Chapter 3
Smart University: Conceptual Modeling and Systems' Design

Vladimir L. Uskov, Jeffrey P. Bakken, Srinivas Karri, Alexander V. Uskov, Colleen Heinemann and Rama Rachakonda

Abstract The development of Smart University concepts started just several years ago. Despite obvious progress in this area, the concepts and principles of this new trend are not clarified in full yet. This can be attributed to the obvious novelty of the concept and numerous types of smart systems, technologies and devices available to students, learners, faculty and academic institutions. This paper presents the outcomes of a research project aimed at conceptual modeling of smart universities as a system based on smartness levels of a smart system, smart classrooms, smart faculty, smart pedagogy, smart software and hardware systems, smart technology, smart curriculum, smart campus technologies and services, and other distinctive components. The ultimate goal of this ongoing research project is to develop smart university concepts and models, and identify the main distinctive features, components, technologies and systems of a smart university—those that go well beyond features, components and systems used in a traditional university with predominantly face-to-face classes and learning activities. This paper presents the up-to-date outcomes and findings of conceptual modeling of smart university.

Keywords Smart university · Smartness levels · Smart university components · Conceptual modeling · Software systems for a smart university

3.1 Introduction

The "smart university" (SmU) concept and several related concepts, such as smart classrooms [1–11], smart learning environments [12, 13], smart campus [14–17], smart education [18–23], and smart e-learning [22–24], were introduced just several

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

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

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years ago; they are in permanent evolution and improvement since that time. The introduced ideas and approaches to build SmU, as well as smart education (SmE), are rapidly gaining popularity among the leading universities in the world because modern, sophisticated high-tech-based smart technologies, systems, and devices create unique and unprecedented opportunities for academic and training organizations in terms of higher teaching standards and expected learning/training outcomes. "The analysts forecast the global smart education market to grow at a CAGR of 15.45% during the period 2016–2020" [25]. "Markets and Markets forecasts the global smart education and learning market to grow from $193.24 Billion in 2016 to $586.04 Billion in 2021, at a Compound Annual Growth Rate (CAGR) of 24.84%" [26].

3.1.1 Literature Review

To-date, most researchers are focused on perspectives of contemporary higher education and tendencies that correspond to the concepts of SmU and SmE. For example, the authors of [27–29] discuss various aspects of contemporary universities and their future perspectives in the context of applications of smart information and communication technologies (ICT) in education. On the other hand, the authors of [30] presented one of the first research studies on new opportunities for universities in the context of smart education.

The other significant part of research in SmE is focused on the problem of educational outcomes in the contemporary educational systems—smart learning environments (SLE). For example, the concept of outcomes-based education has been proposed and this approach can be regarded as a part of the SmE concept. The main part of obtained outcomes includes the studies of cognitive abilities, needs, skills, and their training through e-learning or, in general, to 21st century skills [31]. There are also resources available on instructional design and cognitive science, which consider the problem of learning, structuring material, communication, and forming cognitive competence in this group, for example [32].

Different attempts to make conceptual models of ICT infrastructure of SmU and smart e-learning systems are currently being actively researched; for example, the topics concerning smart e-learning standards, smart gadgets, and learning equipment are discussed [33]. Several research projects were aimed at organizational aspects of SmU, smart education such as organizational structure, educational trajectories, learning strategies, etc. These projects usually emphasize the fact that many aspects of contemporary education need new flexible organizational structures, which can be referred to as "smart" [30, 34].

The detailed literature review on existing approaches to build SmU is available in another chapter of this book, specifically in [35].

Despite the obvious progress in SmU area, the main concepts and conceptual models of smart universities are not clarified in full yet due to obvious uniqueness, innovativeness, and complexity of this research area.

3.1.2 Research Project Goal and Objectives

The performed analysis of above-mentioned and multiple additional publications and reports relevant to (1) smart universities, (2) university-wide smart software and hardware systems and technologies, (3) smart classrooms, 94) smart learning environments, and (5) smart educational systems, undoubtedly shows that SmU-related topics will be in the focus of multiple research, design, and development projects in the upcoming 5–10 years. It is expected that, in the near future, SmU concepts and hardware/software/technological solutions will start to play a significant role and be actively deployed and used by leading academic intuitions in the world.

Project Goal. The overall goal of this ongoing multi-aspect research project is to develop conceptual modeling of a smart university, i.e. to identify and classify SmU's main smart features, components, relations (links) between components, interfaces, inputs, outputs, and limits/constraints. The premise is that SmU conceptual modeling will (1) enable us to identify and predict the most effective software, hardware, pedagogy, teaching/learning activities, services, etc., for the next generation of a university—smart university—and (2) help traditional universities understand the strengths, weaknesses, opportunities, and threats of becoming a smart university and also identify and evaluate paths for a possible transformation from traditional university into a smart one.

Project Objectives. The objectives of this project were to identify SmU's main (1) smartness levels (or smart features), (2) components, and (3) specific software and hardware 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.

3.2 Smart University: Conceptual Modeling

3.2.1 Smartness University: Modeling of Smartness Levels

Based on our vision of SmU and up-to-date obtained research outcomes, we believe that SmU as a smart system should significantly emphasize, not only pioneering software/hardware features and innovative modern teaching/learning strategies, but also "smart" features of smart systems (Table 3.1) [36, 37]. Therefore, the designers of SmU should pay more attention to a maturity of smart features of SmU that may occur on various levels of SmU's smartness—smartness levels.

Several examples of SmU possible distinctive functions for every proposed SmU smartness level are presented in Table 3.2.

Table 3.1 Classification of smartness levels of a smart system [36, 37]

Smartness levels	Details
Adaptation	Ability to modify physical or behavioral characteristics to fit the environment or better survive in it
Sensing	Ability to identify, recognize, understand, and/or become aware of phenomenon, event, object, impact, etc.
Inferring	Ability to make logical conclusion(s) on the basis of raw data, processed information, observations, evidence, assumptions, rules, and logic reasoning
Learning	Ability to acquire new or modify existing knowledge, experience, behavior to improve performance, effectiveness, skills, etc.
Anticipation	Ability of thinking or reasoning to predict what is going to happen or what to do next
Self-organization and re-structuring (optimization)	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

Table 3.2 SmU distinctive features (that go well beyond features of a traditional university) [38]

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

(continued)

Table 3.2 (continued)

SmU smartness levels	Details	Possible examples (limited to 3)
		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
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 of student enrollment
		• University-wide Risk Management System (snow days, tornado, electricity outage, etc.)

(continued)

Table 3.2 (continued)

SmU smartness levels	Details	Possible examples (limited to 3)
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.

3.2.2 *Smartness University: Conceptual Model*

The proposed conceptual model of a SmU, labeled as *CM-SmU*, can be described as follows [40].

