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Mobile Learning as the Key to Higher Education Innovation: A Systematic Mapping

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ABSTRACT The study of educational innovations has attracted increasing attention from academics and researchers around the world. Educational innovation proposes the implementation of new approaches or practices that are beneficial and make an impact on individuals or academic communities. The current educational model of many higher education institutions (HEIs) was not designed for this generation of ''digital natives''. For this reason, HEIs face the challenge of building teaching strategies that generate meaningful educational experiences. This research seeks to address this issue through a systematic mapping that includes empirical research papers from 2015 to 2020 that study innovations in educational practices using mobile devices. A qualitative and quantitative approach was applied using a four-stage research methodology to evidence innovation in higher education. After employing the selected methodology and applying all the exclusion criteria, 27 papers related to the research topic were identified. Mapping was also performed between the corpus of papers and five dimensions on educational innovation (the purpose of learning, the context of learning, the role of the teacher, the role of the learner, and the evidence of the outcome). The findings reveal that the role of the teacher is the dimension that is least analyzed in innovation initiatives, whereas the most analyzed dimension is the purpose of learning. The goal of this work was to explore and identify educational innovations and unveil uncovered fields of research to generate opportunities for new lines of research in educational innovation.

INDEX TERMS Innovation learning, higher education, m-learning, innovation, systematic mapping.

I. INTRODUCTION

Technological advances of today's world provide inexpensive, fast, new, accessible, portable and digital technology for learners [1]. All these tools, widgets and new technology allow students to create, own, transform, discuss, discard, share, store, and disseminate ideas, opinions, images, and information, and to create and transform identities and communities, all ubiquitously [1]. In the last decade, information and communication technologies have increased at a rate never seen before [2]. Mobile devices, due to their characteristics of mobility and ubiquity, have become very popular and indispensable in our daily lives [3]. Cisco, in its annual Internet Report (2018-2023) published in March 2020, forecasts that smartphones will have very accelerated growth. This means that more than 70 % of the world's population will have a cell phone by 2023 [4]. Mobile technology, in education, has the potential to change the traditional educational paradigm from imposed teaching to cooperative learning [5]. Therefore, the use of mobile devices and their features are transforming and improving current education [6].

Nowadays, learning using mobile devices is linked to almost all knowledge-related activities. Consequently, the use of mobile learning as a strategy for educational innovation is growing at an accelerated rate [7], [8]. The interest shown towards mobile learning has increased in the last years due to the intrinsic characteristics of mobile technology, which are: mobility, ubiquity, interactivity, accessibility, collaboration, utility, privacy, adaptability, portability, multiplatform, flexibility, and universality [9]. Nevertheless, the

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correct deployment of this technology continues to be a challenge for both educational institutions and teachers [10], [11]. Moreover, the use of mobile devices can be a strong factor to improve educational management, to improve graduation rates and diminish drop-out rates [12].

Access to the Internet, the use of mobile devices, social networks, along other digital technologies, facilitate the transformation, generation, exchange, valorization, and dissemination of information (ideas, images, etc.). This information is transformed into opinions and debates that take place outside the classroom, in other words, outside the control and jurisdiction of the educational institution, transforming established educational practices and standards and challenging old notions of inclusion [1].

In recent years, new generations of students known as ''digital natives'' have developed a set of technological skills useful for their education [13], [14]. They grew up exposed to digital technologies, Internet access, social networks, mobile devices and are always attracted to cutting-edge technologies [15], [16]. This generation has different ways of discovering entertainment, communication, technology, and learning [17]. As a result, educational institutions should generate teaching spaces and curriculum in line with the study preferences of new generations and create innovative learning environments that are adequate to the current work environment [2].

The correct use of mobile devices in educational institutions can be enhanced by the creation of innovative environments that engage students in their learning [18]. These spaces are designed to commit students to their education and thus achieve improved learning outcomes [19]. Besides, learning new skills through mobile technology can generate self-confidence, self-determination, and self-efficacy in students [20], [21]. These new skills foster the ability to perform certain ''complex'' tasks and achieve academic goals [6].

