Chapter 2
Smart University: Literature Review and Creative Analysis

Colleen Heinemann and Vladimir L. Uskov

Abstract Research, design, and development of smart universities, smart education, smart classrooms, smart learning environments, smart pedagogy, smart learning and academic analytics, and related topics became the main themes of various pioneering international and national events and projects, governmental and corporate initiatives, institutional agendas, and strategic plans. This paper presents the outcomes of an ongoing project aimed at a systematic literature review and creative analysis of professional publications available in those areas. The premise is that the outcomes of the performed systematic creative analysis will enable researchers to identify the most effective and well-thought ideas, approaches, developed software and hardware systems, technical platforms, smart features and smartness levels, and best practices for the next evolutionary generation of a university—a smart university. The presented Smart Maturity Model can be viewed as an evolutionary approach for a traditional university to progress to various levels of maturity of smart university.

Keywords Smart university · Literature review · Systematic approach · Creative analysis

2.1 Introduction

In several recent years, the ideas of smart education (SmE), smart university (SmU), smart classroom (SmC), smart learning environments (SLE), and related topics became the main themes of various pioneering international and national events and projects, governmental and corporate initiatives, institutional agendas, and strategic plans.

C. Heinemann · V.L. Uskov (✉)
Department of Computer Science and Information Systems, InterLabs Research Institute, Bradley University, Peoria, IL, USA
e-mail: uskov@bradley.edu; uskov@fsmail.bradley.edu

C. Heinemann
e-mail: cheinemann@mail.bradley.edu

V.L. Uskov et al. (eds.), *Smart Universities*, Smart Innovation, Systems and Technologies 70, DOI 10.1007/978-3-319-59454-5_2

The KES International professional organization organizes annual conferences on Smart Education and e-Learning, beginning in 2014 [1]. The first annual international conference on Smart Learning Environments (ICSLE) was also held in 2014 [2]. Additionally, the Springer open international journal on Smart Learning Environments was launched in 2014 [3].

One of the most well-known national initiatives in SmE area is the Smart Education Initiative (SEI) in South Korea. "Smart education has been a topic of conversation in all Korean schools since June 29, 2011 when the Korean government announced its smart education initiative. … First, smart education calls for a new pedagogy. That is, the new pedagogy should not just deal with letters and numbers but also address sounds and images together with all other types of multimedia. Second, teachers and students as workforce have the same importance in classrooms. Third, a resource-enriched learning environment will be implemented in the form of content cloud where teachers and students can freely and safely upload and download open educational resources and content together" [4]. In general, it presents a paradigm shift from traditional education to SMART Education, that is an abbreviation of Self-directed, Motivated, Adaptive, Resource enriched, Technology embedded education (Fig. 2.1) [5].

"The IBM company has created the Smarter Educational Framework to demonstrate how it works in partnership with clients to support and enable—through the use of technology—smarter education establishments, making them

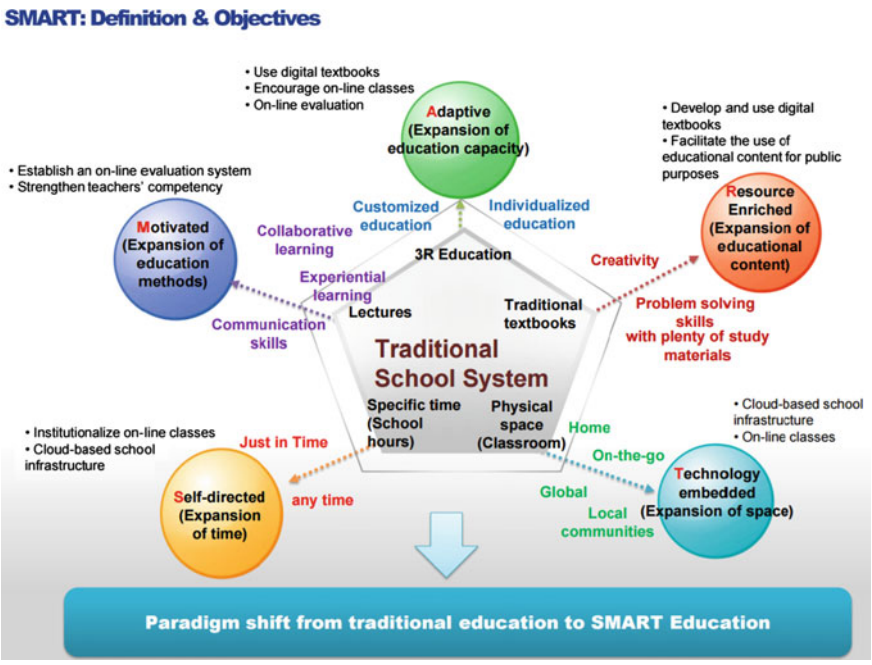

Fig. 2.1 Paradigm shift from traditional education to SMART education [5]

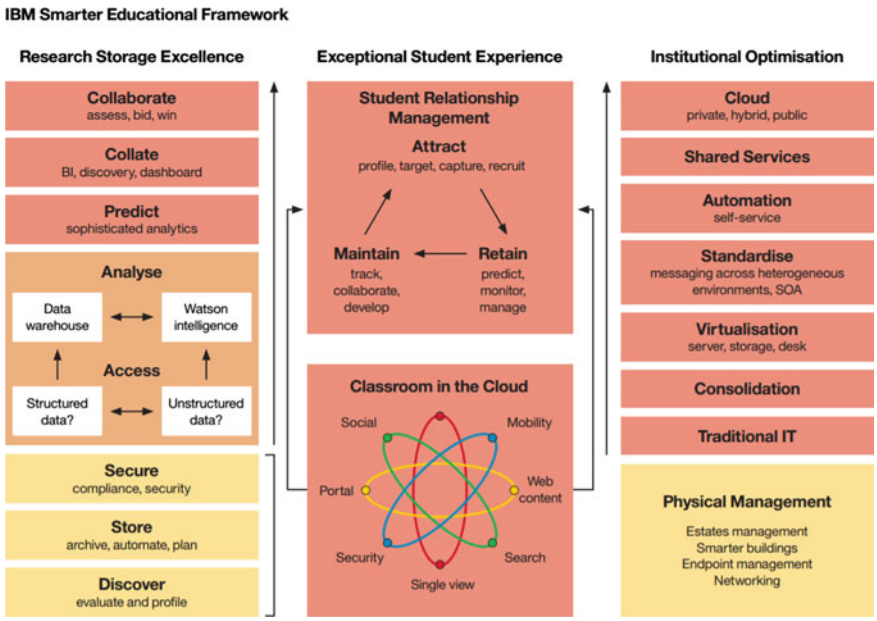

Fig. 2.2 IBM Smarter Educational Framework [6]

more efficient, productive and competitive. … Smarter education drives sustainable performance improvement by leveraging information to make better decisions, anticipate problems and resolve them proactively, and coordinate resources to operate effectively" (Fig. 2.2) [6].

The Smart School solution by the Samsung company 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 [7].

2.2 Literature Review: a Classic Approach

Recently, various creative researchers and developers began presenting their visions of SmU, SmC, SmE, SLE, smart campus, smart teacher, smart pedagogy, etc.; a brief summary of several remarkable publications on those topics—a classic literature review—is given below.

Smart University. Tikhomirov in [8] presented his vision of smart education as follows: "*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 Environments. Hwang [9] 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 [10] 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. [11] describes *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 [12] defines *intelligent campus* (*i-campus*) as "… 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 [13] 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 [14] argues that "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. [15] 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. A detailed overview of first generation smart classrooms and requirements for second-generation smart classrooms is available in [16]. For example, Huang et al. in [17] 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 [18] 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 instruct 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" [18]. Glogoric et al. in [19] 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" [19].

Our vision of the next generation SmC is based on the idea that SmC—as a smart system—should implement and demonstrate significant maturity at various "smartness" levels such as (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organization and re-structuring. The components of an SmC include, but are not limited to,

(a) hardware, smart devices, or equipment, (b) software systems, applications, and smart technologies, (c) various activities related to smart learning and teaching or Smart Pedagogy, and (d) systems for learning, teaching, and performing academic analytics in SmC—Smart Analytics systems [16, 20].

