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Investigating the Impact of the Internet of Things in Higher Education Environment

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ABSTRACT The developments in information and communications technologies (ICT) come with changes in all the fields of life, including the education system. At the same time, the IoT (Internet of Things) is turning ever more important as regards the overall benefits that it brings to smart cities as well as the education system. Starting March 2020, the COVID-19 pandemic has caused fast-paced changes in education and forced the ICT integration in higher education. Despite that, the IoT is still at the beginning in the education system and the impact of its adoption is far from being fully understood. This article is aimed at describing a smart education environment and the extent to which the IOT is conducive to this desideratum. The paper also identifies and describes the most important benefits and challenges related to the adoption of the IoT in higher education. In order to analyze the impact of the IoT adoption in the education environment, the authors propose an assessment model based on six hypotheses, including their definitions and descriptions. They are validated against the Romanian higher education system, as well as a set of survey data. Structural equation modelling (SEM) is used in the study to validate the suggested model as well as to determine how the adoption of the IoT relates to intra- and extra-university connectivity, to attracting additional resources, to the teaching and learning activities, to data security and integrity as well as to education policies. The last part of the paper dwells on the analysis of a set of survey data and of the hypotheses shaped herein. The paper also includes recommendations, as well as the main conclusions, limitations and future research directions. It contributes both from the theoretical and practical perspective to the development of smart universities in the future.

INDEX TERMS Higher education, information and communication technologies, Internet of Things, smart education, smart learning, smart university, smart teaching, structural equation modeling.

I. INTRODUCTION

In recent years, the Internet of Things (IoT) has gained an increased importance, as it offers global networks whereby devices and things are connected through the Internet infrastructure. The IoT thus enables objects and individuals to connect anytime and anywhere, which results in the identification and integration of knowledge and intelligence as well as in the creation of added knowledge, globally.

In this context, universities will no longer need to lay particular emphasis on the use of information and communication technologies (ICT), but on the ways to adapt to the changing needs of a knowledge worker, to the new forms of work and the economy of the future [1]. Higher education systems must allow for the integration of lifelong teaching, research and learning activities, enable their integration both with the national education systems and the instruments that connect them to the labor market. Concurrently, the IoT will lead to multiple changes in the sphere of education, such as technological changes (Cloud/Fog Computing, instructional technologies, mobile apps), the reform of education, changes in teaching and learning, practical and experimental changes, changes in the campus [2], changes in security and confidentiality, in quality and ethics, changes of financial nature and other types of changes [1].

The IoT will connect people, processes, devices and data, which will enable the stakeholders in education to find an easier way to turn the data collected from sensors and portable devices into valuable information [3] and to carry out significant actions based on that information [4]. It is critical to look at the impact that the adoption of the IoT may have, to see the benefits and challenges of the IoT in education [5], especially since the IoT is still incipient in the education system. The IoT comes with countless benefits, such as: the creation of smart interactive classrooms; the possibility to customize interactive models whereby students are proactive actors in the learning process; the stimulation of creativity; real time reporting on the students' cognitive activities [6].

The COVID-19 pandemic has put a lot of pressure on research as well as on the applicability of new technologies

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in education. Higher interest in this field of research [7] is reflected in the numeric increase of publications on the use of the IoT in education, whereas current practices in education are a factual demonstration of such interest.

The paper includes the following sections: Section II outlines the smart concept in the education environment and how the IoT can contribute to reaching this desideratum, Section III introduces the research objectives, the hypotheses regarding the impact that the adoption of the IoT will have on the higher education system, and the current situation in the Romanian public education system, Section IV includes data and methodological aspects, and Section V reports the results of a survey conducted in the Bucharest University of Economic Studies (BUES) on the intensive use of the ICT in online school and on the adoption of the IoT in the university, and also includes recommendations about how to integrate the IoT in universities, in general. The last part lists the main conclusions, limitations and research directions.

II. LITERATURE REVIEW - SMART EDUCATION ENVIRONMENT

The IoT changes the face of every field of life by turning every object into a smart entity. This is also true for the education environment where one encounters a true chain in which energy smartly passes from smart education, smart university, smart classroom, smart teaching and smart learning up to smart assessment (figure 1).

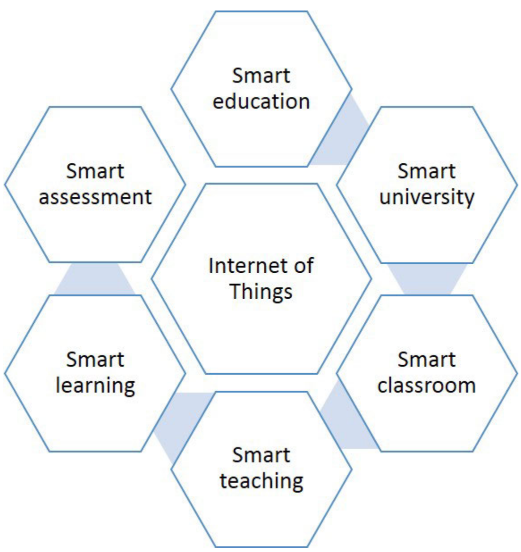

FIGURE 1. **Smart education environment.**

A. SMART EDUCATION

Smart technologies such as cloud computing, big data and the IoT make it possible to convert education in smart education [8] and play an important role in building a smart education environment [9]. The purpose of smart education is to provide the 21st century skills and knowledge to the workforce, which will enable it to cope with the challenges of the society. The achievement of smart education relies on an IoT infrastructure, made up of sensing devices, user applications and communications links [10]. The use of the IoT in the education environment will result in an increased quality of the education process, because students will learn faster and the teaching staff will be able to carry through their teaching activity [11].

B. SMART UNIVERSITY

A smart university integrates innovative concepts, smart hardware and software concepts, smart classrooms that are endowed with the latest technology, and education processes based on modern and smart teaching and learning strategies [12]. A smart university comes with an interactive education environment, access to global contents, adaptive learning based on the data collected and analyzed within the network. The IoT is currently present in many universities as security cameras, temperature control devices, access devices to buildings, electricity and heating systems [13].

C. SMART CLASSROOM

A smart classroom is the place that accommodates all the education activities based on electronic devices such as: digital screens, video-projectors, internet-connected devices [3]. In [14], a smart classroom is defined as a physical classroom space used to teach the content, where class management, access to the learning resources and interaction are achieved and combined with contextual awareness. Starting 2012, a smart class is based on mobile technologies, mobile learning and automated communication devices [15], on video-projectors, cameras, sensors, facial recognition algorithms and other modules that monitor various parameters of the physical environment [16].