Mobile technology would enable educational institutions to use a set of features that provide flexibility in learning and would serve as training for both teachers and students for the new digital era [2]. To harness student interest and exploit the benefits of mobile learning in teaching and learning, teachers need to improve their current methodologies and practices [20]. Educational institutions must also design an academic offer that allows the integration of technology as a support for learning [20], [21]. Due to the accessibility and opportunities that this technology offers, it is important to investigate how mobile devices are used in higher education innovation. That is why this work, through a systematic mapping (SM), aims to explore and identify educational innovations and find uncovered spaces to generate opportunities for new lines of research in educational innovation using mobile devices. The research objectives for this work are detailed in Table 1.

To give the reader a common understanding of mobile learning, we use this Section to introduce the topic; the rest of the article is organized as follows: Section 2 describes the acceptance of mobile technology in education, Section 3 presents initiatives of mobile learning in education, Section 4 shows the methodology used to conduct this work, Section 5 presents the results obtained, Section 6 provides the discussion of the findings, Section 7 indicates the limitations of the systematic mapping, and finally, Section 8 provides conclusions and future work.

TABLE 1. Research objectives and motivation.

Research objectives (RO) & research questions (RQ)	Motivation
RO1. Establish the number of studies with the keywords used in the search string associated with this work. RQ1. What are their titles, authors, institutional affiliations, and countries? RQ2. Which open-source journals have published them?	Know the main experts in the field of mobile educational innovation and the main sites (journals) where new initiatives in this field are published.
RO2. Find out what research dimensions that have been addressed in relevant studies. RQ3. What are the most researched dimensions? RQ4. What are the least researched dimensions?	These questions allow researchers to identify the imbalance that exists in research efforts and the current needs in the field of educational innovation through mobile devices.

II. ACCEPTANCE OF MOBILE TECHNOLOGY IN EDUCATION

Educational methodologies such as a master class or a lecture have been traditionally used in university contexts [22]. These educational strategies promote learning by memorization and not by skill development (reading, sharing, listening and doing) [23]. As a result, the introduction of mobile technologies in teaching, together with an appropriate pedagogical design, are expected to promote and generate a transformation in higher education learning [24].

The Technology Acceptance Model (TAM), and its extended models, have provided evidence of characteristics that can influence students' adoption of mobile technology [2], [25]. Innovation, external influence (recommendations), perceived usefulness, perceived ease of use, self-efficacy, and positive attitude towards technology can lead to students using mobile devices in learning [26]. For example, this model was used at a South Korean University to analyze the acceptance and intention to use of mobile learning among university students. It was determined that a positive attitude toward technology had a directly proportional effect with the intention to use and accept mobile technology [26]. Meanwhile, in China, usefulness (short and long term) and personal innovativeness were perceived to positively influence mobile learning adoption among university students [3]. Another study of undergraduate students and medical professionals indicates that external influence (recommendation to use mobile learning) and self-efficacy in performing tasks using this technology are determinants of students' intention to use mobile devices [25]. Other factors related to the adoption of

mobile learning in higher education were: confidence, character, personal capabilities, and context [27]. Based on the results, as long as the factors presented above are taken into account, mobile learning could be one of the most developed strategies in educational environments in the future [25], [27].

Places such as work, public transport, or the car have become recurrent spaces for informal learning [28]. The use of mobile technologies facilitates learning outside the classroom, and ubiquity features ensure access to educational material whenever and wherever the student wants. Just-in-time learning to take advantage of unexpected free time, make mobile technology a tool with great potential that can be embraced by students with these needs [28].

The use of mobile technology creates an opportunity for teachers to reinvent traditional teaching methods and generate a change in the educational methodology [7]. This would transform the traditional learning model into a more flexible one, capable of offering teachers and students access to multiple sources of information and a change in the structure of learning [6]. In the process for teachers and educational institutions to find the best ways to use mobility to drive learning, other learning strategies could be explored and combined to create effective learning experiences for students [28]–[30].

III. USE OF MOBILE DEVICES IN EDUCATION

The development of different types of mobile devices can be considered the most important technological contribution in recent years, causing a social revolution, due to the omnipresence of this technology in all aspects of our lives [2], [31].

The United Nations Educational, Scientific and Cultural Organization (UNESCO) promotes the learning of skills and competencies through mobile technology, which is considered a tool for teaching and training future professionals. This organization states that the use of mobile devices not only allows ubiquitous access to educational and learning material but can also improve learning achievements in students [32].