The performed classic review of the above-mentioned, as well as 100 + additional publications and reports relevant to SmU, SmE, SmC, and SLE areas, unfortunately, does not provide readers with a clear understanding of focus, scope, and important details of analyzed publications. Moreover, the classic literature review usually does not help readers to compare the proposed approaches, features, smartness levels, and details in those publications. This was the main reason that we proposed and used a systematic approach to literature review in SmU, SmE, SmC, and SLE areas, using a developed framework as described below.

2.3 Literature Review: Creative Analysis Based on Systematic Approach

In order to (a) overcome problems of a classic literature review approach and (b) be able to compare various publications in SmU, SmE, SmC, SLE and related areas, we developed a framework for systematic creative analysis of those publications. In the general case, this framework may contain multiple sections (rubrics) that may include, but are not limited to,

(1) general information about a publication (i.e. main topic or title of a publication, list of authors, publisher, year of publication, reference number, etc.);
(2) main topic(s);
(3) proposed idea or approach and main details (as described by authors);
(4) identified list of main features (or, functions) that are relevant to SmU or SmE concepts;
(5) identified smartness levels of SmU addressed by proposed approach, developed framework or system, etc.

The outcomes of performed systematic creative analysis for 8 selected publications are presented in Tables 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 2.8 below; however, the outcomes for additional 13 examples are available in Tables 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.20, 2.21, 2.22 and 2.23 in Appendix.

2.3.1 Approaches to Develop Smart Universities

Table 2.1 A smart University using RFID technology [27]

Item	Details
Main topic	Smart university—technology
Approach used	Smart university development approach is based on implementation and active utilization of RFID technology to enhance varying aspects such as employee/equipment tracking, security, etc.
Details	"…present how emerging technology of RFID can be used for building a smart university. … Several actors and assets should be tagged: • Each employee will be tagged using smart employee card • Each student will also be tagged having their unique ID i.e. roll numbers • Different office items will be tagged using RFID based labels • Each office, classroom, lab will be assigned a unique ID that will be stored in RFID reader unit RFID reader units are placed at strategic places as follows: • RFID reader unit will be placed next to the door of each room • Reader unit will also be placed at the University entrance and exit • University cafeteria and common rooms will be equipped with reader node • Labs and classrooms will also be having at-least one reader at the entrance and exit" [27]
Identified features	• Facial recognition system • Intelligent cyber-physical systems (for safety and security) • Location awareness technologies (indoor and outdoor) • Gesture (activity) recognition systems • Context (situation) awareness systems
Smartness levels addressed	• Sensing—by technology specifically used for identification and human sensing • Anticipation—keeps track of location awareness and intelligent cyber-physical systems for safety and security

Table 2.2 Smart University taxonomy: features, components, systems [20]

Item	Details
Main topic	Smart university—smartness levels, systems and technology, teaching strategies
Approach used	SmU development approach is based on the idea of next generation of Smart Class-room systems that should significantly emphasize not only software/hardware features but also "smart" features and functionality of smart systems. 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

(continued)

Table 2.2 (continued)

Item	Details
Details	"The objectives of this project were to create a taxonomy of a smart university … and identify 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. … The premise is 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" [20]
Identified features	*Software systems to be deployed by SmU* • 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)
	Technologies to be deployed by SmU • 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

(continued)

Table 2.2 (continued)

Item	Details
	• Wireless sensor networking technology • RFID (radio frequency identification) technology • Location awareness technologies (indoor and outdoor) • Sensor technology (motion, temperature, light, humidity, etc.)
	Hardware systems to deployed by SmU • 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
	Smart curricula to be deployed by SmU • 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.
	Smart pedagogy to be deployed by SmU • 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
Smartness levels addressed	• Adaptation • Sensing (awareness) • Inferring (logical reasoning) • Self-learning • Anticipation • Self-organization and restructuring

The outcomes of creative analysis of several other publications relevant to current developments in smart universities are available in Tables 2.11, 2.12, 2.13 and 2.14 in Appendix.

2.3.2 Approaches to Develop Smart Campuses

Table 2.3 An ontology-based framework for model movement on a smart campus [26]

Item	Details
Main topic	Smart campus—concepts
Approach used	Smart campus development approach is based on ontology-based framework as a way to represent, analyze, and visualize human mobility and movement, specifically when it relates to scheduling activities
Details	"This work introduces an ontology-based framework for modeling, analyzing, and visualizing human movement associated with scheduled activities through integrates semantic web technologies" [26]
Identified features	• Smart learning/teaching analytics (big data analytics) systems • 3D visualization technology • Smart data visualization technology • Speaker/instructor motion tracking systems
Smartness levels addressed	• Sensing—by technology specifically used for modeling, analyzing, and visualizing human movement • Inferring—analyzing the information gathered through the sensors and sensing systems

Table 2.4 Constructing smart campus based on cloud computing platform and internet of things [31]

Item	Details
Main topic	Smart campus—technology
Approach used	Smart campus development approach is based on a higher stage of education information systems that connect everything through RFID technology, sensors, and the Internet of Things technology
Details	"…smart campus includes portal architecture, management and service, smart management, infrastructure, etc. Smart campus system integrates hardware device of digital school, and cloud storage as the means of data storage is applied…" [31]
Identified features	• Internet-of-Things technology • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents • Repositories of digital learning content and online (web) resources, learning portals
Smartness levels addressed	• Adaptation—of classroom model • Sensing—by technology specifically used for identification

The outcomes of creative analysis of several other publications relevant to current developments in smart campuses are available in Tables 2.15, 2.16, 2.17 and 2.18 in Appendix.

2.3.3 *Approaches to Develop Smart Learning Environments*

Table 2.5 Conditions for effective smart learning environments [21]

Item	Details
Main topic	Smart learning environment—technology
Approach used	SLE development approach is based on an idea of setting of a set of varying levels of physical and digital locations through which a student can learn through context awareness
Details	"… Human Learning Interfaces (HLIs) that can facilitate the research and development of SLEs…" [21]
Identified features	• Augmented and virtual reality technology • Various smart software agents • Collaborative Web-based audio/visual one-to-one and many-to-many communication systems • Systems to host, join, form and evaluate group discussions (including both local and remote students) • Learning analytics
Smartness levels addressed	• Adaptation—of learning methods and classroom models • Self-learning—active use of innovative hardware such as Web-lecturing systems

The outcomes of creative analysis of an additional publication relevant to current developments in smart learning environments are available in Table 2.19 in Appendix.

2.3.4 Approaches to Develop Smart Classrooms

Table 2.6 Incorporating a smart classroom 2.0 Speech-Driven PowerPoint System (SDPPT) into University teaching [34]

Item	Details
Main topic	Smart classroom—systems and technology
Approach used	SMC development approach is based on idea of having a classroom equipped with networked computers and audiovisual devices to allow instructors to teach students in remote locations as well as physically in the classroom
Details	"The newly developed SDPPT system utilized voice recognition technology to identify certain keywords as they were spoke and the system then automatically responded by presenting the corresponding PowerPoint slides on the overhead screen" [34]
Identified features	• Face recognition system • Repositories of digital learning content and online (web) resources, learning portals • Speech/voice recognition system • Augmented and virtual reality technology • SMART boards and/or interactive white boards • Adaptive programs of study—major and minor programs, concentration and certificate programs—with variable structures adaptable to types of students/learners, smart pedagogy, etc. • Systems to host, join, form and evaluate group discussions (including both local and remote students)
Smartness levels addressed	• Adaptation—of teaching style • Sensing—by technology specifically used for identification and sensing ability • Inferring—based on Power Point systems information gathered

Table 2.7 The ontology of next generation smart classrooms [16]

Item	Details
Main topic	Smart classroom—smartness levels, systems and technology, teaching strategies
Approach used	SmC development approach is based on the idea of next generation of Smart Class-room systems that should significantly emphasize not only software/hardware features but also "smart" features and functionality of smart systems. 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