Definition 3.1 Smart University is described as *n*-tuple of n elements that can be chosen from the following main sets:

$$\begin{aligned} CM - SmU = <&\{\text{SmU\_FEATURES}\}, \{\text{SmU\_STAKEHOLDERS}\}, \\ &\{\text{SmU\_CURRICULA}\}, \{\text{SmU\_PEDAGOGY}\}, \\ &\{\text{SmU\_CLASSROOMS}\}, \\ &\{\text{SmU\_SOFTWARE}\}, \\ &\{\text{SmU\_HARDWARE}\}, \{\text{SmU\_TECHNOLOGY}\}, \\ &\{\text{SmU\_RESOURCES}\} > \end{aligned} \tag{3.1}$$

where:

SmU_FEATURES — a set of most important smart features of SmU, including adaptation, sensing, inferring, self-learning, anticipation, self-optimization or re-structuring;

SmU_STAKEHOLDERS — a set of SmU stakeholders; for example, it includes a subset of SmU faculty (instructors) at SmU, i.e. those who are trained and predominantly teach classes in smart classrooms and actively use smart boards, smart systems, smart technology, etc.,

SmU_CURRICULA	a set of smart programs of study and smart courses at SmU—those that can, for example, change (or optimize) its structure or mode of learning content delivery in accordance with given or identified requirements (due to various types of students or learners);
SmU_PEDAGOGY	a set of modern pedagogical styles (strategies) to be used at SmU;
SmU_CLASSROOMS	a set of smart classrooms, smart labs, smart departments and smart offices at SmU;
SmU_SOFTWARE	a set of university-wide distinctive smart software systems at SmU (i.e. those that go well beyond those used at a traditional university);
SmU_HARDWARE	a set of university-wide smart hardware systems, devices, equipment and smart technologies used at SmU (i.e. those that go well beyond those used at a traditional university);
SmU_TECHNOLOGY	a set of university-wide smart technologies to facilitate main functions and features of SmU;
SmU_RESOURCES	a set of various resources of SmU (financial, technological, human, etc.)

In general, SmUs may have multiple additional minor sets; however, for the purpose of this research project, we will limit a number of SmU most important sets as presented in (3.1).

3.2.3 *Smart University: Modeling Distinctive Components and Elements*

SmU may have numerous components of a traditional university; however, it must have multiple additional components to implement actively use and maintain SmU distinctive features that are described in Table 3.2. Based on our vision of SmU and outcomes of our research, the SmU main sets should include at least those set elements (or SmU distinctive sub-components) that are described in Table 3.3.

3.2.4 *Smart University: "Components and Features" Matrix*

The performed research enabled us to arrive with a very important outcome —"Smart University: Components and Smartness Levels" matrix (Fig. 3.1). This matrix clearly shows that there should be a one-to-one correspondence between a

Table 3.3 SmU main sets (components) and main distinctive sub-sets (sub-components) that go well beyond components of a traditional university

SmU sets (components)	Examples of SmU distinctive sub-components (that go well beyond those in a traditional university)
SmU_SOFTWARE	• Pre-class learning content development systems • In-class activities' recording systems • Post-class activities' supporting systems (for example, systems to replay automatically recorded lectures, in-class discussions, and activities; learning content management systems, post-class review, and discussion systems for both local and remote students, etc.) • Smart cameraman software systems to automatically record and synchronize various in-class activities • Systems for seamless collaborative learning (of both local and remote students) in smart classroom and sharing of learning content/notes/documents • Web-based audio/video conferencing systems for smooth one-to-one and many-to-many communication/collaboration/interaction between local/in-class and remote/online students/learners • Systems to host, join, form, and evaluate group discussions (including both local and remote students) • Repositories of digital learning content and online (Web) resources, learning portals, digital libraries on appropriate learning modules • Smart learning/teaching analytics (big data analytics) systems • Speech/voice recognition systems • Speech-to-text systems • Text-to-voice synthesis systems • Automatic translation systems (from/to English language) • Speaker/instructor tracking systems (in the classroom) • Gesture (activity) recognition systems • Face recognition systems • Emotion recognition systems • Context (situation) awareness systems (including location awareness, learning context awareness, security/safety awareness systems) • Intelligent cyber-physical systems (for safety and security) • Various smart software agents • Power/light/HVAC consumption monitoring system(s)
SmU_TECHNOLOGY	• Internet-of-Things technology • Cloud computing technology • Web-lecturing technology • Web-based collaborative and communication technologies • Ambient intelligence technology • Smart agents technology

(continued)

Table 3.3 (continued)

SmU sets (components)	Examples of SmU distinctive sub-components (that go well beyond those in a traditional university)
	• 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 and situation awareness technologies (indoor and outdoor) • Sensor technology (motion, temperature, light, humidity, etc.)
SmU_HARDWARE/ EQUIPMENT	• SMART boards and/or interactive white boards (at least 84" in size) • Ceiling-mounted projectors (in some cases, 3D projectors) • Smart panoramic video cameras (to web-tape all in-classroom activities) • Interconnected big screen monitors or TVs (to create an effect of "smart learning cave") • Interconnected laptops or desktop computers • Smart pointing devices • Voice controlled smart classroom hub (i.e., a central system to integrate and control various smart devices in a classroom) • Smart controlled and self-activated microphones • Smart speakers • Smart security video cameras • Smart classroom lock • Smart card readers • Biometrics-based access control devices (including face recognition devices) • Smart robotic controllers and actuators Smart thermostats • Smart switches
SmU_ CURRICULA	• Adaptive programs of study—major and minor programs, concentration and certificate programs—with variable structures that are adaptable to students/learners with different academic background, various components of smart pedagogy, including modes of learning content delivery, 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.

(continued)

Table 3.3 (continued)

SmU sets (components)	Examples of SmU distinctive sub-components (that go well beyond those in a traditional university)
SmU_STAKEHOLDERS	• SmU Local (in-classroom) students • SmU remote (online) students • SmU students with disabilities • SmU life-long learners • SmU faculty (full-timers and part-timers) • SmU professional staff • SmU administrators • SmU sponsors
SmU_PEDAGOGY (or, Smart Pedagogy)	Active utilization and, if needed, adaptable combination of the following innovative types of pedagogy (teaching/learning 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 approach • Smart robots (robotics) based learning
SmU_CLASSROOMS	• Smart classrooms that actively deploy various components of SmU_SOFTWARE, SmU_HARDWARE, SmU_TECHNOLOGY, SmU_PEDAGOGY sets (see above)
SmU_FEATURES	• Adaptation • Sensing (awareness) • Inferring (logical reasoning and analytics) • Self-learning • Anticipation • Self-optimization (re-structuring)

Smart University components	Smart University smartness levels					
	Adaptation	Sensing	Inferring	Self-learning	Anticipation	Self-optimization
SmU_SOFTWARE						
SmU_HARDWARE						
SmU_TECHNOLOGY						
SmU_CLASSROOMS						
SmU_PEDAGOGY						
SmU_CURRICULUM						
SmU_STAKEHOLDERS						
SmU_RESOURCES						

Fig. 3.1 "Smart University: Components and Features" matrix

particular SmU component and SmU smartness levels. The designers of SmU should clearly understand, for example, how to-be-deployed software systems will help SmU to

(1) adapt (for example, (a) to smoothly accommodate remote students or students with disabilities in a smart classroom, (b) to various modes of teaching, (c) to various types of learning content delivery and types of courses, etc.),
(2) sense (for example, (a) to get data about various activities or processes in a smart classroom or on smart campus, (b) to get data about student learning activities and academic performance, etc.),
(3) infer (i.e. process the obtained data, run learning analytics systems, and generate well-thought conclusions or recommendations based on big data analytics)
(4) self-learn (for example, to deploy innovative types of teaching and learning strategies or to offer classes on innovative topics that are in high demand in industry),
(5) anticipate (for example, to monitor as may areas on campus or inside buildings as possible, and predict and prevent any potentially bad events), and
(6) self-optimize (for example, to minimize consumption of electricity/heat in university classrooms and labs during night time and weekends, etc.).