When smart devices are connected by means of the IoT, they create an efficient smart class that makes it possible to provide knowledge anywhere and anytime through remote access [17]. Furthermore, the IoT-based learning systems allow students suffering from locomotive disorders to learn in the comfort of their own homes, those with impaired hearing to convert audio files in text files and the students with vision problems to convert text files in audio files, which means that the IoT can address part of the needs of the disabled. The IoT plays a major role in supporting disabled people, and that mainly builds on connectivity [18]. A smart class comes with benefits such as flexibility, knowledge communication, improved thinking abilities, interaction, and sharing educational content, to list but a few [19].

D. SMART TEACHING

Smart teaching is different from traditional teaching, especially in the way in which content is conveyed by means of various electronic devices. Moreover, the content is available 24/7 and learning is adaptive [3]. Through sensing devices, the IoT may offer access to the real world, which turns the teaching process in a challenging experience, as it has to be tailored and adapted, involve different teaching approaches and address students that are faced with learning challenges (impaired vision, hearing or locomotion and hyperactivity disorders) [20].

E. SMART LEARNING

Smart learning is an adaptive learning process mediated by electronic devices [3], [21]. In [22], smart learning is defined as a studying process that has at core the students and the content. It is less device-oriented and its effectiveness, smartness and adaptiveness relies on the ICT structure. The IoT-based e-learning applications are crucial, especially in putting in place a virtual class and in creating a competitive learning environment, both locally and globally. The IoT also encourages online self-teaching, as the students can connect to any lab or library in the world in order to take part in experiments, collect data, be assigned and send homework or for self-assessment [11].

F. SMART ASSESSMENT

Smart assessment exceeds the traditional assessment framework which is based on multiple choice tests or the development of knowledge. In a smart context, assessment becomes an ineluctable process based on the ICT and evolves in the context of an actual IoT ecosystem. The modern learning systems must integrate the adequate instruments able to capture the students' behaviors in the assessment strategies of online learning. The IoT devices can be used to measure a student's focus, which is essential in the assessment of education [23]. Smart education also involves new types of teaching and learning, which are conducive to new assessment methods and/or other elements to consider in the assessment strategies.

Smart assessment should include instruments/methods to detect fraud, plagiarism (e.g., to detect whether solutions are copied from the internet) as well as cases when students learn by heart the solutions to exercises, which may only mimic the internalization of knowledge in an examination [24]. It is also possible to create adaptive smart students' assessments, which are tailored according to the answers given to the questions and presented in the student's favorite learning style [25]. Such an assessment would allow to probe into the students' knowledge, into the way they understand and implement it, their abilities and learning styles. Simulations during the teaching activity are an important smart assessment component and also a potential learning method.

III. RESEARCH OBJECTIVES AND HYPOTHESES

This article is a qualitative study that focuses on the impact on IoT on higher education. It is important to review the impact of the IoT both on the physical and the virtual learning environments [10]. The latter describes the e-learning systems used in smart campuses [5].

This section is aimed at defining a number of hypotheses regarding the benefits and the challenges of the adoption the IoT in higher education. It also refers to the current situation of the Romanian education system in the light of ICT use and the adoption of the IoT and the extent to which the hypotheses are supported by the existing education platforms.

The hypotheses suggested in this section will then be analyzed and validated through a survey on the timeliness of the IoT, which was conducted within the Bucharest University of Economic Studies. The survey is also be designed to collect feedback about the online school platform used during the pandemic and about the extent to which this period is supportive of a faster adoption of the IoT in universities.

A. RESEARCH OBJECTIVES OF THE STUDY

The research objectives of this study are the following:

O1. Identification of the major benefits and challenges which come with the adoption of the IoT in higher education and proposal of a theoretical model to be used in the IoT impact analysis

O2. Validation of the proposed theoretical model based on empirical data and recommendations on IoT integration in similar universities

B. HYPOTHESES

This study proposes six main hypotheses about the adoption of the IoT in higher education, which are detailed further down.

H1. The adoption of the IoT in higher education has a positive influence on intra- and extra-university connectivity

The IoT enables people and objects to connect irrespective of place and time, by using any network or service [26] in order to track, follow and manage things [27]. The adoption of the IoT in the education environment enables the students and professors to interact with the objects from the education environment, allows for communication between the physical and the virtual worlds [28], as well as for the development of communication and links between students and professors [29].

The status quo in Romania shows that there are in place data capture devices as well as university and national levels platforms that enable better interaction: between students and the academic staff (e-learning platforms, smart classrooms, SIMUR – Integrated University Management System, SIMCE – Economic Knowledge Integrated Management System – within the BUES), between the academic world and the labor market (SAPM – Students, Graduates and the Labor Market), between the academia and European countries (ANS – The National Statistical Data Collection Platform for Higher Education), as well as between education entities (SIIIR - Romanian Education Integrated Information System).

The intensive use of the ICT has made it possible to develop and implement various cooperation models, to put in place consortia with national and international partners (e.g., UNIVERSITARIA Consortium – the strongest consortium in higher education in Romania, which includes Babe -Bolyai University of Cluj-Napoca, Alexandru Ioan Cuza University of Ia i, West University of Timi oara) and to share experience between universities, as well as between the business environment and both the national and international education systems.

The use of the IoT in universities and throughout the national education system will be a step forward in increasing connectivity between students, the academic staff/researchers and the labor market. This is achieved through the analyses of the data made available by the integrated systems/devices, which results in better adaptability of the academic curricula to the changing needs and a step forward towards new forms of work and stronger support for societal trends. The IoT enables universities to work together with cultural and governmental organizations as well as the business environment, which maximizes the relevance of education and endows the future generation of employees with better abilities and knowledge.

H2. The adoption of the IoT in higher education has a positive influence on attracting additional resources from the stakeholders

Increased national connectivity enabled by the adoption of the IoT makes all stakeholders more responsible in providing resources to higher education. The business environment thus gets closer and can play an active role in higher education by putting in place university labs, by providing hardware and software training resources to the future employees, by supporting expert-assisted learning – associated teaching staff, funds for student studies or sponsorships, complete or partial financial coverage of proposed doctoral and post-doctoral research topics or other forms of financial support. Based on the data delivered by the national platforms, the government may act and earmark additional resources for priority areas, such as scholarship or drop out financial strategies. One relevant example is secondary education in Romania (ROSE), a project aimed at reducing drop out in secondary and tertiary education and at increasing the pass rate in the baccalaureate examination. Funded through a EUR 200 million loan from the International Bank for Reconstruction and Development, the project is implemented on a 7-year period (2015-2022) by the Ministry of National Education through the Externally Funded Project Management Unit (UMPFE) - https://www.edu.ro/etichete/proiect-rose.