(continued)

Table 2.7 (continued)

Item	Details
Details	"… the next generation of smart classroom systems should significantly emphasize not only software/hardware features but also "smart" features and functionality of smart systems … Therefore, next generation of smart classrooms should pay more attention to implementation of "smartness" maturity levels and abilities of various smart technologies. … 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…" [16]
Identified features	*SmC hardware/equipment (with relevance to various types of users)* **Common for entire SmC**: • 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 for 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 for local (in-classroom) student/learner**: • Array of mobile devices: smart interconnected mobile devices—smart phones, PDAs, laptops, smart headphones, etc. • (In some cases only): 3D goggles **Specific for remote/online student/learner**: • Desktop or tablet PC or laptop with connected or built-in microphone, speakers • Access to the broadband Internet

(continued)

Table 2.7 (continued)

Item	Details
	SmC software systems (with relevance to various types of users) **Common for entire SmC**: • 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 for local (in-classroom) student/learner**: • Smart notebook/laptop/tablet PC software • Main office software applications • Same view and smart view software Systems to analyze presence, attendance, etc. **Specific for remote/online student/learner**: • Remote client programs to facilitate remote learning • Main office software applications • Software systems to analyze presence, attendance, etc. *SmC types of teaching/learning strategies to be deployed* **Common for entire SmC**: • 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
Smartness levels addressed	• Adaptation • Sensing (awareness) • Inferring (logical reasoning) • Self-learning • Anticipation • Self-organizations and restructuring

The outcomes of creative analysis of several other publications relevant to current developments in smart classrooms are available in Tables 2.20, 2.21 and 2.22 in Appendix.

2.3.5 *Approaches to Develop Smart Education or Smart Learning*

Table 2.8 Smart approach to innovated education for 21st century [22]

Item	Details
Main topic	Smart education—concepts
Approach used	SmE development is based on an educational concept that does not simply rely on technological education, but is also self-directed, motivated, adaptive, resource-enriched, as well as technology-embedded education
Details	"Why School Education Should be Innovated? • Address desynchronization issues between students and education systems • Quality of education outcomes emerges a key issue • New quality frameworks pay more attention to evidence-based planning rather than examination-dominated assessment • Education systems should be reformed to accommodate the behavior and characteristics of digital native students: what, and how to educate students • Leveraging technology is vital factor to reform education system: mobile network, Learning Analytics, OER, OCW, MOOCs, open platforms. • Schools and classrooms should be reformed to accommodate changes in education environment: smart school, future schools, restructuring classroom settings" [22]
Identified features	• Flipped classroom teaching/learning strategy • Repositories of digital learning content and online (web) resources, learning portals • Internet of Things technology • RFID (radio frequency identification) technology • System for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents • E-Books • Interconnected laptops or desktop computers
Smartness levels addressed	• Adaptation—of classroom models • Sensing—by technology specifically used for identification and sensing ability • Self-learning—active use of innovative hardware such as Web-lecturing system

2.4 Smartness Levels of Smart Universities

We believe that SmU as a smart system should significantly emphasize, not only state-of-the-art software/hardware features, emerging technology and innovative technical platforms, pioneering teaching and learning strategies, but also "smart" features of smart systems [20]. Therefore, the designers of SmU should pay more attention to the maturity of smart features of SmU that may occur on various levels of SmU's smartness, or smartness levels, such as adaptation, sensing, inferring, self-learning, anticipation, and self-organization.

The performed creative analysis of designated publications enabled us to identify sets of smartness levels addressed in those publications. These sets are presented in Tables 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 2.8 in Sect. 2.3 and also in Tables 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.20, 2.21, 2.22 and 2.23 in Appendix. Additionally, we present a brief summary of examples of addressing SmU smartness levels in various publications (Table 2.9).

Table 2.9 Context awareness systems for smart university: A list of most important features in existing systems

Smartness level	Target audience	Details	Ref. # or our analysis
Adaptation	Students	SmC should be able to adapt to various types of students, for example, students with disabilities	[20]
	Faculty and students	The course content used by the faculty can be posted on the website and content could be available to different users in different formats, making it adaptable to every user	[15]
	Faculty	Smart Pedagogy should help faculty with 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.)	[20]
	Professional staff	University network should be able to adapt to new technical platforms and mobile devices (mobile networking, tablets, mobile devices with iOS and Android operating systems, etc.)	Our analysis

(continued)

Table 2.9 (continued)

Smartness level	Target audience	Details	Ref. # or our analysis
Sensing	Students and faculty	One of the most sensible options is to integrate the attendance monitoring and recording processes into an existing access control system, thereby optimizing value and minimizing cost, disruption, and system duplication	[23]
	Faculty	Local information services connect to the sensors and provide their measurements to the instructor	[15]
	Professional staff	A single smart card solution can work both with wired and wireless locks installed on secure storage receptacles such as cabinets. This locks can be connected to the building's online access control system for near online and near real-time control. Cards also can be used to protect and monitor higher-value resources	[23]
	University administrators	The smart card can be used as a credit/debit card. This allows the card to be used effectively in e-commerce applications. Smart cards greatly improve the convenience and security of any transaction	[27]
Inferring	Students	When a student enters a room, his unique ID is sent to the control circuit and the central attendance server. The person is identified and a log is made according to the time and location. If the person identified has a valid ID, the control circuit performs the room automation function as described in its profile	[27]
		Contactless smart card technology provides the necessary security, not only to get through entrances, etc., but also to make meal purchases, pay for laundry, printing, copying, and additional campus services. Students can check out books automatically, with all of their information recorded and loaded into the student database. This provides real-time information on the status of overdue books	[23]
	Faculty	Faculty can use data pulled from sensors and devices to sense that a student is not grasping a concept, a student is bored, etc.	[23]
		RFID technology provides faculty/instructors with access to the labs and classrooms	[27]
	Technical staff	All lighting and parking systems at the university become a part of the Internet of Things technology. The smart campus system controls manage the lights, intelligent parking assistance, etc.	[23]
	University administrators	The smart classroom's ability to sense a student's gestures or facial expressions helps bolster the university's reputation because students can get help from instructors on a more personal level to ensure that everyone understands the material presented	[23]
		University administrators can gather information regarding where students spend their time, what they purchase, etc. based on information gathered from the student's smart card in order to optimize the utilization of the university	[26]

(continued)

Table 2.9 (continued)

Smartness level	Target audience	Details	Ref. # or our analysis
Anticipation	Professional staff	Issuing a smart ID card to all faculty, students, staff, and visitors allows security departments and technical staff to keep better tabs on what resources will be necessary and how much of each will be necessary based on how many people there are	[23]
		Data regarding how many people are in a classroom, how many parking spaces are available, etc. can be gathered in order to plan ahead to let everyone know that the parking lot is full, the classroom is full, etc. RFID-enabled cards present the optimal solution for planning for visitors, having resources ready, etc.	[27]
	University administrators	Access to data stored on the card allows the university administrators to analyze the data and anticipate necessary resources, funding, etc. for projects or classes	[27]
		Seeing the data that tells where students spend their time, what resources they use most, etc. allows university administrators to anticipate what resources need to be repurchased or reallocated	[23]
		Enrollment Management System to predict, anticipate, and control variations on student enrollment	[20]
		Campus-wide Safety System (CSS) to anticipate, recognize and act accordingly in case of various events on campus	[20]
Learning	Students	Gesture recognition systems and facial recognition systems can gather data regarding if a student understands a concept or is having trouble with a concept. This data can be interpreted by the system to show what percentage of the time, for example, the student is understanding the content	Our analysis
	Faculty	The online repositories of resources can determine what resources the students spend the most time with and request that the instructor provide additional resources of a similar nature. The collected data gives the ability to do statistical investigation from a pedagogical point of view	[15]
	Professional staff	Based on how sensors are set up in the classroom or building, it may take the system some time to learn where other sensors are in order to develop the optimal path for sending or receiving information	[27]
		The databases are not only collecting large volumes of data but are also learning to understand the relationships between entities by mapping their connection to the system	[15]
	University administrators	Learning from anonymous Opinion Mining System (OMS)	[20]
		Learning from different types of classes—MOOCs, blended, online, SPOCs, etc.	[20]