Due to the limits of this chapter, it is impossible to provide details on all obtained research outcomes and findings regarding smart software systems, smart hardware, smart technology, and smart pedagogy; therefore, below we will focus on outcomes of detailed analysis of several important types of software systems for SmU.

3.3 Smart University: Software Systems' Design

Based on our vision of SmU, we believe that SmUs should deploy various types of distinctive software systems; a comprehensive list of corresponding software systems is presented in Table 3.3 above. As a part of this research project, for several most important classes of selected software systems to be deployed by SmU, the research team

(1) identified a list of desired functions (functionality) of those systems from SmU stakeholders' point of view;
(2) identified, downloaded, and analyzed approximately 10 to 20 existing software systems of designated type—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 or trial version, (c) installation and testing of actual system, and d) review of user and analysts' feedback;
(3) identified a list of main functions of system of designated type—i.e., functions to be beneficial for SmU stakeholders, and
(4) evaluated and ranked those systems.

A brief summary of our research outcomes for selected classes of software systems for SmUs is presented in multiple tables below, including

(1) pre-class learning content development systems for SmU (Tables 3.4, 3.5, 3.6 and 3.7);
(2) in-class activities recording systems for SmU (Tables 3.8, 3.9, 3.10 and 11);
(3) post-class activities' supporting systems for SmU (Tables 3.12, 3.13, 3.14 and 3.15);

Table 3.4 Pre-class learning content development systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Screen capturing	Allows instructors to record dynamic and static visuals from computer screen
2	Audio capturing	Allows instructors to record sound, narrations for videos, VoIP calls, music, and audio that comes from the other applications on computer
3	Capturing from Webcam	Allows computer's webcam to record instructor while he/she teaches class or makes a video
4	Capturing streaming files	Allows to record streaming video and audio files onto a computer
5	Schedule recording	Allows instructor to set a time and date for an application to automatically record what's happening on computer screen (that possibly displays video from other connected resources)
6	Capturing from mobile device	Allows instructor to connect a smart phone or other mobile device to a desktop computer and record what is displayed on smart phone's screen
7	Zoom&pan	Ability to zoom in on a portion of computer screen helps an audience to focus on specific fragments of displayed learning content and better understand it; the pan effect allows instructor to smoothly move from one part of computer screen to the other one
8	Add media	Allows instructor to import video, sound, and image files from a computer into learning content files
9	Adjust audio	Supports fine-tuning of audio files
10	Add titles	Allows instructor to add title information to the beginning and/or end of video files
11	Add annotations	Add text comments and remarks to various recordings (a note: annotations are very useful for augmenting videos with additional useful information or comments that usually are not covered in the audio portion of a video)
12	Split/join video and audio files	Allows user to trim/eliminate unwanted (or low quality) video and audio fragments away from existing audio/video files and insert, if needed, other parts into final recording files

Table 3.5 Pre-class learning content development systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform(s)	Ref. #
Commercial systems				
1	Camtasia Studio	Techsmith	Windows/Mac	[42]
2	Adobe Presenter 11	Adobe	Windows/Mac	[43]
3	Movavi screen capture studio V7.3.0	Movavi	Windows/Mac	[44]
4	SmartPixel	SmartPixel	Windows/Mac/Android	[45]
5	Snagit 13	Techsmith	Windows/Mac	[46]
6	Screenpresso PRO	ScreenPresso	Windows	[47]
7	Bandicam	Bandisoft	Windows/Mac	[48]
8	Debut video capture software	NCH Software	Windows/Mac	[49]
9	CamVerce 1.95	Support	Windows	[50]
10	Replay Video Capture 8	Applian technologies	Windows	[51]
11	WM Recorder Bundle	WM Recorder	Windows	[52]
12	Adobe Captivate 9	Adobe	Windows/Mac	[53]
Open source (free) systems				
1	CamStudio	Cam Studio	Windows	[54]
2	Ezvid screen recorder	Ezvid	Windows	[55]
3	Screencast-O-Matic	Screen cast Matic	Windows/Mac	[56]
4	ActivePresenter	Atomi	Windows	[57]
5	Jing	Techsmith	Windows	[58]
6	Webinaria	Webinaria	Windows	[59]
7	Rylstim	SketchMan Studio	Windows	[60]
8	IceCream screen recorder	IceCream Apps	Windows/Mac	[61]
9	Flash back Express Recorder	BlueBerry Software	Windows	[62]
10	Screen Video Recorder	DVDVideo Soft	Windows	[63]

(4) Web-based audio- and video-conferencing systems for SmU (Tables 3.16, 3.17, 3.18 and 3.19);
(5) collaborative learning systems for SmU (Tables 3.20, 3.21, 3.22 and 3.23);
(6) context awareness systems for SmU (Tables 3.24, 3.25, 3.26 and 3.27).

Additionally, a summary of our research outcomes and findings for software systems, which are focused on students with disabilities at SmU, is presented in [41]. Those software systems include (a) voice-to-text (voice recognition) systems, (b) text-to-voice (voice synthesis) systems, and (c) gesture and motion recognition systems.

3.3.1 Smartness University: Pre-class Learning Content Development Systems

A brief summary of our research outcomes for pre-class learning content development systems for SmU is presented in Tables 3.4, 3.5, 3.6 and 3.7.

3.3.2 In-class Activities Recording Systems

A brief summary of our research outcomes for in-class activities recording systems for SmU is presented in Tables 3.8, 3.9, 3.10 and 3.11.

3.3.3 Post-class Activities' Supporting Systems

A brief summary of our research outcomes for post-class activities' supporting systems for SmU is presented in Tables 3.12, 3.13, 3.14 and 3.15.

Table 3.6 Pre-class learning content development systems for smart university: A list of most important features in existing systems

#	Desired system's feature	Details
1	Recording from desktop resources	Allows to record a video of what's happening on your computer screen
2	Recording of streaming audio	Allows to record video and audio streams as they come onto a computer
3	Scheduled recording	Ability to set a time and date for an application to automatically record what's happening on computer screen
4	Cropping and splice	Allows instructor to crop the unwanted or extra portions from a recording
5	Convert audio files	Allows to convert audio files into MP3, WMA, WAV formats
6	Watermarks and titles	Allows instructor to add a title information to the beginning or end of video and audio files
7	Split/join video and audio files	Allows instructor to trim unwanted portions away and insert other elements into video and audio files
8	Cursor effects	Selecting important information and highlighting it in recordings
9	Take screenshot	Capability to create screenshot images
10	Clean-up audio	Ability to fine-tune the audio portion of recording; users can alter features like volume, pitch, and reduce background noise
11	User forums	Provides students with a platform to discuss learning topics
12	Zoom in	Ability to zoom in on a portion of your screen helps your audience focus on and better understand your message.
13	Resize graphics	Ability to resize recorded video/graphics to fit window user is viewing in