The IoT-embedded facilities provide the stakeholders with cooperation opportunities in carrying out research projects, either funded under EU funds or by the business environment. When implemented in higher education, the IoT may boost the research opportunities for researchers, academic staff and students [30]. Moreover, the IoT makes it possible for professors and administrators to collect and process the data, which offers the stakeholders a real time image of the students, professors and non-teaching staff [10] and ensures information transparency as well as opportunities to invest in education or to capitalize on/validate the investments.

H3. IoT in higher education has a positive influence on the excellence of teaching activity

The IoT enables the teaching staff to provide new teaching/assessment models, to receive fast feedback from the students and to calibrate the pedagogical methods so as to achieve better results in the teaching activity. The IoT also makes it possible to achieve adaptive teaching, the self-generation of contents for the materials required by the students and to continuously improve the teaching methods based on students' feedback. The current circumstances brought about by the COVID-19 pandemic forces education institutions to adopt e-learning solutions in order to ensure the continuity of the education processes. The effects are felt by students and teaching staff alike. The teaching activity is completely changing face for many professors who were not necessarily supportive of the IoT or the use of its elements in the didactic process before the current critical situation. The outcome will offer support for hypotheses that the IoT promotes excellence both in the teaching activity (H3) and the learning activity (H4).

The use of IoT sensors (e.g., web cameras, microphones) will allow to collect and analyze the data (cloud data storage and processing) for each student, which arms professors with indicators based on which they can promptly react in their teaching and assessment activities [6]. Such analyses will underpin the teaching staff's efforts towards improving their teaching plans and methods for the next generations [1]. Moreover, considering that it connects the real and the virtual worlds, the use of the IoT will also involve the emergence and application of new pedagogical methods [31] that will add to the excellence of the teaching activity. The COVID-19 pandemic came with the exploration of innovative pedagogical methods, a must in ensuring good quality courses in higher education [32]. The IoT also makes it easier to find and bring experts to the smart classrooms in real time (by means of video-recordings and remote conferencing solutions), which again increases the quality of education processes [33].

H4. IoT in higher education has a positive influence on the excellence of learning activity

The IoT makes it possible to provide the requested information to the right person, at the right time, which results in a more efficient type of education as well as an improved learning time and student motivation [33]. The IoT also has the capacity to enhance the learning experience and offer real time information about the students' results [1]. In other words, the IoT allows to check the existence of homework and of the time the student took to do it, which is useful for a professor to be aware of the students who may need additional assistance, of the tasks that caused them difficulties and adjust the teaching methods accordingly. Moreover, in association with smart teaching, the IoT makes it possible for disabled students to cover the educational materials, which is a way for them to learn and get assessed.

H5. The adoption of the IoT in higher education results in data security and integrity challenges

The existence of a large number of IoT devices and sensors increases the threat of malicious software attempts and requires more layers of security. Addressing these challenges and issues related to the security of the IoT devices and services must be approached as a fundamental priority [34]. Universities will have to work closely with the government authorities in order to ensure the development of the IoT in education and, at the same time, the authorities must ensure the safety and security of the citizens. Moreover, they must ensure the integrity of the data, their accuracy, authenticity, completeness and updating [35]. Among the reasons that have resulted in the failure of the IoT projects, it is noteworthy data quality and integration as well as the shortage of financial resources.

H6. There is a relationship between the adoption of the IoT in higher education and education policies, in terms of managerial support and attitude towards change

Education policies are critical to encouraging the adoption of technology in classrooms and their effective integration in education programs [35]. The sanitary crisis generated by COVID-19 forced decision makers to design education reform policies/guidelines/strategies required by the intensive use of the ICT and by the transition to online and remote mode education. Starting May 17, 2020, more that 69.3% of the total school-age population all over the world suffered the effects of the closure of schools and of the transition to online education [36]. These education policies facilitate the adoption of the IoT. They also encourage a positive attitude to change and international cooperation in the advancement and strengthening of education. Despite that, there are still managerial positions held by individuals who are reluctant to the adoption and the use of the ICT, hence, reluctant to change. The individuals' change process involves more than one step also in the IoT context, such as: denial, awareness, use and integration. New behaviors or abilities are conscientiously put into practice only with the third stage.

In their decision-making process, the managerial teams of higher education institutions should consider the fact that the IoT requires systems that are often costly, therefore many schools in the world will not have enough funds to embark on such initiatives [13]. Universities may use the IoT devices to monitor the students, staff, resources and equipment to the end of reducing operational costs [37]. Furthermore, the IoT connects the equipment in the campus (lights, parking lot, surveillance cameras), which can offer valuable analysis data if we want to determine specific use and resource-optimization patterns [35].

The Romanian institutions already took a step towards the digitization of education and national integration of platforms before the outbreak of the COVID-19 pandemic. March 2019-December 2020 saw countless investments in online and hybrid learning platforms, in connecting the existing national platforms, in terminals, as well as in data and platform security, in licenses for video and audio platforms (such as zoom.us) and in the education system overall. The pandemic put extreme pressure on the education system, pressure to enable change, but also related to securing the financial resources required by the ICT investment.

Figure 2 describes a theoretical model based on the six hypotheses.

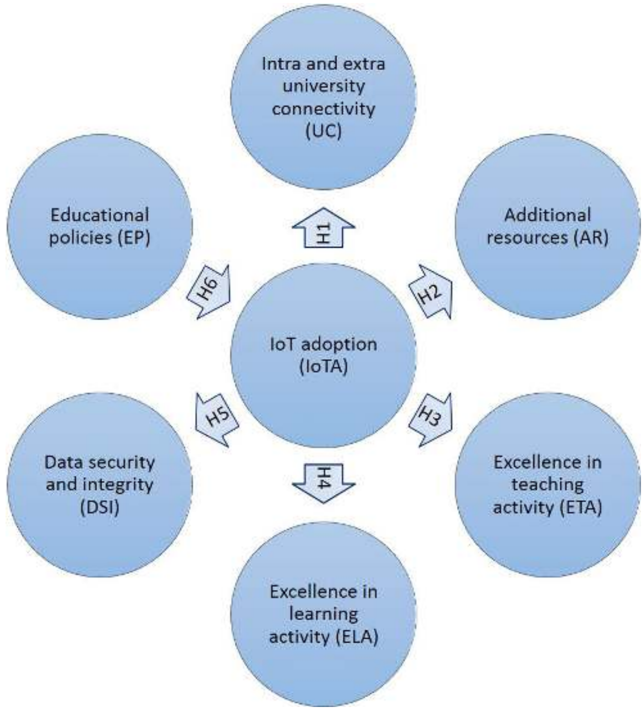

FIGURE 2. Theoretical model and suggested hypotheses.