The UNESCO-UNEVOC program promotes the use of mobile technology and devices to improve educational initiatives around the world [32]. The three most significant examples are the Paraguay Foundation, which created a mobile teaching-learning system that can be used online and even in rural areas that do not have Internet access [32]. The Federal Institute for Vocational Education and Training in Germany presented the Social Augmented Learning project, which includes the use of mobile devices for teaching and training professionals [32]. The National Council for the Federal Network of Vocational, Scientific and Technological Education Institutions in Brazil developed a mobile learning program that can be used in formal and informal education [32].

Moreover, there are several kinds of research that have been performed based on mobile and associated technologies for the benefit of education. For example, improving the achievement of clinical competencies in psychology graduate students [19]. Improving communication skills (listening, speaking, reading and writing) in students [33]. Blended learning (training, supervision and mentoring) in healthcare workers [34]. Design of security services and countermeasures to be implemented to ensure safe examination with mobile devices [35]. Learning programs for radiology internists and professionals with limited time for training [36] and learning different languages, especially English through educational apps and games [37]–[39] and many additional initiatives.

When discussing mobile learning it is important to define it properly, which is not easy because there are different definitions in the literature, probably due to the novelty of this field of study. Examples of such definitions are:

- Mobile learning is the acquisition of knowledge, skills and attitudes by leveraging the use of mobile technology, anywhere and anytime that will produce changes in behavior [27], [40].
- Mobile learning is a ubiquitous communications technology with intelligent user interfaces [41].
- Mobile learning is a complement to e-learning and together they enable the teaching and learning process to be learner-centered [35].
- Mobile learning is an innovative technology that can be integrated into the educational system using different user-friendly applications [33].
- Mobile learning refers to the technology used in learning that leverages mobile technologies and devices [8].
- Mobile learning refers to the technology that is used in learning and that takes advantage of mobile technologies and devices [19].

Some previous research has proposed a techno-centric definition by choosing a particular device and a specific form of use. However, despite not having a precise definition, they all agree that at present, mobile technology in education plays a significant role regardless of the space and place in which the learning activity occurs [31].

Although many teachers and educational institutions are encouraging the use of technology in their classrooms, a review on collaborative learning revealed a negligible number of studies on mobile technology [18]. Initiatives found reveal the effects produced in education when using mobile devices seem to be better than when using a desktop computer [42]. A review examined articles on mobile applications used for scientific learning. The results indicate that to adequately design mobile applications, there must be studies with specific characteristics and a theoretical basis that focuses on the learning results associated with that particular knowledge [43]. These authors propose that the use of mobile devices is appropriate when both teachers and educational institutions can provide innovative learning experiences that match the learning objectives. In this regard, an SM is needed to identify which innovative practices are being used to support teaching and learning using mobile devices.

Mobile learning in education has been a topic of research for several years, but so far there is little or no research on what constitutes innovative or disruptive mobile learning, especially for students in higher education. The mapping

performed in this article provides original, evidence-based and relevant information on this topic.

In this research paper, only innovative works that will contribute to effective learning were included for the proposed analysis. This review represents a complete study to evidence or discover gaps for future initiatives in the field of innovation in education using mobile devices.

IV. INNOVATION THROUGH MOBILE LEARNING

Before discussing the design and implementation of the SM, it is useful to clarify what is meant by innovation using mobile devices. Thus, a literature search was previously conducted on articles that studied innovation in education using IT in a general way and mobile devices in particular, in order to find the dimensions that should be addressed in an educational innovation study using mobile devices.

Innovation through mobile devices refers to the use of all methodologies designed to take advantage of the characteristics of these devices with the intention of making learning happen. References [44]. Innovative practices are very different from normal and traditional practices adding the effective use of mobile technologies, which allow students to create, transform, discuss, share, store and disseminate ideas and opinions, allowing the creation and transformation of identities and communities, all this in a ubiquitous way [1], [45].

Other definitions focus on innovations using IT in a general way, but their results can be an aid to the work being done. For example, one research defines innovation as new ideas or practices that are beneficial and leave an impact on individuals or communities [46].