Table 3.7 Pre-class learning content development systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref. #
Commercial systems				
1	Camtasia Studio	Windows/Mac	$179 yr/$75 yr	[42]
2	Adobe Presenter 11	Windows/Mac	$149/yr	[43]
3	Movavi screen capture studio V7.3.0	Windows/Mac	$49.95 per copy	[44]
Open source (free) systems				
1	Screencast-O-Matic	Windows/Mac	Open Source	[56]
2	CamStudio	Windows	Open Source	[54]
3	Ezvid screen recorder	Windows	Open Source	[55]

Note Several co-authors developed (as a part of major NSF grants in 1999-2004) and actively used their own Web-lecturing system from 2001 to 2016—the InterLabs system; the examples of developed online learning content are available at http://www.interlabs.bradley.edu/cis573/. In this case, the Microsoft Internet Explorer web browser should be used to watch pre-recorded video lectures because the InterLabs system is based on Microsoft Media player and codecs. However, as a tangible result of this research project, the same co-authors switched to a very useful and multi-functional Screen-O-Matic system. Particularly, it significantly helps to create pre-class learning content and easily post it on YouTube to avoid any potential problems due to various technical platforms (devices) used by users (students, faculty, or learners) of developed learning content

Table 3.8 In-class activities recording systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Screen recording	Ability to capture the contents on computer screen like videos, PPT slides, animations, computer simulations, etc.
2	Live webcasting	Ability to webcast (over the Internet) classes online to remote students
3	Multi camera video	Video should be recorded and presented by multiple video cameras (views)
4	Mobile streaming	Allows faculty to broadcast live video from various mobile devices
5	Capturing of in-classroom activities	All activities (teaching, discussions, presentations, etc.) in a classroom should be captured and stored (for possible after class re-play) to provide "presence-in-classroom" effect (feeling) to remote students
6	Customization	Faculty should have an opportunity to create and edit customized instructional content
7	Sensing and automated recording	Ability to sense various activities inside a smart classroom and start recording automatically
8	Video recording management	Ability to capture video from different angles should be taken and maintained properly
9	Scheduling and automation	Basic and general-purpose activities in a smart classroom should be scheduled and/or automated (for example, an identification and registration of all in-class and remote students, automatic turn-on and set-up of all needed equipment in a smart classroom in accordance with profiles of a specific instructor or particular class, etc.)
10	Media board	Facilitates remote students to smoothly interact with local classroom

Table 3.9 In-class activities recording systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform(s)	Ref. #
Commercial systems				
1	Panopto	Panopto	Windows/Mac/Linux	[64]
2	Echo360 Lecture Capture	Echo360, Inc.	Windows	[65]
3	Mediasite	Sonic Foundry Inc.	Windows/Mac/Linux	[66]
4	Camtasia	TechSmith	Windows/Mac	[67]
5	Valt Software	Intelligent Video Solutions	Windows/Mac	[68]
6	Yuja Lecture Capture/Room Webcasting	YuJa Active Learning	Windows	[69]
7	Lecture Recording System	Beegeesindia	Windows	[70]
8	VIDIZMO	VIDIZMO	Windows/Mac	[71]
9	GALICASTER VIDEO PLATFORM	TELTEK	Windows	[72]
10	Adobe Presenter 11	Adobe	Windows/Mac	[73]
Open source (free) systems				
1	Opencast Matterhorn	Matterhorn	Windows/Mac	[74]
2	Kaltura	Kaltura	Windows	[75]
3	Class X	Classx	Linux	[76]
4	CamStudio	RenderSoft	Windows	[77]
5	Audionote	AudioNote	Android/Windows/Mac	[78]
6	Lecture Recordings, Lecture Notes	Everyone	Android/Windows/Mac	[79]
7	Super Notes	SuperNote	Android/Windows/Mac	[80]
8	SameView	Publication	Windows	[81]
9	INKredible	Viet Tran	Windows/IOS/Android	[82]
10	Squid	Steadfast Innovation, LLC	Windows/IOS/Android	[83]

3.3.4 Web-Based Audio- and Video-Conferencing Systems

A brief summary of our research outcomes for Web-based audio and video-conferencing systems for SmU is presented in Tables 3.16, 3.17, 3.18 and 3.19.

3.3.5 Collaborative Learning Systems for Smart University

A brief summary of our research outcomes for collaborative learning systems for SmU is presented in Tables 3.20, 3.21, 3.22 and 3.23.

Table 3.10 In-class activities recording systems for smart university: A list of most important features in existing systems

#	Desired system's feature	Details
1	Video capturing	Video of faculty is captured from different angles
2	Computer screen recording	Ability to capture the contents on computer screen like videos, PPT presentations, graphics, diagrams, photos, etc.
3	Download and publish recordings	The recorded learning content can be downloaded from or published into a repository of files with various components of learning content
4	Multi-point capture	Shows both presentation and presenter by capturing video, audio, and screen (or SMART board) in a smart classroom
5	Live streaming/Webcasting	Sessions can be made live/online to remote students
6	Voice narration	Ability to detect and record the voice of presenting or talking person
7	Capture keyboard input	Allows students to see what the professor is typing on keyboard of his/her laptop or desktop computer in smart classroom
8	Easy sharing	Recordings should be automatically be added to repository of files
9	Mobile streaming	Allow users to broadcast videos from their mobile devices onto main desktop computer in smart classroom
10	Video management	Manage camera and recording settings, view multiple camera feeds, and set alerts for tampering and motion detection
11	Watch anywhere	Plays files directly from browser on any technical platform and device like mobile, tablet, laptop, etc.
12	Media board	Allows remote students to smoothly interact with in-classroom students
13	Automated recording	Ability to sense various activities inside a smart classroom and start recording automatically
14	Remainders/alerts	Alerts are given to the students/faculty/learners before class starts
15	Presentation recording	Ability to record presentations by instructor (audio + video + PPT slides + computer simulations and other components)

3.3.6 Context Awareness Systems for Smart University

In the general case, there may be multiple types of context awareness systems to be used by SmU; they primarily deal with user's awareness of (a) learning environment, (b) learning process, (c) location on campus or inside a building, (d) safety or security inside a building or on campus, etc. As a result, it is almost impossible to integrate all types of desired user "awareness" in one system. However, below we provide (a) a united list of most desired features for learning/environment/location/safety-related context awareness systems for SmU and (b) lists of identified systems that cover various components or fragments of learning/environment/ location/safety-related awareness.

Table 3.11 In-class activities recording systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref. #
Commercial systems				
1	Panopto	Windows/Mac/Linux	SaaS, per user $50	[64]
2	Echo360 Lecture Capture	Windows	$400 per classroom or $15 per student	[65]
3	Mediasite	Windows/Mac/Linux	$20,000 (for department CS)	[66]
Open source (free) systems				
1	Opencast Matterhorn	Windows/Mac	Open Source	[74]
2	Class X	Linux	Open Source	[75]
3	Kaltura	Windows	Open Source	[76]

Note Bradley University (Peoria, IL, U.S.A.) equipped 11 smart classrooms between 2014 and 2017. The Panopto system has been purchased, installed, and is actively used in 11 smart classrooms at Bradley to record all in-classroom activities

3.4 Towards a Smart University: Developed Components at Bradley University (Examples)

Bradley University (Peoria, IL, U.S.A.) is actively involved in research and development of SmU conceptual models, strategies, smart learning environments, smart classrooms, smart software and hardware systems, etc. in order to move from a traditional university model towards a well-thought and well-discussed smart university model. Several Bradley University pioneering initiatives in the area of design and development of smart classrooms are presented below.