(continued)

Table 2.9 (continued)

Smartness level	Target audience	Details	Ref. # or our analysis
Self-organization	Students	Sensors determine whether or not a student is in a classroom, the lights are on, etc. and readjust accordingly. This may need to be changed numerous times depending on where students are or how long they are there	Our analysis
	Faculty	Automatic re-configuration of SmC systems, performance parameters, sensors, actuators and features in a smart classroom in accordance with instructor's profile	[20]
		Faculty can walk around classrooms freely and allow gesture recognition systems or motion detection systems to reorganize and ensure that the instructor is always in the camera view; it is done automatically	Our analysis
	Professional staff	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.	[20]
		Sensors determine whether or not someone is in a classroom, the lights are on, etc. and readjust accordingly	Our analysis

2.5 Smart University: Smartness Maturity Model

The performed systematic creative analysis of publications in SmU, SmC, SmE, and SLE areas clearly shows that various research, design, and development teams, as well as colleges and universities, addressed different levels of college/university maturity as a smart college/university. For example, one extreme case (SmU's initial level of maturity in terms of SmE) may deal with the following situation: a college/university purchased a SMART board for a classroom and, therefore, may say that they already developed or implemented smart education. The other case may be as follows: a university already has multiple smart classrooms that are equipped with various software and hardware systems to provide smart education and smart pedagogy; however, that university may not have university-wide policies and strategies regarding SmE yet.

In order to recognize and classify the current status of SmE education development in a college/university or status of evolution of a traditional university towards SmU, we proposed and developed the Smart Maturity Model (SMM) for SmU. This model was inspired by the CMMI (Capability Maturity Model Integrated) model [43, 44] that is actively used in the software development industry for improving the quality of software engineering process and final product —software systems.

Definition. Smart Maturity Model is a methodology used to design, develop, and continuously improve a smart university's main business functions such as

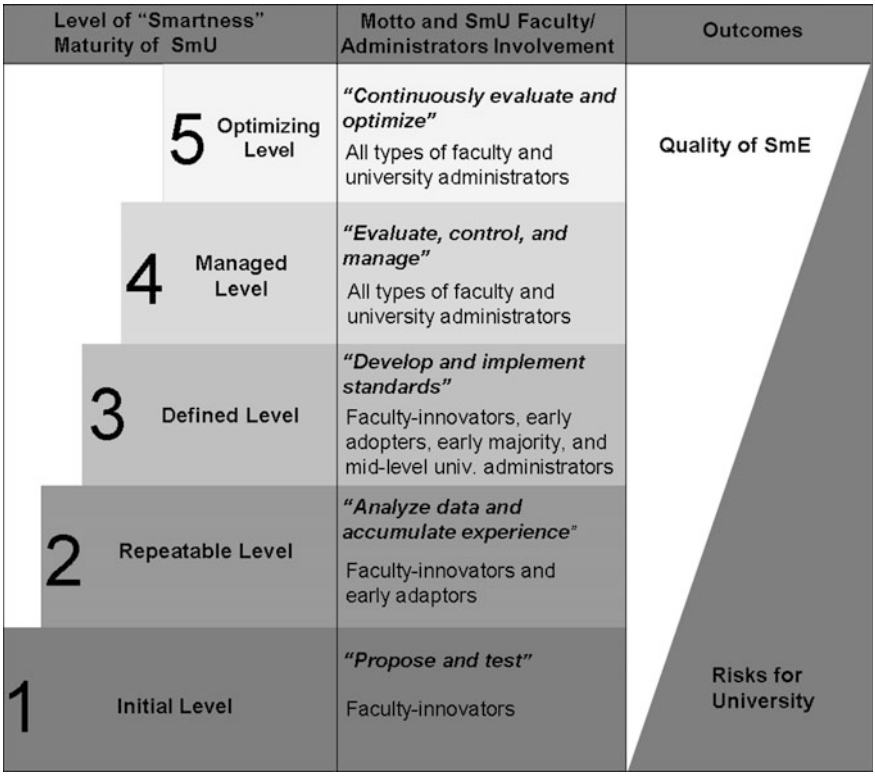

Fig. 2.3 The proposed smartness maturity model for SmU: level-based hierarchical structure (inspired by CMM Irepresentation in [45])

education, teaching, learning, research, services, enrollment, management, administration, control, security, safety, etc.

SMM broadly can be viewed as SmU evolution and/or improvement approach to progress level-by-level from traditional university status to SmU status.

Levels. SMM defines 5 levels of university "smartness" maturity in terms of a university's readiness to implement SmE, create and actively use multiple SmC, involve various types of faculty to learn and use innovative technology in teaching, implement and use smart pedagogy, etc.

In terms of a university's maturity of implementation and use of smart education on campus, creation of smart classrooms, use of smart pedagogy, deployment and use of smart technology, smart analytics on campus, etc., the SMM for SmU (Fig. 2.3 and Table 2.10) uses the following levels of "smartness" maturity: (1) initial level (lowest level of maturity), (2) repeatable level, (3) defined level, (4) managed level, and (5) optimizing level (highest level of maturity). If a university does not use smart devices or SMART board(s) in classrooms or smart technologies and systems on campus at all, then this model assumes that the "smartness" maturity level of that university in terms of SmE is equal to zero.

Table 2.10 The proposed Smartness Maturity Model for SmU: levels of "smartness" maturity and examples

Level # and name	*Motto* and types of faculty/admins involved	Examples of main activities relevant to research, design and development of SmU, SmE, SmC, SLE, Smart Pedagogy, Smart Analytics, etc.	Examples (Ref. #)
1 Initial level (lowest level of maturity)	"*Propose-and-test*" Faculty-innovators (2–3% of faculty)	• Propose innovative ideas/approaches and test them (for example, use of interconnected mobile devices in classrooms, or use of flipped classroom learning strategy); • Propose new type of learning activity and test it in SmC (for example, perform experiments with a joint work and collaboration of in-classroom and remote/online students when they work on joint course project—collaborative learning) • Perform stand-alone experiments and testing with smart devices in teaching/learning (for example, use of a single SMART Board in a classroom or use of just one classroom on campus) • Process testing data and get information • Compare obtained outcomes with current practices (for example, compare *learning-by-doing* approach with *learning-by-listening* approach in education)	[13, 14, 18, 19, 23, 25, 26, 30–33]
2 Repeatable level	"*Accumulate and analyze*" Faculty-innovators and early adopters (13–15% of faculty)	• Repeat proposed and best practices for different types if students/learners, in different locations and setups, for different majors (for example, use of the same smart classroom by Computer Science majors and Communication majors or creation of multiple smart classrooms on campus) • Measure and creatively analyze obtained outcomes • Generalize accumulated experience/findings/outcomes/best practices (internal and external), get information, and make conclusions • Identify user requirements for software, hardware, technology, teaching and learning styles, etc. (for example, faculty requirements for teaching Programming classes in a smart classroom for in-classroom and remote/online student)	[2, 12, 15–17]

(continued)

Table 2.10 (continued)