Innovation in education using information technologies has been studied in several research papers. For instance, one article points out that there are four dimensions to evidence IT-based innovations [47]:

- teaching practices (including methods, roles and collaborations),
- student practices (including activities and roles),
- IT practices (the roles and functions performed by IT in the case study), and
- types of IT used in schools.

Other work proposes four dimensions for the selection of innovative practices in education using technology [22]:

- There was evidence of significant changes in teacher and student roles, curriculum objectives, assessment practices, and/or instructional materials or infrastructure.
- Technology played a substantial role in the practice/nature of the technologies involved.
- There was evidence of measurable positive student outcomes.
- The practice was sustainable and transferable.

In a comparison of various innovative practices, pedagogical approaches to the nature of teaching and learning activities were added [22]. The results identified six dimensions as the most important aspects of any academic implementation using IT:

- Intended academic objectives of the innovative practices
- Pedagogical role(s) of the teacher(s).
- Role(s) of students.
- Nature and sophistication of IT used.
- Multidimensional learning outcomes exhibited.
- Classroom connectivity.

One research initiative proposes four dimensions for innovation using mobile devices [48]:

- Domain and space configuration.
- Student roles.
- Teacher roles.
- Curriculum.

Another research systematically studied the transformation processes in schools that widely adopted the use of IT. Four innovation domains were defined for analysis, one for each major area of impacts that IT has created in the school environment [44]:

- The purpose of learning.
- The context of learning.
- The role of the teacher.
- The role of the learner.

The papers presented above differ in the perspectives they adopted in studying IT-supported innovations in education. Each paper resolves a different hypothesis, some focus on the impact of IT on some aspects of learning and teaching, others on academic change and few dimensions were explicitly linked to the use of technology and only one was related to the use of mobile devices [44], [48], [49].

Innovation in education through technology and mobile devices goes far beyond ubiquitous access to educational material. It is necessary that through all the features this technology offers, innovative teaching methods such as cooperative/collaborative learning [11], [50], exploratory (outside the classroom) [51], game-based [52], behavioral [53], cognitive [54], constructivist [55], conversational [56], permanent [57], and informal [58] are promoted.

Analyzing the dimensions reviewed in previous works, this research proposes the five dimensions that are shown in Table 2. These dimensions encompass the main characteristics necessary for innovation in higher education practices using mobile devices.

V. METHODOLOGY

An SM was used as a methodology to conduct this research; the objective of an SM is to present and categorize published research within a time frame and those that are available on a specific topic or research trend [59]. The SM provides a summary of the results that serve to give readers an overview of the studied topic. Also, in this review, a one-level backward snowballing technique was used, which consists of analyzing the reference list of the selected articles and finding other valuable research that can contribute to the investigation [45]. This technique allows the discovery of new pertinent work and research that otherwise would not have been considered even with the keywords of the search.

TABLE 2. Dimensions of educational innovations.

Dimension	Detail
The purpose of learning	This dimension contains the academic curriculum that includes the learning objectives and challenges to be achieved using innovative practices, and the nature of the task or activity linking and integrating mobile devices.
The context of learning	This dimension contains everything related to the place or time in which learning takes place, pedagogical practices, spatial delocalization, and classroom connectivity.
The role of the teacher	This dimension contains educators and their relationship with students, pedagogical roles of the teacher.
The role of the learner	This dimension contains the role of the learner as an active or passive agent.
Evidence of results	This dimension contains evidence of measurable learning outcomes.

The search string was adapted to guarantee its correct functioning in each database. Three databases were selected: Web of Science (WOS), Scopus and IEEE Xplore. These databases were selected because of their extensive content in high quality and high impact journals in different disciplines, including science education and educational technology. In addition, there were several articles that were repeated in the three chosen repositories. Thus, to avoid more overlapping, no other databases were added in this research.