C. SUPPORT FOR THE HYPOTHESES THROUGH THE PLATFORMS ALREADY OPERATING IN THE ROMANIAN EDUCATION SYSTEM

The Romanian public education system already benefits from several software platforms that are managed by the Executive Unit for the Funding of Higher Education, Research, Development and Innovation (UEFISCDI), a public institution with legal entity status subordinated to the Ministry of National Education (MEN). UEFISCDI manages several IT systems aimed at making reporting more efficient as well as at increasing institutional transparency and public trust in the public higher education system [38]: REI (Integrated Education Register), RMU (Individual Academic Record), SAPM (Students, Graduates and the Labor Market), ANS (The National Statistical Data Collection Platform for Higher Education), SIR (Study in Romania).

a) The REI platform ensures the interoperability of the IT systems within the education sector: pre-university education and higher education. It also ensures the interaction with related information systems in a cloud solution in order to trace individual education records. (http://rei.gov.ro).

b) The RMU platform ensures the integrated management of the data for every student in public and private universities in Romania, for all study years and levels of academic achievement. The platform consistently collects and consolidates the data in order to render administrative activity more efficient and improve the capacity to design institutional strategies and national policies in the field (through http://rei.gov.ro).

c) The SAPM platform supports the development of institutional mechanisms in Romanian universities by securing access to survey generating tools needed in the periodic implementation of the follow up studies - professional insertion of higher education graduates (www.sapm.forhe.ro).

d) The ANS platform is a modular architecture integrated information system dedicated to higher education in Romania, which is compatible with the European data collection systems. It brings together the main statistical data on higher

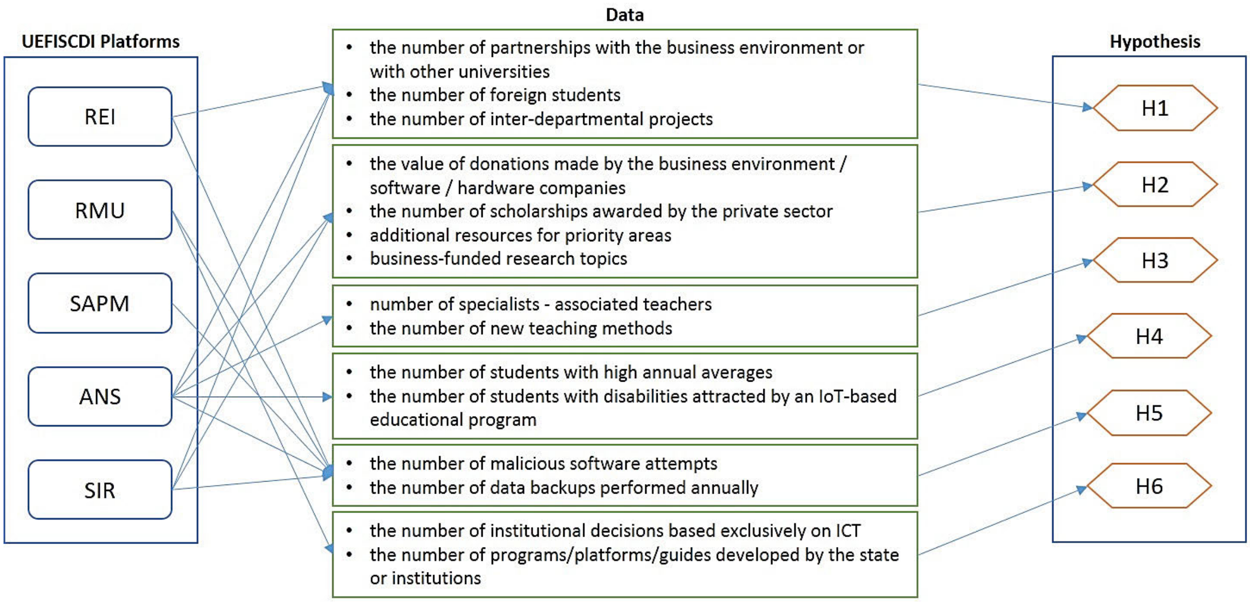

FIGURE 3. Illustration of the data provided by the existing national education platforms.

education and can be accessed by all the interested actors (https://date.invatamant-superior.ro/).

e) The SIR platform promotes Romanian higher education across the world, thus contributing to attracting national and international students in the study programs included in the education offer of Romanian universities (www.studyinromania.gov.ro).

Figure 3 presents the data side of the manner in which the existing information systems (platforms) managed by MEN through UEFISCDI can support the proposed model in Romania. The figure illustrates the types of hypotheses' supporting data that can be collected from the described platforms through their specific facilities and information functionalities. Unfortunately, not all these functionalities are currently available, and it will take a while before a fully integrated IoT-based higher education system is in place.

The use of the ICT both at national and university level ensures the continuous improvement of the quality of lifelong learning, the continuous adjustment of the syllabi to the needs on the labor market, the integration of the students on the labor market and, generally speaking, an increased quality in higher education at national level as well as integration at European level. Universities must constantly change, however, and meet technological trends halfway if they want to build a good future.

Considering that the proposed research model equally builds on the things part (Internet of Things) and individuals (teaching staff, students), processes (teaching, assessment, learning, management etc.) and data (learning outcomes, trended indicators etc.), we may unreservedly introduce/call on the Internet of Everything (IoE) concept, as defined by Cisco – "*The Internet of Everything (IoE) brings together people, process, data, and things to make networked connections more relevant and valuable than ever before*" [39]. The IoE can thus be perceived as a higher rank paradigm that encapsulates the IoT phenomenon/concept.

In this study, we considered that the IoE approach would have been too "daring" for the level of digitalization of the Romanian society. Romania ranks on the 26th place out of the 28 EU member states (including the UK) for the 2020 digital economy and society index (DESI), which is based on statistical data for 2019 [40].

IV. DATA AND METHODOLOGY

This section introduces the instruments applied in the study as well as the data collection features that allow to validate the hypotheses.