Level # and name	*Motto* and types of faculty/admins involved	Examples of main activities relevant to research, design and development of SmU, SmE, SmC, SLE, Smart Pedagogy, Smart Analytics, etc.	Examples (Ref. #)
3 Defined level	"*Develop and implement standards*" Faculty-innovators, early adopters and early majority (about 30-35% of all faculty) and mid-level university administrators	• Develop standards at SmU in terms of smart education, smart teaching, smart learning, smart pedagogy • Identify standard sets of required software and hardware systems, technology for "standard' smart classroom on campus • Develop standards for smart education, software and hardware systems and smart technologies to be used by various types of students (including students with disabilities) and various types of faculty (for example, faculty with different background in SmE and experience) • Create multiple SmC on campus, create smart campus • Create and implement faculty development programs in SmE and SmC	[5, 22, 36]
4 Managed level	"*Evaluate, control, and manage*" All types of faculty, including late majority (30-35%) and laggards (about 15%) and upper-level university administrators	• Develop university policies on SmE, smart teaching, smart leaning, active use of SmC, etc. for all types of faculty and students • Identify well-defined quantitative indicators of SmE effectiveness (including tangible and intangible benefits) • Active (if necessary—mandatory) faculty development of all faculty groups in SmE, smart pedagogy, SmC software and hardware systems areas	
5 Optimizing level (highest level of maturity)	"*Continuously evaluate and optimize*" All types of faculty and university administrators	• Continuous evaluation of current SmE outcomes, smart teaching, smart learning, smart pedagogy, etc. and continuous comparative "expected vs actual outcomes" analysis • Causal analysis and resolution, correction and/or optimization of identified drawbacks or weaknesses • Continuous implementations of new well-tested systems, hardware, technologies, smart pedagogy for SmU, SmE and SmC • Continuous improvement of SmU main business functions • Continuous improvement of SmU management and administration	

Based on our obtained experience in SmC and SmE, therelations between (a) highly-technological SmE, SmC, and SLE (asinnovative technology-based approaches to education) and (b) various types of college/university faculty may be described by Roger's "Diffusion of Innovation" typology (Fig. 2.4) [35]. As a result, specific groups of faculty should be involved in SmE and SmC only on designated levels of SMM to optimize the "cost-benefits" ratio.

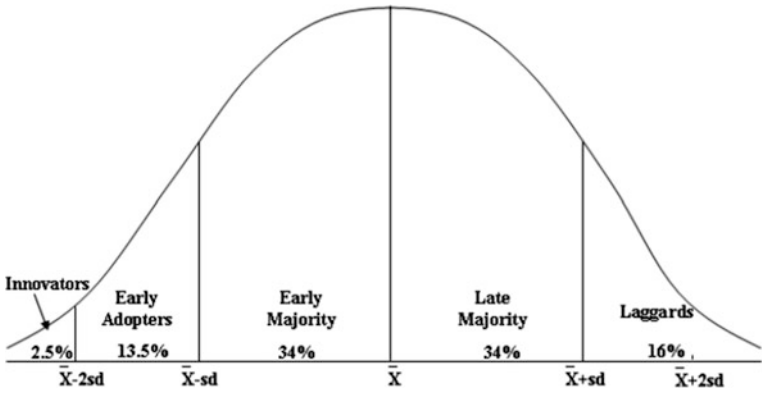

Fig. 2.4 Diffusion of innovation [35] or Roger's typology

The performed literature review and creative analysis enabled us (to the level of information presented in a publication) to classify multiple related projects in accordance with introduced SMM levels—some analysis outcomes are available in the most right column in Table 2.10.

2.6 Strengths of Smart Universities

Our vision of SmU is based on the idea that SmU—as a smart system—should implement and demonstrate significant maturity at various "smartness" levels such as (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organization and re-structuring—see details and examples in Table 2.9 above. We believe these are the most important advantages of SmU in comparison with traditional universities. However, the performed literature review and creative analysis enabled us to arrive with an additional list of reported advantages of SmU and opportunities for traditional universities if they decide to evolve to certain level of SmU.

SmU strengths provide advantages in numerous aspects of education, such as staying abreast with advanced technology, providing exposure to this advanced technology, flexible learning styles and modes of learning content delivery, ubiquitous access to educational materials, etc.

Technological advances. An advance provided by SmU is the implementation and active utilization of advanced technology; some examples of this advanced technology implemented in current variations of Smart Universities are as follows:

- RFID tags allow for easier logistics and product-related information storage and retrieval [23, 27];
- contactless ID cards for identification and financial transaction performance [31, 32];

- cloud computing technologies allow for file sharing and access for all students [25];
- RFID tags provide security enhancements as they provide identification;
- cloud computing technology allows easier access to information for students so that they can work at their own pace and access information as needed.

Educational advances. SmU are advantageous due to the fact that they utilize more advanced technology than traditional universities. SmU provides both students and faculty with exposure to technological advances as well as their active use in teaching and learning. This provides the ability for students, learners, and faculty to use, for example:

- state of the art facilities [37];
- technology in combination with human interaction [38];
- well-equipped laboratories, libraries, and IT facilities [39].

Each of these provides users at SmU with unique hands-on experience with advanced technology—smart technology, smart systems, smart devices, smart classrooms, etc.—that perhaps would not be used in a traditional university setting. Having exposure to this advanced technology provides a holistic education for students that also contains customization, personalization, and subjection to unique teaching and learning styles [21].

Additionally, SmU provides the advantage of having flexibility when it comes to learning. This can be done because of SmU's ability to tailor its educational style to in-classroom learning, e-learning, or a combination of the two as blended learning (b-learning). This is a major strength of SmU over traditional universities due to the fact that these days (and, as expected, in the future) so many students have unique situations that perhaps require being out of the classroom for a majority of the time. The advantages of this concept provide SmU with the following strengths:

- learning at one's convenience (any place, any time, any device) [40];
- potential for independent learning as well as structured learning [41];
- curriculum designed to meet both local needs and international standards [39];
- resources available anytime and anywhere [42].

The listed strengths above provide students, who normally might not have access to higher education, with the ability to learn in any location and at any time.

These reported advantages of SmU provide the foundation to continually expand on the concepts discussed above. This can provide opportunities for a wider variety of students to take advantage of the educational resources available to them, providing them with a richer educational experience at SmU.

2.7 Conclusions

The performed literature review, creative analysis, proposed SMM model, and obtained research findings and outcomes enabled us to make the following conclusions:

(1) In several recent years, the ideas of smart education, smart university, smart classroom, smart learning environments, and related topics became the main topics of various pioneering international and national events and projects, governmental and corporate initiatives, institutional agendas, and strategic plans.
(2) Our vision of SmU is based on the idea that SmU—as a smart system—should implement and demonstrate significant maturity at various "smartness" levels such as (1) adaptation, (2) sensing (awareness), (3) inferring (logical reasoning), (4) self-learning, (5) anticipation, and (6) self-organization and re-structuring.
(3) The performed classic literature review of 100 + publications and reports relevant to SmU, SmE, SmC, and SLE areas usually does not provide readers with a clear understanding of focus, scope, and main details of analyzed publications; moreover, it usually does not help to compare the proposed approaches, features, smartness levels, and details in those publications.
(4) In order to overcome problems of the classic literature review approach, and in order to be able to compare various publications in SmU, SmE, SmC, SLE and related areas, we developed a framework for systematic creative analysis of those publications. In the general case, this framework may contain multiple sections (rubrics) that may include, but are not limited to, a) general information about a publication (i.e. main topic or title of a publication, list of authors, publisher, year of publication, reference number, etc.); b) main topic; c) proposed idea or approach and main details (as described by authors); d) identified list of main features (or functions) that are relevant to SmU concepts; e) identified smartness levels of SmU addressed by proposed approach, developed system, and other rubrics. Examples of applications of the developed framework to creatively analyze various related publications are presented in Tables 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 2.8 in Sect. 2.3 and Tables 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.20, 2.21, 2.22 and 2.23 in Appendix.
(5) Examples of utilization of proposed SmU smartness levels in several analyzed publications are described in Table 2.9 (Sect. 2.4).
(6) In order to recognize and classify the current status of smart education development in a particular college/university or status of evolution of a traditional university towards smart university, we proposed and developed the Smart Maturity Model (SMM) for SmU (Table 2.10 in Sect. 2.5).
(7) The relations between SmE, SmC, and SLE (as innovative approaches to education) on one side and types of faculty on the other side are well described by Roger's "Diffusion of Innovation" Typology (Fig. 2.3 in Sect. 2.5). As a result, we conclude that specific types of faculty should be involved in SmE and SmC initiates only on designated levels of SmU "smartness" maturity to optimize "cost-benefits" ratio.
(8) Finally, the performed literature review and creative analysis enabled us (to the level of information presented in each publication) to classify multiple related projects in accordance with introduced SMM model levels (some of examples are available in the most right column in Table 2.10).