Smart classrooms built (2014–2015, Westlake 316 project). From 2014 to 2016, Bradley University contracted the Crestron company (http://www.crestron.com) to set up top-quality multimedia Web-lecturing and capturing equipment for eleven (11) smart classrooms with different software/hardware configurations and set ups from a generic set of equipment for smart classroom (Fig. 3.2). For example, a smart classroom in room 316A in Westlake Hall of Bradley University is equipped with a) 84" smart board (with smart board projector), (2) HD Pro video camera and corresponding Capture HD software, (3) instructor's console with a smart control unit, (4) ceiling-mounted projector, (5) ceiling mounted microphones, (6) document camera, (7) speakers., and (8) Ponopto software system for recordings all in-classroom activities, etc.

Smart classroom of the 2nd generation (2017, Bradley 160 project). In 2017, Bradley University and, specifically, the College of Liberal Arts and Sciences (LAS), designed and developed a smart classroom of a new generation [11]—it is

Table 3.12 Post-class activities supporting systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Video Webcasting	Allows instructors to webcast recorded class activities to students
2	Quizzes and polls	Allows instructors to quickly create quizzes and polls and assign it to a class or individual student within class
3	Mobile streaming	Allows instructors to broadcast live video from mobile devices; in this case, students can access those files using their mobile devices
4	Media uploading	Allows instructors to upload different media content
5	Interactive distance learning	Facilitates interactive (i.e., with active 2-way communication) online instructions and/or audio/video conferencing
6	Secure learning assignment submission	Allows instructors to post learning assignments on course web site; allows students to securely submit learning assignments
7	Automatic publishing	Allows instructor to easy publish various course components and learning content (recorded lectures, assignments, grades, notes, announcements, etc.) on course web site
8	Video streams' management	Allows instructor to manage camera and recording settings, view multiple camera feeds, and set alerts for tampering and motion detection
9	Scheduling and automation	Common learning activities can be scheduled and/or automated
10	Discussion threads	Allows students and instructors to discuss various after a class
11	Remainders/alerts	Facilitates students with remainders and/or alerts about the assignments
12	Post-editing	Allows instructor to edit files with recorded class activities
13	Inside-video search	Allows students to search inside the posted videos when needed

considered Phase# 1 (Sep 1, 2016—Feb 1, 2017) of the to-be-developed Center of Smart Education at LAS College and Bradley University in room 160 of Bradley Hall at Bradley University—the so-called Bradley 160 project (Fig. 3.3).

As of February 1, 2017, it is equipped with (1) a new type of SMART board—SMART Board 84—that actually works as a very big tablet with 84-inch touchable screen (the market cost is about $12,000); (2) twenty one (21) DELL 7459 AIO computers with built-in 3D video cameras and microphones (the market cost is about $1,100 per unit); each computer may serve as both desktop computer as well as flat 24" tablet with touchable screen; (3) ceiling-mounted projectors (market cost is about $1,000), (4) at least three (as of March 2017) 55" big screen TVs (market cost is about $750) for virtual presence in a classroom and communication/

Table 3.13 Post-class activities supporting systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform (s)	Ref. #
Commercial systems				
1	Panopto	Panopto	Windows/Mac/Linux	[64]
2	Echo360 Lecture Capture	Echo360, Inc.	Windows	[65]
3	Tegrity	McGraw Hill Education	Android/Windows/Mac/IOS	[84]
4	Camtasia	TechSmith	Windows/Mac	[67]
5	Adobe Presenter 11	Adobe	Windows/Mac	[73]
6	Corel Video Studio Pro X9.5	Corel	Windows/Mac	[85]
7	Power Director 15	Cyber link	Windows/Mac/Linux	[86]
8	Yuja Lecture Capture/Room Webcasting	YuJa Active Learning	Windows	[87]
9	Mediasite Lecture Capture	SonicFoundry	Windows/Mac/Linux	[88]
10	Mediatech Custom Classroom	Gomediatech	Windows	[89]
Open source (free) systems				
1	Sakai	SakaiProject	Windows	[90]
2	Moodle	Moodle	Windows/Mac	[91]
3	ATutor LMS	Atutor	Windows/Mac	[92]
4	CamStudio	RenderSoft	Windows	[93]
5	RCampus	Rcampus	Windows	[94]
6	Learnopia	Learnopia	Windows	[95]
7	Claroline	claroline	Windows	[96]
8	VideoPad Video Editor	NCH software	Windows/Mac	[97]
9	Jing	Techsmith	Windows	[98]
10	VSDC Free Video Editor	Videosoft	Windows	[99]

collaboration with remote/online students, (5) multiple video cameras, (6) speakers, (7) three students collaboration areas (big tables with chairs that are close to big screen TVs), and other electronics.

Support of research in Smart University area (Bradley grant REC # 1326809). In 2015, Bradley University OSP awarded one of the co-authors with a grant to support research, design, and develop conceptual models of a smart university, identify suitable software and hardware systems, smart technology, smart pedagogy, etc., in order to identify and investigate multiple aspects of Bradley University transition from a traditional university towards a smart university. A summary of up-to-date research outcomes and findings are already available in various publications by members of research team [11, 22, 23, 37, 38, 39, 40, and

Table 3.14 Post-class activities supporting systems for smart university: A list of most important features in existing systems

#	Desired system's feature	Details
1	Integrated quizzes and polls	Strengthens two-way communication and builds engagement with the system
2	Inside-video search	Provides search of the content of video lectures by automatically transcribing words used in the lecturer's visual aids
3	Digital notes and bookmarks	Facilitates student to type their notes directly into files on his/her computer or tablet
4	Record videos anywhere	Provides access to all uploaded and shared screen captures and recorded videos from anywhere on the Web
5	Secure assignment submission	Facilities for submission of assignments, their subsequent testing and marking, and the provision of feedback on assignments to students
6	Interactive distance learning	Supports regular and substantive interaction between the students and the instructor, either synchronously or asynchronously, as well as student-to-student interaction
7	Mobile streaming	Allows users to broadcast live video from their mobile devices with the touch of a button
8	Media uploading	Allows instructors to upload content produced by their institutions, researchers and even students, regardless of what tools were originally capture this content
9	Video editor	Allows instructor to edit videos after recorded and posted
10	Session management	Helps with management of learning or discussion session
11	Chat	Facilitates students to chat online
12	Multipoint capture	Allows system to capture multiple views from instructor's screen
13	Pause recording	Allows instructor to pause a recording of lectures or class activities
14	Broadcast class live	Facilitates instructors to Web-cast classes live (in real time)

Table 3.15 Post-class activities supporting systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref. #
Commercial systems				
1	Panopto	Windows/Mac/Linux	SaaS, per user $50	[64]
2	Echo360 Lecture Capture	Windows	$400 per classroom or $15 per student	[65]
3	Tegrity	Android/Mac/Windows/IOS	Need Based	[84]
Open source (free) systems				
1	Sakai	Windows/Mac	Open Source	[90]
2	Moodle	Windows/Mac	Open Source	[91]
3	ATutor LMS	Windows/Mac	Open Source	[92]