A. APPLIED INSTRUMENTS

The validation of the research model relies on structural equation modelling (SEM). SEM is a hypothesis-intensive analytical model [41]. SEM can be looked at as a statistical procedure used as a confirmation model (for testing the hypotheses, for instance), based on the analysis of the structural theory on a given phenomenon [42]. SEM is considered a complex statistical method used to assess the relationships between latent variables (or constructs – conceptual terms used to point to theoretical notions) [43]. Two main models are distinguished in SEM: 1) the measurement model, showing the relationships between indicators and latent variables and 2) the structural model, showing causal dependencies between the latent variables [44]. Based on the relationship between the latent variables and their observed indicators, SEM evinces two measurement models: 1) reflective measurement models (using reflective indicators/main factors) and 2) formative measurement models (using formative indicators/composite indices) [44]. The reflective measurement specifies the fact that a latent or unobserved concept causes

TABLE 1. Survey questions used to validate the hypotheses in the model.

Construct	Construct items
Intra and extra university connectivity (UC)	UC1. Online school supports the improvement of student-professor communication UC2. The IoT stimulates cooperation between students and the business environment UC3. The IoT supports the conclusion of partnerships between the university and the business environment/universities from abroad UC4. The IoT facilitates student exchanges between universities
Additional resources (AR)	AR1. The use of the IoT increases the donations made by the business environment AR2. The adoption of the IoT increases the number of scholarships granted by the private sector AR3. IoT contributes to the numeric increase of research topics that are publicly funded and/or funded by the business environment
Excellence in teaching (ETA)	ETA1. Online education stimulates excellence in the teaching-assessment activity ETA2. The IoT in the university attracts experts – associated teaching staff ETA3. The use of the IoT may generate new student-tailored teaching/pedagogical methods
Excellence in learning (ELA)	ELA1. Online education stimulates excellence in the learning activity ELA2. The use if the ICT in online school stimulates participation in didactic activities ELA3. Attracting disabled students through IoT-based education programs
Challenges in data security and integrity (DSI)	DSI1. Intensive ICT use may generate data security vulnerabilities (malicious software attempts at institutional level) DSI2. Intensive ICT use may generate data integrity vulnerabilities DSI3. The use of the IoT requires additional expenses related to data security and integrity
Education policies (EP)	EP1. The programs/platforms/guidance designed at international level stimulate the adoption of the IoT in universities EP2. The programs/platforms/guidance designed at national level stimulate the adoption of the IoT in universities EP3. The programs/platforms/guidance designed at institutional level stimulate the adoption of the IoT in universities
IoT adoption (IoTA)	IoTA1. There is a preference for the higher education programs that use the IoT technology IoTA2. The intensive use of the technology facilitates the adoption of the IoT in the education environment IoTA3. A sanitary crisis is the premise for the adoption of the IoT and of smart education IoTA4. We are now ready to use the IoT [10]

variations in a set of observable indicators, hence they can be used to obtain a direct measurement of the concept [45].

The literature dwells on two commonly used SEM-related statistical methodologies: covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM). Each approach comes with benefits and drawbacks and certain circumstances may tilt the balance in favor of one of them (when the sample is small, for instance). Smaller samples may result in inaccurate path estimations in CB-SEM [46]. The adequate method for developing and testing and early-stage theory [44], [47], which allows to examine the constructs as well as the relationships between complex structural models, is PLS-SEM. Moreover, data features such as the smallest sample size, non-normal data and the measuring scale (the application of different types of scales, for instance) are among the reasons that most often call for the application of PLS-SEM [48]. PLS-SEM can be used to tests hypotheses when the research is exploratory in nature, when the model is very complex (it includes both reflective and formative constructs) and when the model includes higher order constructs [49], [50]. According to [51], its typical implementation as a path model is SmartPLS. In PLS-SEM, the guiding idea is that the size of the sample should be ten times as large as the number of arrows pointing to a construct [44].

Considering the previous arguments as well as the features of the data and the size of the sample, the validation of the model relied on PLS-SEM SmartPLS software instrument.

B. DATA COLLECTION

In the BUES, there are available several integrated platforms aimed at not only assisting the activities of the students, of the management and of the employees, but also at reporting the data to the national platforms: SIMUR (Integrated University Management System), SIMCE (knowledge-based integrated collaborative system aimed at the improvement of university management in the context of the new National Qualifications Framework in Higher Education), Blended/Hybrid Learning (https://online.ase.ro/). In order to make the most of the current technologies, BUES should act in the sense of analyzing the timeliness of the IoT in the university and of developing education policies that promote the constant adjustment to the new technologies and the graduates' qualifications that fit the new society.

The authors conducted a survey based on a Google form at BUES. It was sent to 48 students in the first year of their master's studies, 73 students in their second year of master's studies, 70 distance learning students in their first year of undergraduate studies and 63 members of the teaching staff (254 potential responders in all). Out of all the filled out and submitted questionnaires, we have only considered those of the respondents who showed at least an average IoT knowledge. Thus, the questionnaire was filled out by 31 first master's program year (64.58%), 46 second master's program year (63.01%), 44 distance learning first year undergraduate students (62.85%) and 44 members of the teaching staff (69.84%). The questions in the survey considered the profile of the respondents, their online education activity during the pandemic and the adoption of the IoT in education. The questions that targeted the validation of the hypotheses are included in Table 1.

The survey involved the BUES because for two consecutive years, the university ranked on the first place among higher economic and public administration education institutions in Romania and South-Eastern Europe, which was confirmed by the prestigious Times Higher Education World University Rankings 2021 [52] [53]. This leading position in economic sciences at national level is also confirmed by Top Shanghai [54]. The Faculty of Cybernetics, Statistics and Economic Informatics within BUES successfully provides undergraduate, master's and doctoral studies in Economic Informatics, the specialty from where we selected the students to respond to the survey.

The answers are represented on a 5-point Likert scale (from 1 – strong disagreement to 5 – strong agreement). Most of the users in BUES are students, therefore it is important to identify their expectations from a new way of education as well as their level of knowledge related to the new technology [10].

V. RESEARCH OUTCOMES AND RECOMMENDATIONS

A. RESPONDENT PROFILE AND OUTCOMES

Following the survey conducted within the BUES, we collected 165 forms from the respondents who showed at least average IoT knowledge, out of which 44 from the teaching staff and 122 from students specializing in economic informatics. Out the total number of respondents, 80 were women and 85 men. The age spread was the following: 69 were aged 18-25, 39 were aged 26-35, 23 were aged 36-45, 23 were aged 46-55 and 11 were 55 plus. One parameter of the survey was set to measure the impact of the ICT and online education (as practiced during the sanitary COVID-19 crisis) on the education process (figure 4). We thus sought to measure the effects on student-professor communication, on the teaching-learning-assessment activities and whether participation in didactic activities is stimulated or not, irrespective of the level of IoT knowledge of the respondents. For this analysis, we considered 206 forms (165 from the respondents who have at least an average IoT knowledge and 41 respondents with no IoT knowledge).