Acknowledgements The authors would like to thank Dr. Jeffrey P. Bakken, Associate Provost for Research and Dean of the Graduate School, Dr. Cristopher Jones, Dean of the LAS College, and Sandra Shumaker, Executive Director, Office of Sponsored Programs at Bradley University for their strong support of our research, design and development activities in Smart University and Smart Education areas.

This project is partially supported by grant REC # 1326809 from Bradley University.

Appendix

1. **Approaches to develop smart universities: the outcomes of systematic creative analysis** (Tables 2.11, 2.12, 2.13 and 2.14)
2. **Approaches to develop smart campuses: the outcomes of systematic creative analysis** (Tables 2.15, 2.16, 2.17 and 2.18)
3. **Approaches to develop smart learning environments: the outcomes of systematic creative analysis** (Table 2.19)
4. **Approaches to develop smart classrooms: the outcomes of systematic creative analysis** (Tables 2.20, 2.21 and 2.22)
5. **Approaches to develop smart learning: the outcomes of systematic creative analysis** (Table 2.23)

Table 2.11 Smarter Universities: a vision for the fast changing digital era [11]

Item	Details
Main topic	Smart university—concepts
Approach used	SmU is considered as a place where knowledge is shared in a seamless way and is a system that is green, robust, personalized, responsible, interactive, and adaptive, as well as accessible anywhere, anytime, and from any device
Details	"…We analyze the current situation of education in universities, with particular reference to the European scenario. Specifically, we observe that recent evolutions, such as pervasive networking and other enabling technologies, have been dramatically changing human life, knowledge acquisition, and the way works are performance and people learn" [11] • "Opinion mining—The first step of the process is collecting different option, which will be later organized and structured. • Needs collection—The second phase of the proposed model corresponds to an in-depth analysis of the needs emerging from the area, the communities and the organizations • Vision—The presence of multiple variables and constraints encourages the creation of a "strategic" vision that must be translated into clear objectives, ambitious yet realistic • Priorities—The above mentioned objectives are then ordered as a two-dimensional array according to their priority and their measure of urgency. • Common contents—The model extracts common contents, knowledge and skills that an individual must have in multiple scientific areas • Domain specific contents—The vertical part of the T is represented by the knowledge and the skills that individuals must possess in a specific domain.

(continued)

Table 2.11 (continued)

Item	Details
	• Competencies, standards and policies—The competencies are described in the ECF and teachers' skills are taken into account • Matching—One of the most challenging parts of the model is the task of matching the choices with the needs • Monitoring and analytics—The proposed model provides an abstract representation of a vision"
Identified features	• Collaborative and communication technologies • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents • Elements of Internet-of-Things technology • Cloud computing technology in place • Elements of Smart Agents technology
Smartness levels addressed	• Adaptation—various classroom models can be used • Sensing—by observing the recent evolutions • Inferring—based on opinion mining and needs that were collected previously

Table 2.12 Designing smart University using RFID and WSN [23]

Item	Details
Main topic	Smart university—technology
Approach used	Smart university design approach is based on implementation and active use of Radio Frequency Identification (RFID) technology and wireless sensor network (WSN) technology to improve student's experience whether they experience it remotely or physically in the classroom
Details	"There is a necessity to build a smart system that decrease load in managing the attendance and improves the performance of colleges, universities and any education institute. … The developed prototype shows how evolving technologies of RFID and WSN can add in improving student's attendance method and power conservation. RFID technology provides the means of persons identification and forms the basis of: • Student attendance record • Employee attendance record • Authentication of attendance • Automation of electrical appliances."[23]
Identified features	• RFID technology • Smart card readers • Biometric-based access control devices • Robotic controllers and actuators • Intelligent cyber-physical systems • Flipped classrooms • Remote (virtual) labs
Smartness levels addressed	• Sensing—by technology specifically used for identification and sensing ability • Anticipation (of student behavior)—by keeping track of attendance records, authentication of attendance, etc.

Table 2.13 System architecture for a smart university building [25]

Item	Details
Main topic	Smart university—buildings
Approach used	Smart university development approach is based on idea of having smart buildings that are able to remotely monitor and manage processes while being energy efficient
Details	"…An intelligent platform is proposed, that integrates sensors within a university building and campus based on Web Services middleware. The aim is to provide automation of common processes, reduce the energy footprint and provide control of devices in a remote manner" [25]
Identified features	• Sensor technology (motion, temperature, light, humidity, etc.) • RFID technology • WSN technology • Power/light/HVAC consumption monitoring system(s)
Smartness levels addressed	• Sensing—by technology specifically used for identification and sensing ability • Inferring—make inferences based on information gathered by sensors to enhance ability of smart classroom • Self-organization—use systems and sensors that are automatically configured to run smart classroom

Table 2.14 Smart education environment system [30]

Item	Details
Main topic	Smart university—library
Approach used	Smart university development approach is based on a framework that upgrades the traditional, book-based library to a digital resource library to meet the needs of an emerging IT-aware generation
Details	"…a framework for an Smart Education Environment System (SEES), which will provide a library with an integrated database incorporating three core sub-systems: 'Electronic Bookshelves', for automating access to the bookshelves; 'Virtual White Space', for the discussion of information found in the library; and 'Innovation and Social Network Database (ISND)', for disseminating and storing new ideas and concepts…" [30]
Identified features	• E-books • SMART boards and/or interactive white boards • RFID technology • Repositories of digital learning content and online (Web) resources, learning portals • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents
Smartness levels addressed	• Adaptation—of classroom model • Sensing—by technology specifically used for identification

Table 2.15 Exploration on security system structure of smart campus based on cloud computing [32]

Item	Details
Main topic	Smart campus—technology
Approach used	Smart campus development approach is based on a cloud computing technology and the Internet of Things technology to ensure everything is completely digital and all information, class interaction, and lectures are available from remote locations
Details	"This paper studies such problems as smart campus, smart campus system structure and campus cloud structure from the perspective of information security, designs security system structure of smart campus on this basis and describes the security system structure at six levels" [32]
Identified features	• Intelligent cyber-physical system (for safety and security) • Various smart software agents • Internet-of-Things technology • Repositories of digital learning content and online (web) resources, learning portals
Smartness levels addressed	• Sensing—by technology specifically used for identification

Table 2.16 New challenges in smart campus applications [15]

Item	Details
Main topic	Smart campus—concepts
Approach used	Smart campus development approach is based on a framework that can be used by both local and remote participants. This framework contains everything to improve the usability of the system and provide users with a better and more effective learning experience
Details	"…create an architecture framework which allows various members of the community to create and use services based on the data that is collected in a university environment. … The overall goal is to improve the usability of the system and provide better user experience by applying personalization" [15]
Identified features	• Sensor technology (motion, temperature, light, humidity, etc.) • Repositories of digital learning content and online (Web) resources, learning portals • Collaborative Web-based audio/visual one-to-one and many-to-many communication systems • E-books • 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. • Systems to host, join, form and evaluate group discussions (including both local and remote students)
Smartness levels addressed	• Adaptation—of teaching style and classroom model • Sensing—by technology specifically used for identification and sensing ability

Table 2.17 A vision for the development of i-campus [12]

Item	Details
Main topic	Smart campus—concepts
Approach used	Smart campus development approach is based on holistic e-learning, social networking and communications for work collaboration, green and CIT sustainability with intelligent sensor management systems and smart building management with security control and surveillance
Details	"…envision the possible ways of intelligent campus development. … Personalized learning is a board term which includes personalized study plan and learning path, personalized information gathering and learning resource retrieval, and personalized learning activities. … Adaptive learning refers to the fulfillment of dynamic needs of learners and provision of feedbacks to the current state of learning in a smart learning environment. … There are some possible research and development opportunities relating to the development of intelligent campus which may include learning management systems and knowledge management, personalized learning, adaptive learning and e-portfolio, immersive educational space, and safe learning environment" [12]
Identified features	• Smart data visualization technology • Repositories of digital learning content and online (Web) resources, learning portals • Web-lecturing technology • Interconnected laptops or desktop computers • Elements of Internet-of-Things technology
Smartness levels addressed	• Adaptation—of teaching style and classroom model