Note Bradley University (Peoria, IL) actively uses the Sakai learning management system and the Panopto system for various post-class activities. On the other hand, some online programs on Bradley campus actively use the Pearson Embanet system for full-scale online teaching and online program management

Table 3.16 Web-based audio- and video-conferencing systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Recording	Allows users to record video and/or audio conference and review it when needed
2	Chat/text	Allows students and faculty to chat or send instant textual messages
3	Voice calling	Allows users to make voice calls to other users available online
4	Video conferencing	Allows users to make video calls to others online users using the Internet
5	Web casting	Allows live stream video meetings on different media and/or record them for post-editing
6	Mobility	Facilitates conversations to be synchronized across various technical platforms such as make or receive voice or video calls over Wi-Fi with devices that use iOS and Android operating systems
7	Screen sharing	Facilitates faculty and students to share their desktop screen with each other and other students (usually, this feature is controlled by an instructor)
8	File sharing	Allows faculty to share different files with students
9	Group conversations	Facilitates creation of various student groups, a single group calling to multiple selected students at a time, and sharing information between them
10	Drawing tools	Facilitates user to make notes or mark certain fragments on computer screens and videos to highlight certain things on screen or video

41]. As a result, Bradley University installed a well-recognized national and international profiles in the areas of Smart Education, Smart e-Learning, Smart Classrooms and Smart University.

As an integral part of this research-focused grant, during Phase # 2 of this project (Feb 1–May 15, 2017), the Center for Smart Education will be additionally equipped with multiple identified, analyzed and tested software systems for smart education (as described above) and corresponding smart devices.

Additionally, a special emphasis in this research project is given to installation, analysis and testing of software systems to support students with disabilities in the Center of Smart Education [39, 41].

3.5 Conclusions. Future Steps

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,

Table 3.17 Web-based audio- and video-conferencing systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform(s)	Ref. #
Commercial systems				
1	Cisco Webex	Cisco	Windows/Mac/Linux	[99]
2	Go to Meeting	Citrix	Windows/Mac	[100]
3	ClickMeeting	ClickMeeting	Windows/Mac	[101]
4	Readytalk	ReadyTalk	Windows/Mac	[102]
5	BigMarker	BigMarker	Windows/Mac	[103]
6	Adobe connect	Adobe	Windows/Mac/Linux	[104]
7	Onstream meeting	OnStream	Windows/Mac	[105]
8	Blackboard collaborate	Blackboard	Windows/Mac	[106]
9	Ring Central	RingCentral	Windows/Mac/Linux	[107]
10	GlobalMeet	PGI	Windows/Mac	[108]
Open source (free) systems				
1	Google Hangouts	Google	Windows/Mac	[109]
2	Skype	Microsoft	Windows/Mac	[110]
3	BigBlueButton	BigBlueButton	GNU/Linux	[111]
4	Meeting Burner	MeetingBurner	Windows/Mac	[112]
5	Join.me	Join me	Windows/Mac	[113]
6	Team viewer	TeamViewer	Windows/Mac	[114]
7	Zoom	Zoom	Windows/Mac	[115]
8	Zoho Meeting	Zoho	Windows/Mac	[116]
9	Mikogo	Mikogo	Windows/Mac	[117]
10	Yugma	Yugma	Windows/Mac/Linux	[118]

technologies, systems, and pedagogy will be essential parts of multiple research, design, and development projects in upcoming years.

(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 (Table 3.1) 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 3.2.

(3) It is necessary to create a taxonomy of a smart university, i.e. to identify and classify SmU main (a) features, (b) components (smart classrooms, technological resources—systems and technologies, human resources, financial resources, services, etc.), (c) relations (links) between components, (d) interfaces, (e) inputs and outputs, and (f) limits/constraints. The premise will (a) enable SmU designers and developers to identify and predict most effective software, hardware, pedagogy, teaching/learning activities, services, etc., for the next generation of a university—smart university—and (b) help traditional

Table 3.18 Web-based audio- and video-conferencing systems for smart university: A list of most important features in existing systems

#	System's feature	Details
1	Accessibility	Easy (and intuitive) use of a system by students and faculty
2	Flexibility	Provides support (mobile applications) to various mobile communication devices –smartphones, tablets, etc. for secure and reliable business and personal communication
3	Call management	Allows user to maintain and manage calls
4	Instant messaging	Allows students and faculty to chat or send instant textual messages
5	Voice calling	Allows users to make voice calls to other online users
6	Video conferencing	Allows users to make video calls to others online users using the Internet
7	Web casting	Allows live stream video meetings on different media and/or record them for post-editing
8	Cross Platform	Facilitates conversations to sync across the devices make or receive voice or video calls over Wi-Fi with iOS and android.
9	Screen sharing	Facilitates faculty and students to share their desktop screen with each other and other students (usually, this feature is controlled by an instructor)
10	File sharing	Allows faculty to share different files with students
11	Group conversations	Facilitates creation of various student groups, a single group calling to multiple selected students at a time, and sharing information between them
12	Drawing tools	Facilitates user to make notes or mark certain fragments on computer screens and videos to highlight certain things on screen or video
13	Zoom and annotate	Zoom in on what is being shared and annotate your application or slideshow
14	Multiple monitor support	Presenters can switch between multiple monitors during a meeting; typically, the presenter will set up a specific monitor to use for desktop sharing

Table 3.19 Web-based audio- and video-conferencing systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref.#
Commercial systems				
1	Cisco Webex	Windows/Mac/Linux	$19/month Annually	[99]
2	Go To Meeting	Windows/Mac	$19/month Annually	[100]
3	ClickMeeting	Windows/Mac	$25/month Annually	[101]
Open source (free) systems				
1	Google Hangouts	Windows/Mac	Open Source	[109]
2	Skype	Windows/Mac	Open Source	[110]
3	BigBlueButton	GNU/Linux	Open Source	[111]

Table 3.20 Collaborative learning systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Web-based meetings at any time	Allows students/learners/faculty at different locations to work as a virtual group of project members, have online meetings/discussions, and share content or documents in real time over the Internet
2	Shared whiteboard space	Allows in-class and remote students and faculty to work together in real time over the Internet and communicate each other's thoughts and ideas and share content (using special or smart boards or tables)
3	Active online discussions and communications	Students can openly discuss and share their thoughts with their group of students, project team members or everyone in the class
4	File uploading and sharing	Faculty, students, learners, and tutors can upload different files related to student groups' activities and course learning content and share them online with a group or all classmates
5	Problem-based learning	Team-based working on student project improves student engagement and retention of learning content
6	Group calling and communication	Student group leader or moderator or tutor can call a group virtual meeting and talk to a particular group of students/learners (probably course project team members) online using various available Web-based communication tools
7	Chat/group chat	Student can talk to other student or a group of students and share ideas/thoughts/docs
8	Annotation of readings	Allows students to add notes for clarity of understanding and visually communicate thoughts/ideas/questions to other members in student group or project
9	Scheduling	Student group leader or moderator or tutor can schedule various events/meetings/sessions with various groups of students
10	Customizing content and docs to be discussed	Student group leader or moderator or tutor should be able to customize the content for a group or individual advising session as needed per each student group or individual student
11	Recording of collaborative learning sessions	All audio/video collaborative learning sessions should be recorded for possible re-play (if needed later by student group members)
12	Screen capturing	Student group leader or moderator or tutor should be able to capture all activities/processes/graphics on group's main (shared) computer screen or smart board, record, store and re-play them (if needed); it is especially important feature for "brain storming" types of collaborative group-base meetings or sessions when student bring/write ideas onto Web-based virtual "table/desk"
13	Assignments/quizzes and review/grading reports	Student group leader or moderator or tutor should be able to create assignments for various groups of students, and provide those groups with review/grading outcomes (like grading reports)

(continued)

Table 3.20 (continued)

#	Desired system's feature	Details
14	Notifications	Students should be notified about a scheduled or new upcoming event or activity
15	Reports	Ability to generate automatically various types of reports on student group activities or individual student academic performance (attendance of virtual group meetings, time spent on virtual discussions, time spent on completing test or quiz, number of attended virtual group meetings per week, etc.)