By analyzing the results, one may notice a strong positive impact of the ICT and online school on the participation in didactic activities. On the other hand, there emerges another positive trend related to the impact on the learning and teaching-assessment activities (strong agreement/agreement – 44% vs. disagreement/strong disagreement – 21%). Opinions are mixed on the degree to which online school can improve student-professor communication (50% pros vs. 30% cons, 20% neutral).

In conclusion, the study clearly evinces the way in which the ICT and online school are supportive of participation in didactic activities, on the one hand. On the other hand, the rather large share of neutral positions (35%) may suggest that online school, as it is now, does not seem to be a reliable solution for the time being, one that can stimulate excellence in the teaching-learning-assessment activities. Concurrently, there is 30% disagreement with regard to stimulation of communication and of an increased interaction between the actors of the education process. Under the circumstances, moving to another level, that of IoT adoption in universities may be a solution, as the suggested theoretical model and the hypotheses with further show.

B. EVALUATION OF THE MEASURING MODEL

The quality and usefulness of the collected data is determined by factors of reliability and validity. There are several criteria to measure the reliability and validity of the measurement model, including the coefficient of determination (R-squared), the average variance extracted (AVE), the composite reliability (CR) and Cronbach's alpha [55]. Reliability refers to the outer loadings of the construct measurement indicators. In order to preserve an element inside the measurement model, it must have a higher outer loading. The validity of the construct in the SEM model can be checked through construct validity and discriminant validity [56].

The reliability of indicators is checked by investigating the outer loadings numbers, where the preferred value is at least 0.7, but for exploratory research, values in excess of 0.4 are also acceptable (ELA1 and ETA3). All indicators whose outer loadings are under 0.4 are removed from the model, according to [55].

One way to check the reliability of internal consistency (whether a construct is measured through its indicators) may be the composite reliability, whose preferred values are at least 0.7, but for exploratory research, values in excess of 0.6 are also acceptable [57].

Convergent validity emerges from the AVE numbers, which must be at least 0.5 [58].

Table 2 presents a summary of the results following the execution of the PLS algorithm.

The UC4 indicator, with an outer loading under 0.4, is to be removed. Table 3 shows the results of the second estimation.

The new results showed that the values exceed the recommended threshold, which leads to the reliability of the constructs.

The next step is to check the validity of the discriminant in the reflective model (correlations between the measurement of interest and the measurement of other constructs). The constructs fulfill the criterion that the square root of AVE for each construct should be higher than the values of the other correlations between constructs [59]. Table 4 shows that the validity of the discriminant is supported by the model.

Figure 5 presents the model following the execution of the PLS algorithm. It highlights the coefficients of determination (R^2) for endogenous variables (written on the symbol of the latent variable – in the circle), the path coefficients and the outer loadings.

C. ASSESSMENT OF THE STRUCTURAL MODEL

Once the measuring model is completed, it is important to analyze the coefficients of determination (R^2), the size and significance of the path coefficients, the effect size (f^2) and the predictive relevance (Q^2) [60].

Having determined the estimates of the path coefficients for the structural model, we applied the bootstrap method in

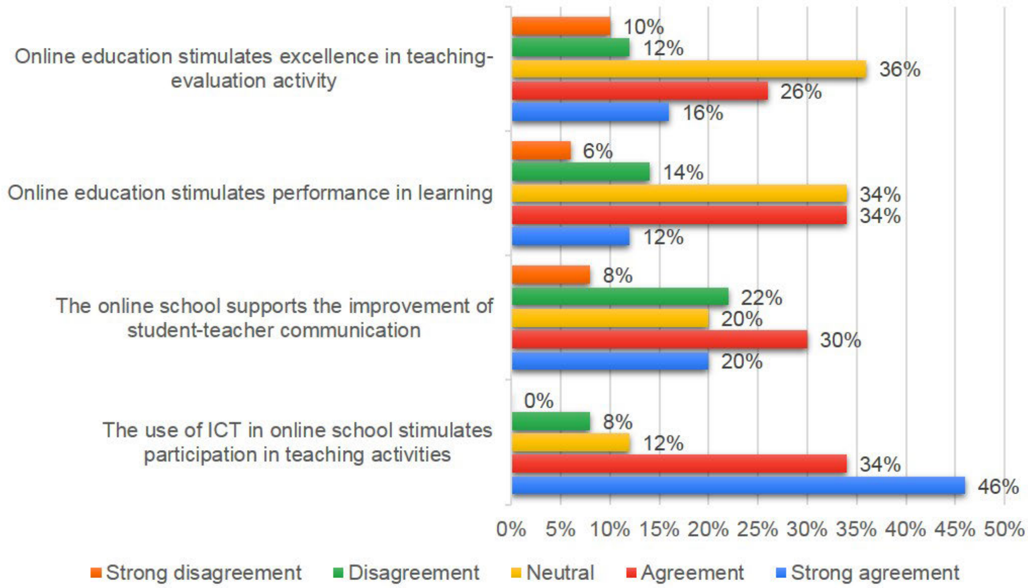

FIGURE 4. The impact of ICT and online education on the education process.

TABLE 2. Summary of the results from the reflective model.

Construct	Items	Outer loadings	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Additional resources (AR)	AR1 AR2 AR3	0.829 0.793 0.785	0.724	0.724	0.844	0.644
Data security and integrity (DSI)	DSI1 DSI2 DSI3	0.955 0.915 0.780	0.864	0.963	0.916	0.786
Education policies (EP)	EP1 EP2 EP3	0.826 0.825 0.830	0.775	0.796	0.866	0.684
Excellence in learning activity (ELA)	ELA1 ELA2 ELA3	0.574 0.940 0.934	0.786	0.944	0.868	0.695
Excellence in teaching activity (ETA)	ETA1 ETA2 ETA3	0.907 0.858 0.654	0.735	0.776	0.853	0.662
Intra and extra university connectivity (UC)	UC1 UC2 UC3 UC4	0.923 0.845 0.845 0.261	0.713	0.836	0.833	0.587
IoT adoption (IoTA)	IoTA1 IoTA2 IoTA3 IoTA4	0.829 0.933 0.901 0.827	0.897	0.930	0.928	0.764

order to assess their statistical significance (SmartPLS offers T statistics to test the significance of the inner and outer models).