Table 2.18 Future content-aware pervasive learning environment: smart campus [24]

Item	Details
Main topic	Smart campus—technology
Approach used	Smart campus development approach is based on technology to allow remote learning, interaction between local and remote students, and access for all students to all digital resources
Details	"…we proposed a novel design of interactive pervasive learning environment. … The proposed solution is actually a service oriented framework in which data mining is used for knowledge discovery, context is identified by using more precise approach, and then automatic service discovery, activation and execution takes place to facilitate the user in pervasive learning environment" [24]
Identified features	• Repositories of digital learning content and online (Web) resources, learning portals • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents • Collaborative Web-based audio/visual one-to-one and many-to-many communication systems • Smart learning/teaching analytics (big data analytics) systems
Smartness levels addressed	• Adaptation—of classroom model • Inferring—based on big data analytics systems information gathered

Table 2.19 Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective [9]

Item	Details
Main topic	Smart learning environment—concepts
Approach used	SLE development approach is based on an idea of student's ability to access digital resources and interact with learning systems from any pack at any time. It also actively provides guidance through context awareness
Details	"The definition and criteria of smart learning environments are presented from the perspective of context-aware ubiquitous learning. A framework is also presented to address the design and development considerations of smart learning environments to support both online and real-world learning activities. … An expert model or expert knowledge model that contains the teaching materials, a student model or learner model that evaluates students' learning status and performance, an instructional model or pedagogical knowledge model that determines teaching content, educational tools and presentation methods based on the outcomes of the student model, and a user interface for interacting with students" [9]
Identified features	• Ubiquitous computing technology • Context (situation) awareness systems • Adaptive teaching • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents
Smartness levels addressed	• Adaptation—of teaching style and classroom model • Sensing—done by ubiquitous computing technology used in a context aware system

Table 2.20 Smart classrooms for distance education and their adoption in multiple classroom architecture [18]

Item	Details
Main topic	Smart classroom—systems and technology
Approach used	SMC development approach is based on implementation and active use of integrated voice-recognition, computer-vision, as well as other varying technologies, to provide a tele-education experience for remote learners that is similar to a traditional classroom experience
Details	"…an overview of the technologies used in smart classrooms for distance education by classifying smart classrooms into four categories and discussing the type of technologies used in their implementation…" [18]
Identified features	• Web-lecturing systems (with video capturing and computer capturing functions) for learning content development pre-class activities • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and shared learning content/documents • Collaborative Web-based audio/visual one-to-one and many-to-many communication systems • Intelligent cyber-physical systems (for safety and security) • Repositories of digital learning content and online (Web) resources, learning portals

(continued)

Table 2.20 (continued)

Item	Details
	• Panoramic cameras • Ceiling-mounted projectors (in some cases, 3D projects) • Interconnected big screen monitors or TVs ("smart learning cave") • Interconnected laptops or desktop computers • SMART boards and/or interactive white boards
Smartness levels addressed	• Adaptation—of teaching style and classroom model • Anticipation—keeps track of location awareness and intelligent cyber-physical systems for safety and security

Table 2.21 Classroom in the era of ubiquitous computing smart classroom [28]

Item	Details
Main topic	Smart classroom—systems and technology
Approach used	SMC development approach is based on context-awareness, such as understanding a user's intentions based on audio/visual inputs or situational information
Details	"…four essential characteristics of futuristic classroom in the upcoming era of ubiquitous computing: natural user interface, automatic capture of class events and experience, context-awareness and proactive service, collaborative work support. This elaborates the details in the details in the design and implementation of the ongoing Smart Classroom project…" [28]
Identified features	• Collaborative Web-based audio/visual one-to-one and many-to-many communication systems • Gesture (activity) recognition and speaker/instructor motion tracking systems • Speech/voice recognition systems • Controlled and self-activated microphones and speakers
Smartness levels addressed	• Adaptation—of classroom model • Sensing—by technology specifically used for identification and human sensing • Self-organization—through classroom's controlled and self-activated systems

Table 2.22 Smart classroom: enhancing collaborative learning using pervasive computing technology [29]

Item	Details
Main topic	Smart classroom—hardware and technology
Approach used	SMC development approach is based on an implementation and active use of a collection of embedded, wearable, and handheld devices that are wirelessly connected to enhance the idea of collaborative learning
Details	"..Smart Classroom that uses pervasive computing technology to enhance collaborative learning among college students… integrate mobile and handheld devices, such as Personal Digital Assistants (PDAs), with fixed computing infrastructures, such as PCs, sensors, etc. in a wireless network environment inside a classroom…" [29]

(continued)

Table 2.22 (continued)

Item	Details
Identified features	• Interconnected laptops or desktop computers • Systems to relay automatically recorded class activities and lectures for post-class review and activities (by both local and remote students) • Systems to host, join, form and evaluate group discussions (including both local and remote students) • Collaborative and communication technologies • Web-lecturing systems (with video capturing and computer screen capturing functions) for learning content development pre-class activities
Smartness. levels addressed	• Adaptation—of teaching style and classroom model

Table 2.23 Competence analytics [33]

Item	Details
Main topic	Smart learning—concepts
Approach used	Smart learning development is based on idea of personalized learning experiences, taking place through learning analytics, analysis, discovery, etc.
Details	"This article introduces a framework called Smart Competence Analytics in Learning (SCALE) that tracks finer-level learning experiences and translates them into opportunities for customized feedback, reflection, and regulation. The SCALE framework is implemented in four layers: the sensing layer, the analysis layer, the competence layer, and the visualization layer. … The SCALE framework has been designed for seamless integration with different types of learning-related artifacts such as the Moodle learning management system…The current SCALE system does not focus as much on the physical context of a student (e.g., classroom, instructor availability) as it does with the student's learning context (e.g., learners' background knowledge, learner motivation)…" [33]
Identified features	• Sensor technology • Smart learning/teaching analytics (big data analytics) systems • Smart data visualization technology • Adaptive programs of study—major and minor programs, concentration and certificate programs—with variable structures adaptable to types of students/learners, smart pedagogy, etc.
Smartness levels addressed	• Adaptation—of classroom model • Sensing—by technology specifically used for identification

