulties that students with disabilities encounter during their lives and in school SmC would benefit them and help them learn more efficiently and effectively. Where traditional classrooms do not specifically address the levels of smartness unless specific lessons focus on them, the implementation of SmC would be suggested to meet the difficulties students with learning disabilities encounter. This way, the exact areas that are of difficulty for students with learning disabilities would be addressed often and continuously in the classroom.