Table 5 shows the values of a set of variables that indicate the level to which the data support the hypothesis of the model.

According to [61], for the field of social and behavioral sciences, a coefficient of determination $R^2 \geq 0.02$ associates with a low effect (impact), a coefficient $R^2 \geq 0.13$ is considered to show an average effect, whereas $R^2 \geq 0.26$ indicates a strong effect.

On the other hand, according to [62], in social sciences, R^2 values of 0.04-0.16 can be considered relatively weak. Generally speaking, the higher the R^2 value, the stronger the suggested model dependence for each latent variable [63].

As illustrated in figure 5, the hypotheses regarding the impact of the IoT on ETA ($R^2 = 0.192$), ELA ($R^2 = 0.123$)

TABLE 3. Summary of the results after the removal of the indicators and data cleaning.

Construct	Items	Outer loadings	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Additional resources (AR)	AR1 AR2 AR3	0.829 0.793 0.785	0.724	0.724	0.844	0.644
Data security and integrity (DSI)	DSI1 DSI2 DSI3	0.955 0.915 0.781	0.864	0.962	0.916	0.786
Education policies (EP)	EP1 EP2 EP3	0.826 0.825 0.830	0.775	0.796	0.866	0.684
Excellence in learning activity (ELA)	ELA1 ELA2 ELA3	0.574 0.940 0.934	0.786	0.944	0.868	0.695
Excellence in teaching activity (ETA)	ETA1 ETA2 ETA3	0.907 0.858 0.654	0.735	0.776	0.853	0.662
Intra and extra university connectivity (UC)	UC1 UC2 UC3	0.930 0.850 0.862	0.856	0.873	0.912	0.777
IoT adoption (IoTA)	IoTA1 IoTA2 IoTA3 IoTA4	0.830 0.934 0.901 0.826	0.897	0.931	0.928	0.764

TABLE 4. Analysis of the Fornell-Larcker Criterion to check Discriminant Validity.

	Additional resources (AR)	Data security and integrity (DSI)	Educational policies (EP)	Excellence in learning activity (ELA)	Excellence in teaching activity (ETA)	Intra and extra university connectivity (UC)	IoT adoption (IoTA)
Additional resources (AR)	**0.803**						
Data security and integrity (DSI)	0.072	**0.887**					
Educational policies (EP)	0.124	0.093	**0.827**				
Excellence in learning activity (ELA)	0.180	-0.001	0.152	**0.834**			
Excellence in teaching activity (ETA)	0.178	0.102	0.145	0.785	**0.814**		
Intra and extra university connectivity (UC)	0.135	0.048	0.047	0.624	0.583	**0.881**	
IoT adoption (IoTA)	0.413	0.201	0.271	0.351	0.438	0.246	**0.874**

TABLE 5. Summary of model hypotheses testing (subsamples 5000, significance level of 5%).

Hypothesis. Path	f^2	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Result
H6. Education policies (EP) -> IoT adoption (IoTA)	0.079	0.271	0.284	0.069	3.925	<0.001	Yes
H2. IoT adoption (IoTA) -> Additional resources (AR)	0.206	0.413	0.419	0.062	6.627	<0.001	Yes
H5. IoT adoption (IoTA) -> Data security and integrity (DSI)	0.042	0.201	0.211	0.074	2.725	0.006	Yes
H4. IoT adoption (IoTA) -> Excellence in learning activity (ELA)	0.141	0.351	0.360	0.065	5.438	<0.001	Yes
H3. IoT adoption (IoTA) -> Excellence in teaching activity (ETA)	0.237	0.438	0.443	0.058	7.538	<0.001	Yes
H1. IoT adoption (IoTA) -> Intra and extra university connectivity (UC)	0.065	0.246	0.254	0.064	3.867	<0.001	Yes

and AR ($R^2 = 0.171$) are statistically significant for an average level effect. On the other hand, the hypothesis does not have statistical significance for the EP and IoTA relation, since R^2 is 0.073, in other words lower than 0.13, which means that education policies have a weak influence on the adoption of the IoT in the university. The same is true for DSI ($R^2 = 0.04$) and UC ($R^2 = 0.061$), respectively. In conclusion, the analysis shows that out of the six initially

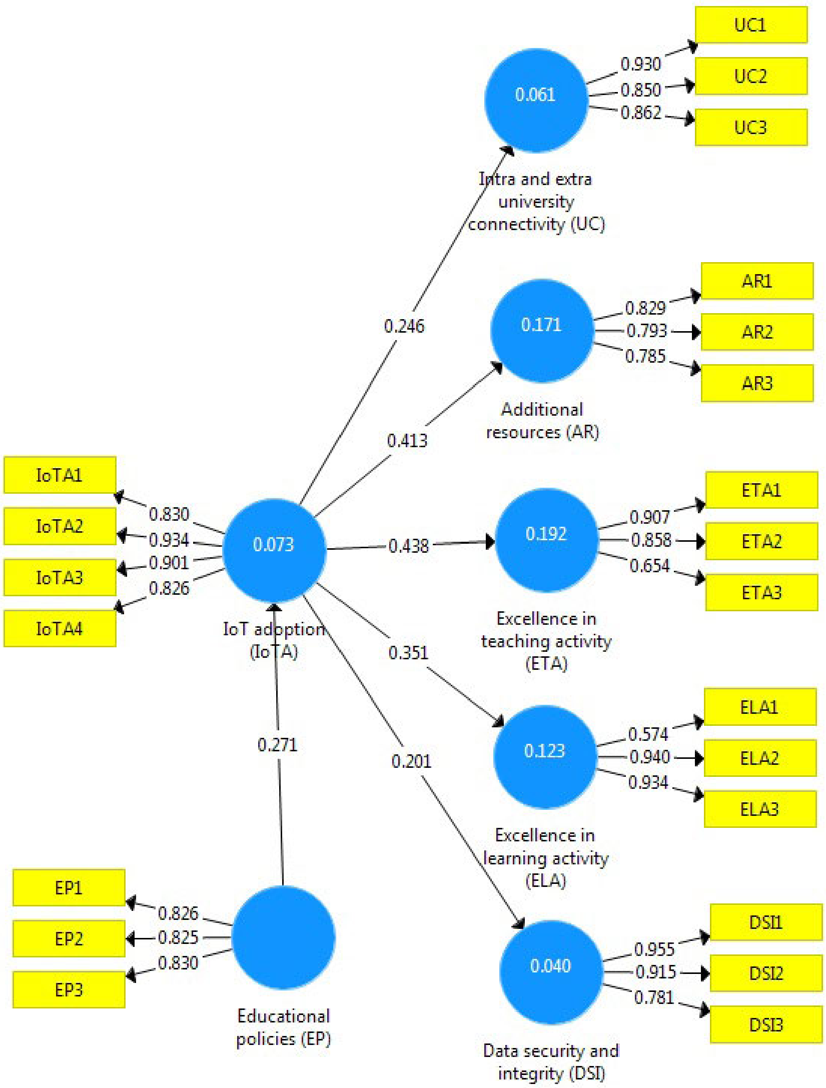

FIGURE 5. Outer model assessment.

suggested and confirmed hypotheses, only three of them are also considered significant.