Table 3.21 Collaborative learning systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform(s)	Ref. #
Commercial systems				
1	Basecamp	Basecamp	Windows, Mac, Linux	[119]
2	Yammer	Yammer, Microsoft	Windows, Android, IOS	[120]
3	Blackboard	Blackboard	Windows, Mac	[121]
4	Haikyulearning	Haikyu	Windows, Mac, Android	[122]
5	OpenText FirstClass	OpenText	Windows, Mac, Linux	[123]
6	LiveText	LiveText	Windows, Mac, Linux	[124]
7	Yugma	YSL	Windows, Mac, Linux	[125]
8	Twiddla	Twiddla	Windows, Mac	[126]
9	Mindmeister	Mindmeister	Windows, Mac	[127]
10	Mikogo	mikogo.com	Windows, Mac, Linux	[128]
Open source (free) systems				
1	Edmodo	edmodo.com	Windows/Mac	[129]
2	Wikispaces	Tangient LLC	Windows, Mac	[130]
3	Wiggio	Wiggio	Windows/Mac	[131]
4	Skype, Outlook	Microsoft	Cross platform	[132]
5	Connect	McGraw-Hill Education	Windows, Mac	[133]
6	Sloodle	Sloodle	Windows, Mac	[134]
7	Google Drive, Hangouts	Google	Cross platform	[135]
8	Web Poster Wizard	ALTEC		[136]
9	OpenStudy	OpenStudy	Windows, Mac	[137]
10	Oovoo	Oovoo LLC	Windows, Mac, Android	[138]

universities to understand, identify, and evaluate paths for a transformation into a smart university. The proposed and developed conceptual modes of SmU are presented in Sect. 3.2 above.

(4) Based on our vision of SmU and outcomes of our research, SmU may have multiple components of a traditional university; however, it must have

Table 3.22 Collaborative learning systems for smart university: A list of most important features in existing systems

#	System's feature	Details
1	Web-based meetings at any time	Allows students/learners/faculty at different locations to work as a virtual group of project members, have online meetings/discussions, and share content or documents in real time over the Internet
2	Shared whiteboard space	Allows in-class and remote students and faculty to work together in real time over the Internet and communicate each other's thoughts and ideas and share content (using special or smart boards or tables)
3	Active online discussions and communications	Students can openly discuss and share their thoughts with their group of students, project team members, or everyone in the class
4	File uploading and sharing	Faculty, students, learners, and tutors can upload different files related to student groups' activities and course learning content and share them online with a group or all classmates
5	Chat/group chat	Student can talk to other student or a group of students and share ideas/thoughts/docs
6	Annotation of readings	Allows students to add notes for clarity of understanding and visually communicate thoughts/ideas/questions to other members in student group or project
7	Scheduling	Student group leader or moderator or tutor can schedule various events/meetings/sessions with various groups of students
8	Customizing content and docs to be discussed	Student group leader or moderator or tutor can to customize the content for a group or individual advising session as needed per each student group or individual student
9	Recording of collaborative learning sessions	All audio/video collaborative learning sessions should be recorded for possible re-play (if needed later by student group members)
10	Screen capturing	Student group leader or moderator or tutor should be able to capture all activities/processes/graphics on group's main (shared) computer screen or smart board, record, store and re-play them (if needed); it is especially important feature for "brain storming" types of collaborative group-base meetings or sessions when student bring/write ideas onto Web-based virtual "table/desk"
11	Notifications	Students should be notified about a scheduled or new upcoming event or activity
12	Reports	Ability to generate automatically various types of reports on student group activities or individual student academic performance (attendance of virtual group meetings, time spent on virtual discussions, time spent on completing test or quiz, number of attended virtual group meetings per week, etc.

(continued)

Table 3.22 (continued)

#	System's feature	Details
13	Search	User should be able to search and find a specific item in the system
14	Assignments/quizzes and review/grading reports	Student group leader or moderator or tutor should be able to create assignments for various groups of students, and provide those groups with review/grading outcomes (like grading reports)
15	Group calling and communication	Student group leader or moderator or tutor can call a group virtual meeting and talk to a particular group of students/learners (probably course project team members) online using various available Web-based communication tools
17	Flexibility of software	Easy to understand and use by students software tools inside the system; easy access to registered students or group of students at any time and from anywhere
18	Interactive collaborative lessons	Highly interactive group meetings and/or sessions with 2-way high quality and reliable audio/video/communication to increase students engagement into collaborative learning and brain storming (research) activities
19	Monitoring and trackability	Instructor/group leader/mentor/tutor is able to easy monitor and track student group's activities, progress in a particular project or task, and also individual student's involvement and progress in a specific task or project or assignment

Table 3.23 Collaborative learning systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref. #
Commercial systems				
1	Basecamp	Windows, Mac, Linux	$29 per month	[119]
2	Yammer	Windows, Android, IOS	$12.50 per month/user	[120]
3	Blackboard	Windows, Mac	N/A (need based)	[121]
Open source (free) systems				
1	Edmodo	Windows, Mac	Open Source	[129]
2	Wikispaces	Windows, Mac	Open Source	[130]
3	Wiggio	Windows, Mac	Open Source	[131]

numerous additional components to support and maintain SmU distinctive features—a summary of our research outcomes is presented in Table 3.3 above.

(5) One of the most distinctive features of SmU will be multiple software systems that are usually not used by a traditional university. The obtained research data on this topic is summarized in twenty-four (24) tables presented in Sect. 3.3 above. Our research team carefully analyzed 120 + suitable software systems, carefully tested 50+ systems, and recommended 18 open-source (free) and 18

Table 3.24 Context awareness systems for smart university: A list of system's desired features

#	Desired system's feature	Details
1	Adaptation	Leaning context awareness and adaptation of learning activities, teaching style and the learning content in accordance with a) current (available) learning environment, b) academic background of current students, c) instructor's current needs and/or profile, d) students' current needs, etc.
2	Dashboard monitoring	In general, monitoring of various situations and providing metrics; particularly, monitoring of quality of learning by students, student activities, student academic performance, etc.
3	Face finding and recognition	Detects faces of different people in various types of environment—learning environment (in classroom, in a lab), buildings, on campus, etc.
4	Motion detection and recognition	To sense or detect motion of different people and objects in a classroom, lab, building, on campus, etc.
5	Gesture recognition	To identify the gestures used by instructor, TA, tutor, or students in learning environment
6	Smart surveillance	Monitoring of activities or behavioral patterns or any changes in learning environment using different types of smart devices; particularly, this feature is important for safety and security in the classrooms, labs, buildings, and on campus
7	Recording	Automatic high quality audio and video recording of various activities (situations) in classrooms, labs, buildings, and various areas on campus
8	Predictive analytics	Processed data obtained from various sensors make predictions about nest steps/actions in learning activities, or location on campus, or safety, security, etc.
9	Quick video processing and analytics	Quick and relatively easy processing of big data from the videos recorded (for example, surveillance video cameras) and processing of these data (getting analytics)
10	Quick and easy access from anywhere	Easy access by instructor (or, probably, safety officer) to real time or recorded video/audio/information from almost anywhere, but at least from a central context awareness unit (system)
11	Notifications	Send regular notifications via Email, text message, or phone call
12	Alerts	Broadcast real time immediate safety or security alerts to all people on campus and mass notifications in case of emergency
13	Smart navigation	Provides users with high accurate data about unknown locations

commercial systems for possible deployment by SmU—see Tables 3.7, 3.11, 3.15, 3.19, 3.23, 3.27 for details.