A. SEARCH STRING

To perform the search for the required items, an initial search string was created and thereafter similar terms were identified for the search of the items. The search string with the alternative or replacement terms is presented below:

(((mobile learn*) OR (mobile supported learn*) OR (mobile enhanced learn*) OR (mobile supported teach*) OR (mobile enhanced teach*) OR (mobile didactics) OR (mobile teach*) OR (mobile technolog*) OR (mobile digital technolog*) OR (mobile educational technolog*) OR (mobile device) OR (mlearn*) OR (m-learn*) OR (handheld) OR (tablet) OR (ipad*) OR (android) OR (app) OR (app-based) OR (smartphone)) AND ((disrupt*) OR (transform*) OR (innovat*) OR (re-vision*) OR (reimag*) OR (renew) OR (re-new) OR (redefin*) OR (re-defin*) OR (future-oriented) OR (future-focus*) OR (future-proof) OR (paradigm shift) OR (paradigm change) OR (pioneer*) OR (change* teaching approach*) OR (enhance* teaching approach*) OR (change* teaching strateg*) OR (enhance* teaching strateg*) OR (change* learning practice*) OR (enhance* learning practice*) OR (change* learning approach*) OR (enhance* learning approach*) OR (emerging practice*) OR (new practice*) OR (best-practice*) OR (exemplary-practice*) OR (emerging teaching approach) OR (new teaching approach) OR (emerging teaching strateg*) OR (new teaching strateg*) OR (emerging learning practice*) OR (new learning practice*) OR (emerging learning approach) OR (new learning approach)) AND ((higher educa*) OR (university students) OR (education*) OR (students*) OR (engineering students*) OR (undergraduate) OR (college))).

The time window of the search was limited to 2015 – 2020, due to the high risk of theoretical and practical expiration in technological innovations using mobile devices for higher education [7].

1) FIRST STEP

Due to limitations of access to various research and scientific journals, this search focused only on papers published in open access journals.

2) SECOND STEP

Once the results were obtained from all the databases, exclusion criteria were applied, these were as follows:

- Discard duplicate articles.
- Discard articles that were not written in English.
- Discard articles that were not from journals located in the first two quartiles of the SCImago journal ranking (SJR). This decision was made because we are looking for high quality papers published in journals with the highest impact index (Q1 & Q2).

3) THIRD STEP

All irrelevant papers were discarded by reading the abstract of the article.

4) FOURTH STEP

In this step, the one-level backward snowball technique was applied to add new papers to the corpus of articles. These articles correspond to papers that did not have in their titles and abstracts the keywords of the search string. Moreover, they may be hosted in different scientific databases, the only similarity to the initial search was the years adopted for the SM (2015-2020).

The data extractions performed on the final set of items were the following:

1) Bibliographic Information: Title, year, first author, geographical location, number of citations in Scopus, journal, SJR and JCR quartile.

2) Argument: How the research was implemented and to what dimension of innovation it contributes.

TABLE 3. Systematic mapping on mobile learning in education.

Source	2015	2016	2017	2018	2019	2020	All
Total of articles	0	2	3	0	0	2	7

3) Findings: Information required for the research objectives.

VI. SYSTEMATIC MAPPING RESULTS

A. SYSTEMATIC MAPPINGS AND LITERATURE REVIEWS

In the findings of the search conducted, including the backward snowballing technique, several initiatives were found that focused on a systematic or normal literature review with mobile devices used in education (See Table 3). The first work is related to augmented reality (AR), the authors note that the intervention of creative and playful aspects can be transformative elements of educational interaction. Therefore, AR together with mobile learning can generate innovative frameworks in education [7].

Another research analyses innovation in higher education using a survey and a comparative study in three countries (USA, China, and Turkey) [60]. Their results indicate that mobile devices are widely used in informal learning, but there are very few mobile learning experiments guided by their teachers [60]. The authors, therefore, encourage educational institutions and teachers to lead the change for the use of mobile devices in education [60]. Two reviews cover the use of mobile learning for science [8], [43], the results of the first paper highlight the need for more research in this area due to the scarcity of published work, this invites researchers to analyze other educational levels and report the failed results in order not to repeat them [8]. The findings of the second paper suggest new mobile applications should allow measuring students' cognitive outcomes and skill-based outcomes such as problem-solving [43]. Another review analyses a disruptive innovation in the field of modern medicine [61]. This study shows that the use of mobile devices can be used as a driver for more advanced ultrasound training available to everyone. The systematic review by Martin *et al.* [62] includes mobile learning as a pillar of emerging learning technologies and environments. Finally, Krull and Duart [63] identify emerging trends in mobile learning research in higher education with a systematic review from 2011 to 2015. The findings indicate that the purpose of mobile learning studies is to evaluate the effectiveness of this technology in higher education. Furthermore, also tells us that the most recent research topics are related to mobile learning and social networks, games and augmented reality.