With regard to the path coefficients (O in table V), the higher the absolute value, the stronger the predictive relation between the latent variables. The adoption of the IoT has the strongest effect (O = 0.438) on excellence in the teaching activity and the weakest effect on data security and integrity (O = 0.201).

With regard to T statistics, according to [64] and [44], for the significance level of 5%, we expect T statistics to be at least 1.96. As indicated in table V, all T statistics are higher than 2.7, therefore the outer model loadings are significant.

For the effect size (f^2), an $f^2 \geq 0.02$ indicates a low effect, an $f^2 \geq 0.15$ indicates and average effect, whereas an $f^2 \geq 0.35$ indicates a strong effect [60] and [61]. Table 5 points to the conclusion that the adoption of the IoT has an average effect on AR, ELA and ETA, respectively, whereas the relationship with EP, DSI and UC is weak (low effect).

TABLE 6. Construct cross-validated redundancy.

Endogenous latent variables	Q^2
Additional resources (AR)	0.104
Data security and integrity (DSI)	0.023
Excellence in learning activity (ELA)	0.071
Excellence in teaching activity (ETA)	0.117
Intra and extra university connectivity (UC)	0.043
IoT adoption (IoTA)	0.054

Q^2 coefficients may be calculated by using the blindfolding method. According to the values in Table 6, all Q^2 coefficients are strictly positive. Consequently, according to [55], there does exist a predictive relevance of the model with regard to the endogenous latent variables.

To wrap up, considering the analyses and the interpretation of the statistical results obtained for the coefficients of determination (R^2), the size and the significance of the path

TABLE 7. University level actions in order to make the most of the IoT.

Action area	Actions/Recommendations
Students	- the presence of the students is achieved in an automated way; - flexible access to courses from any device, anytime, anywhere; - the use of learning patterns based on needs, for adaptive learning. Bob Nilsson argued that IoT devices (e-books, tablets, sensors, virtual reality) may be used to follow and monitor the students in the different aspects of the learning process [13]; - the use of digital scanners or digital highlighters that help turn a manual in a digital text.
Professors	- monitoring the students' progress through digital testing, by means of software and specialized IoT devices; - enhancing the quality of the training-education process through the use of interactive tablets; - connecting with national/international experts in order to create a hybrid teaching environment.
University	- reduction in the energy used to heat the buildings through the introduction of smart heating thermostats; - reduction in water consumption through the introduction of smart sensors; - control over secured access to the university and the classrooms; RFID (Radio-Frequency Identification) and NFC (Near Field Communication) are two of the IoT implementation technologies that can be used to simplify access control and improve security on the premises of the university [4]; - monitoring and optimization of air quality, temperature, humidity and light through the use of sensors; - promoting creativity, operational efficiency, the learning experience [35], and education policies that are more supportive of the adoption of the ICT in the university; - improving the relationships with the students – the IoT offers interactive instruments that allow for real time virtual and customized interaction [4].

coefficients (O and T), the effect size (f^2), as well as predictive relevance (Q^2), we find that the hypotheses suggested in the model are grounded.

D. DISCUSSIONS AND RECOMMENDATIONS

Turning a higher education institution in a smart university is an important step towards the adjustment to a new, knowledge-intensive and interconnected society. The new conditions and restrictions rooted in the COVID-19 pandemic also make it necessary to adopt the ICT as the premise to adopting the IoT and to creating a smart type of education. Table 7 shows the changes that should occur within BUES for the university to make the most of the opportunities that the IoT provides, which can similarly apply to other higher education institutions.

VI. CONCLUSION, LIMITATIONS AND RESEARCH DIRECTIONS

The IoT comes with numerous benefits as well as challenges that should be fully analyzed and understood. Developments related to the ICT, to the knowledge-intensive society as well as to the current pandemic have put additional pressure on the education system, in the sense of intensive ICT adoption and of turning education into smart education. As it emerges from this study, the adoption of the IoT in higher education has a positive influence on excellence in teaching (H3), on additional resources (H2) and excellence in learning (H4). In terms of managerial support and attitude to change, education policies do have an influence on the adoption of the IoT in universities, but that influence is relatively low. The adoption of the IoT in universities also has a positive influence on intra- and extra-university connectivity (H1) and results in challenges related to data security and integrity (H5), but the effect of this influence is rather low. The hypotheses regarding the impact of the IoT on higher education are validated though the SEM analysis of the survey data, through references to the literature as well as to the current status quo on the education environment in Romania. The results of the analyses pointed to the fact that the impact is not major, in other words it does not involve a complete change of the education environment.

Too much technology may also lead to the emergence of vulnerabilities of the information systems and of the IT infrastructures used in education. The wide-scale adoption of the IoT as a technology/instrument specific to the education activity calls for great caution in ensuring data security and integrity, including the specific procedures for disaster recovery. These aspects must be considered primarily in the light of the manner in which malicious software attempts can harm the IT systems in the most critical fields: banking, security, education, healthcare etc. During the pandemic period, when activities unfolded mainly in remote mode and were mediated by the ICT, cyberattacks intensified, including in the education system, and some universities suffered from these attacks.

Our research is not exhaustive and we plan to include in the future research other economic, social, technical, environmental and legal aspects. We will also consider a larger sample, by including several other higher education institutions and stakeholders as well as the interview method. We also envisage to use other instruments to analyze the suggested research model and resort to the comparison method in order to highlight the relationships between constructs and the validity of the hypotheses.

Judging from the incipient stage of the ITC adoption and of the transition to the IoT in higher education in many countries, this study brings additional knowledge about the adoption of the IoT in universities and the transition to a smart university.

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