(6) Bradley University already created and implemented several smart classrooms in its curricula. A design and development of a pioneering smart classroom of the 2nd generation started in 2016. The details of developed smart classrooms are described in Sect. 3.4 above. Based on the pilot teaching of classes in smart

Table 3.25 Context awareness systems for smart university: A list of analyzed systems

#	Name of a system analyzed	Systems' developer (company)	System's technical platform(s)	Ref. #
Commercial systems				
1	NiceVision (Qognify)	Qognify	Windows, Mac	[139]
2	Blue Iris	Perspective Software	Windows	[140]
3	Sighthound	Singhthound Inc	Windows	[141]
4	EyeLine Video Surveillance	NCH Software	Windows	[142]
5	SARA	Status Solutions	Windows	[143]
6	ZoneTrigger	Omega	Windows	[144]
7	Video Insight VI monitor 6	Panasonic	Windows	[145]
8	Fibaro	Fibar Group	Windows	[146]
9	Nice Vision	Qognify	Windows	[147]
10	IP Video Surveillance Software	Qognify	Windows	[148]
Open source (free) systems				
1	Capturix (Software Set)	Capturix Technologies	Windows	[149]
2	Video surveillance software	Contaware	Windows	[150]
3	ISPY Connect	DeveloperInABox	Windows	[151]
4	Intrance Motion detector	Intrance software	Windows	[152]
5	Zone Minder	ZoneMinder	Windows, Linux	[153]
6	Active WebCam	PY Software	Windows	[154]
7	123Motion 1	MakeItEasy	Windows	[155]
8	WebCam monitor	DeskShare	Windows	[156]
9	Yawcam	Yawcam	Windows	[157]
10	Netcam Studio	Netcam Studio	Windows, Mac	[158]

classrooms, the obtained feedback from faculty and students clearly shows a keen interest from students in high-tech smart education, a significant research interest from faculty to implement various smart systems and devices into smart classroom and smart education, and, in general, proved the correctness of major design and development proposals and solution to build and actively use smart classroom in Bradley curriculum.

Next steps. The next steps (Summer 2017—December 2018) of this multi-aspect research, design, and development project deal with

(1) Implementation, analysis, testing, and quality assessment of numerous components of smart software and hardware systems, smart devices, smart technology, and smart pedagogy in everyday teaching of classes in smart classrooms.
(2) Implementation, analysis, testing, and quality assessment of numerous components of smart software and hardware systems, smart devices, and smart

Table 3.26 Context awareness systems for smart university: A list of most important features in existing systems

#	System's feature	Details
1	Adaptation	Leaning context awareness and adaptation of learning activities, teaching style, and the learning content in accordance with (a) current (available) learning environment, (b) academic background of current students, (c) instructor's current needs and/or profile, (d) students' current needs, etc.
2	Dashboard monitoring	In general, monitoring of various situations and providing metrics; particularly, monitoring of quality of learning by students, student activities, student academic performance, etc.
3	Face finding and recognition	Detects faces of different people in various types of environment—learning environment (in classroom, in a lab), buildings, on campus, etc.
4	Motion detection and recognition	To sense or detect motion of different people and objects in a classroom, lab, building, on campus, etc.
5	Gesture recognition	To identify the gestures used by instructor, TA, tutor or students in learning environment
6	Smart surveillance	Monitoring of activities or behavioral patterns or any changes in learning environment using different types of smart devices; particularly, this feature is important for safety and security in the classrooms, labs, buildings, and on campus
7	Recording	Automatic high quality audio and video recording of various activities (situations) in classrooms, labs, buildings, and in various areas on campus
8	Predictive analytics	Process data obtained from various sensors, and make predictions about nest steps/actions in learning activities, or location on campus, or safety, security, etc.
9	Quick video processing and analytics	Quick and relatively easy processing of big data from the videos recorded (for example, surveillance video cameras) and processing of these data (getting analytics)
10	Quick and easy access from anywhere	Easy access by instructor (or, probably, safety officer) to real time or recorded video/audio/information from almost anywhere, but at least from a central context awareness unit (system)
11	Notifications	Send regular notifications via Email, text message, or phone call
12	Alerts	Broadcast real time immediate safety or security alerts to all people on campus and mass notifications in case of emergency
13	Smart Search	Smart Search features in video management software allow users to set up specific search parameters to quickly scan the most relevant clips in recordings
14	Protocols	Special protocols/rules/regulations to identify problems and make improvements to prevent any significant injures, damages, loss of life, property, business, convenience, or comfort
15	Mobile supportive applications	Active use of various multiple mobile applications on smart phones to (1) inform/alert students/faculty/learners/staff about any unwanted events or activities on campus, and (2) and help them to with information to avoid/escape from those situations to secure environment
16	Active use of ONVIF standards	Active use of ONVIF—Open Network Video Interface Forum—standards in all SmU network video products to provide compatibility of and synchronization in IP video cameras and systems from different manufacturers

Table 3.27 Context awareness systems for smart university: A list of recommended systems

#	Name of a system	Platform (s)	Price per copy (in $)	Ref. #
Commercial systems				
1	NiceVision (Qognify)	Windows, Mac	Need based	[139]
2	Blue Iris	Windows, Mac	$59.95/yr	[140]
3	Sighthound	Windows, Mac, Linux	Basic license $60/Pro license $$250	[141]
Open source (free) systems				
1	Capturix (Software Set)	Windows, Mac	Open Source	[149]
2	Video surveillance software	Windows	Open Source	[150]
3	ISPY Connect	Windows	Open Source	[151]

Fig. 3.2 A set of smart devices for usual smart classroom

technology at Bradley Hall (the home of majority of departments of the College of Liberal Arts and Sciences) and in some areas of the Bradley University campus.

(3) Organization and implementation of summative and formative evaluations of local and remote students and learners, faculty and professional staff, administrators, and university visitors with a focus to collect sufficient data on quality of SmU main components—features, software, technologies, hardware, services, etc.

Fig. 3.3 Smart classroom of 2nd generation at Bradley University–BR160 (with a focus on virtual presence of online/remote students in a classroom and active communication/collaboration of in-classroom instructor and students with remote/online students)

(4) Creation of a clear set of recommendations (technological, structural, financial, curricula, etc.) regarding a transition of a traditional university into a smart university.

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