References

1. KES International, Annual KES international conference on Smart Education and e-Learning (SEEL). http://seel-17.kesinternational.org/
2. International conference on Smart Learning Environments (ICSLE). http://www.iasle.net/index.php/icsle2017
3. Springer Open International Journal on Smart Learning Environments. https://slejournal.springeropen.com/
4. Chun, S.: Korea's smart education initiative and its pedagogical implications. CNU J. Educ. Stud. **34**(2), 1–18 (2013)
5. Chun, S. Lee, O.: Smart education society in South Korea. In: GELP Workshop on Building Future Learning Systems, Durban, South Africa (19–21, April 2015). http://gelpbrasil.com/wp-content/uploads/2015/05/smart_education_workshops_slides.pdf
6. Smarter education with IBM. https://www-935.ibm.com/services/multimedia/Framework_-_Smarter_Education_With_IBM.pdf
7. The Next-Generation Classroom: Smart, Interactive and Connected Learning (2012). http://www.samsung.com/es/business-images/resource/white-paper/2012/11/EBT15_1210_Samsung_Smart_School_WP-0.pdf
8. Tikhomirov, V., Dneprovskaya, N.: Development of strategy for smart University. In: 2015 Open Education Global International Conference, Banff, Canada (2015). 22–24, April
9. Hwang, G.J.: Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective. Smart Learning Environments—a Springer Open Journal, 1:4, Springer (2014)
10. IBM, Smart Education. https://www.ibm.com/smarterplanet/global/files/au__en_uk__cities__ibm_smarter_education_now.pdf
11. Coccoli, M., Guercio, A., Maresca, P., Stanganelli, L.: Smarter Universities: a vision for the fast changing digital era, J. Vis. Lang Comput **25**, 1003–1011, Elsevier (2014)
12. Kwok, L.F.: A vision for the development of i-campus, Smart Learning Environments—a Springer Open Journal, 2:2, Springer (2015)
13. Xiao, N.: Constructing smart campus based on the cloud computing platform and the internet of things. In: Proceedings of 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013), Atlantis Press, Paris, France, pp. 1576–1578 (2013)
14. Abueyalaman, E.S. et al.: Making a smart campus in Saudi Arabia. EDUCAUSE Q. **2**, 1012 (2008)
15. Adamko, A., Kadek, T., Kosa, M.: Intelligent and adaptive services for a smart campus visions, concepts and applications. In: Proceedings of 5th IEEE International Conference on Cognitive Infocommunications, 5–7 Nov. 2014. Vietri sul Mare, Italy, IEEE (2014)
16. Uskov, V.L., Bakken, J.P., Pandey, A.: The ontology of next generation smart classrooms. In: Proceedings of the 2nd International Conference on Smart Education and e-Learning SEEL-2016, 17–19 June 2015. Sorrento, Italy, Springer, pp. 1–11 (2015)
17. Huang, R., Hub, Y.,Yang, J., Xiao, G.: The functions of smart classroom in smart learning age. In: Proceedings of 20th International Conference on Computers in Education ICCE. Nanyang Technological University, Singapore (2012)
18. Pishva, D., Nishantha, G.G.D.: Smart classrooms for distance education and their adoption to multiple classroom architecture. J. Netw. **3**(5) (2008)
19. Gligorić, N., Uzelac, A., Krco, S.: Smart classroom: real-time feedback on lecture quality. In: Proceedings of 2012 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), pp. 391–394, 19–23 Mar. 2012. Lugano, Switzerland, IEEE (2012). doi:10.1109/PerComW.2012.6197517
20. Uskov, V.L, Bakken, J.P., Pandey, A., Singh, U., Yalamanchili, M., Penumatsa, A.: Smart University taxonomy: features, components, systems. In: Uskov, V.L., Howlett, R.J., Jain, L. C. (eds.) Smart Education and e-Learning 2016, Springer, pp. 3–14, June 2016, 643 p., ISBN: 978-3-319-39689-7 (2016)

21. Koper, R.: Conditions for effective smart learning environments, in Smart Learning Environments: a Springer Open Journal (2014)
22. Hwang, D. Smart approach to innovative education for 21st century. In: International Conference IITE-2014 "New Challenges for Pedagogy and Quality Education: MOOCs, Clouds and Mobiles" (2014)
23. Al Shimmary, M.K., Al Nayar, M.M., Kubba, A.R.: Designing smart University using RFID and WSN. In: Int. J. Comput. Appl. 34–39 (2015)
24. Khan, M.T., Zia, K.: Future context-aware pervasive learning environment: smart campus. In: Proceedings of International Conference on Information Technology in Science Education, Gazimagusa, Turkish Republic of Northern Cyprus (2007)
25. Stavropoulos, T., Tsioliaridou, A., Koutitas, G., Vrakas, D., Vlahavas, I.: System architecture for a smart University building. In: Diamantaras, K., Duch, W., Iliadis, L.S. (eds.) ICANN 2010, LNCS, vol. 6354, pp. 477–482. Springer, Heidelberg (2010)
26. Fan, J., Stewart, K.: An ontology-based framework for modeling movement on a smart campus. In: Analysis of Movement Data, GIScience Workshop, Vienna, Austria (2014)
27. Rehman, A., Abbasi, A.Z., Shaikh, Z.A.: Building a smart University using RFID Technology. In: Proceedings of IEEE International Conference on Computer Science and Software Engineering, vol. 5, pp. 641–644. IEEE (2008)
28. Jiang, C., Shi, Y., Xu, G., Xie, W.: Classroom in the era of ubiquitous computing smart classroom. In: Proceedings of IEEE International Conference on Wireles LANs and Home Networks, pp. 14–26. IEEE (2001)
29. Yau, S.S., Gupta, S.K.S., Karim, F., Ahamed, S.I., Wang, Y., Wang, B.: Smart classroom: enhancing collaborative learning using pervasive computer technology. In: Proceedings of 2003 Annual Conference of American Society for Engineering Education, pp. 1–9 (2003)
30. Salah, A.M., Lela, M., Al-Zubaidy, S.: Smart education environment system. In: GESJ: Computer Science and Telecommunications, pp. 21–26 (2014)
31. Nie, X.: Constructing smart campus based on the cloud computing platform and the internet of things. In: Proceedings of 2nd International Conference on Computer Science and Electronics Engineering (2013)
32. Zhou, W.: Exploration on security system structure of smart campus based on cloud computing. In: Proceedings of 3rd International Conference on Science and Social Research (2014)
33. Kumar, V., Boulanger, D., Seanosky, J., Kinshuk, Panneerselvam, K., Somasundaram, T.S. Competence analytics. J. Comput. Educ. 251–270 (2014)
34. Chen, C.L., Chang, Y.H., Chien, Y.T., Tijus, C., Chang, C.Y.: Incorporating a smart classroom 2.0 Speech-Driven PowerPoint System (SDPPT) into University Teaching, in Smart Learning Environments: a SpringerOpen Journal (2015)
35. Rogers, E.M.: Diffusion of Innovations, 5th edn, p. 221. The Free Press, New York, USA (2003)
36. Uskov, V.L., Bakken J.P., Karri, S., Uskov, A.V., Heinemann, C., Rachakonda, R.: Smart University: conceptual modeling and system design. In: Uskov, V., Bakken, J.P., Howlett, R., Jain, L. (eds.) Smart Universities. Springer (accepted for publication in 2017)
37. Murray, B.: A SWOT analysis of the teaching process of math and science at Worcester's North High School. https://web.wpi.edu/Pubs/E-project/Available/E-project-052711-122422/unrestricted/BMurray_North_SWOT_v2.pdf
38. Jha-Thakur, U., Fischer, T.B.: 25 Years of the UK EIA system: strengths, weaknesses, opportunities and threats, in environmental impact assessment review, pp. 19–26 (2016)
39. Yigit, A.S., Al-Ansary, M.D., Al-Najem, N.M.: SWOT analysis and strategic planning as an effective tool for improving engineering education at Kuwait University. https://pdfs.semanticscholar.org/275c/3b04f153059daeca4b01cae700bb23cd969e.pdf
40. Odeh, M., Warwick, K., Garcia-Perez, A.: The impacts of cloud computing adoption at Higher Education Institutions: a SWOT analysis. Int. J. Comput. Appl. **127**(4), 15–21 (2015)

41. Grcic, M., Picek, R.: Using SWOT analysis for defining strategies of mobile learning. In: Proceedings of 2013 International Conference on Systems, Control, Signal Processing and Informatics, pp. 307–312 (2013)
42. Kim, T., Cho, J.Y., Lee, B.G.: Evolution to smart learning in public education: a case study of Korean public education. In: Ley, T., Ruohonen, M., Laanpere, M., Tatnall, A. (eds.) Open and Social Technologies for Networked Learning, IFIP Advances in Information and Communication Technology, vol 395. Springer (2013)
43. Software Engineering Institute, Carnegie Mellon University. https://www.sei.cmu.edu/cmmi/
44. CMMI Institute. http://cmmiinstitute.com/
45. CMMI (Capability Maturity Model Integration). https://sultanalmasoud.files.wordpress.com/2014/05/cmmi-pyramid.gif

http://www.springer.com/978-3-319-59453-8

Smart Universities
Concepts, Systems, and Technologies
Uskov, V.; Bakken, J.P.; Howlett, R.J.; Jain, L.C. (Eds.)
2018, XXIII, 421 p. 91 illus., 37 illus. in color., Hardcover
ISBN: 978-3-319-59453-8