Our work performs an SM to find initiatives in educational innovation using mobile learning in all possible contexts. For that purpose, a search string adapted for each one of the scientific databases involved in this research was used.

B. INITIAL SEARCH, EXCLUSION, ANALYSIS AND BACKWARD SNOWBALLING

The first step yielded a total of 609 articles related to the search performed. In the second step, the exclusion criteria were applied and the number of papers was reduced to 114. As a third step, a complete reading of all the articles was carried out to further bias the search and obtain the most representative papers for the objectives of our research. After the application of third step, 38 articles were selected as shown in Table 4. Figure 1 illustrates the four-step model for the proposed SM.

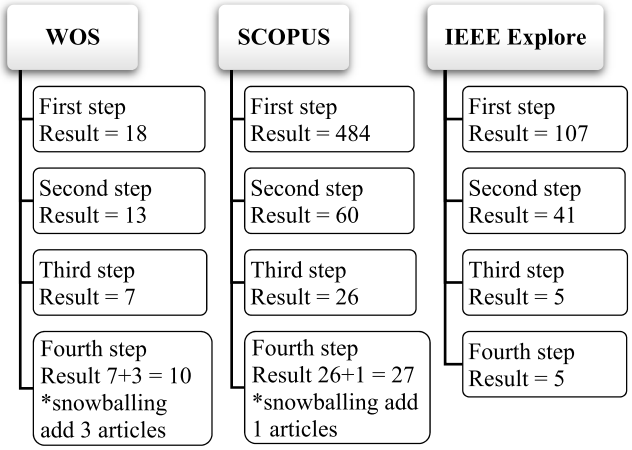

FIGURE 1. Four-stage method for systematic mapping.

In the fourth step, the backward snowballing technique was applied. Four additional articles related to the SM topic were found, giving a total of 42 final articles, as shown in Table 5. Due to the worldwide pandemic and lockdown, the year 2020 was a very peculiar year, in which a massive digital transformation took place and different virtual scenarios and technologies were abruptly adopted all over the world. Education is a clear example in which the adoption of new initiatives and innovations with technology took off incredibly [64]. Most probably, that is why 2020 has the largest number of initiatives using mobile learning as seen in Table 5.

The search string limits the scope of the exploration of articles related to the research objectives.

TABLE 4. Selected works.

Source	2015	2016	2017	2018	2019	2020	All
WOS	0	1	1	1	0	4	7
SCOPUS	1	2	2	7	5	9	26
IEEE Xplore	1	0	0	1	2	1	5
Total of articles	2	3	3	9	7	14	38

The main reason for the exclusion of the studies was the fact that they did not propose innovation in education with the use of mobile devices, or they performed a literature review

TABLE 5. Relevant final works.

Source	2015	2016	2017	2018	2019	2020	All
Total of articles	5	3	3	9	7	15	42

on mobile learning, or their focus was not educational, or they were not relevant to the research topic and many of the works focused on middle and initial education and not on higher education.

C. RESEARCH OBJECTIVES

1) OBJECTIVE 1

Table 6 and Table 7 display all the studies selected for this work and some data extracted such as name, first author, nationality, year of publication, the journal where it is published, quartiles (SJR/JCR) and the number of citations (Scopus/WoS/IEEE Xplore). The publications are ordered from the oldest to the most recent publication. As can be seen in Table 7, Scopus is the repository with the most published papers, with a total of 26 articles. This is followed by WoS with 7 articles, and finally, IEEE Xplore with 5 articles. None of the researchers contributed with more than one article, all of them have only one initiative in these 5 years. The journals contributing most to this SM are International Journal of Emerging Technologies in Learning with five articles [65]–[69], IEEE Access with four articles [70]–[73], followed by IEEE Transactions on Learning Technologies with three articles [24], [28], [74]. The most cited article in the three databases was ''A self-adaptive multi-agent system approach for collaborative mobile learning'' by De la Iglesia *et al.* [74] with a total of 41 citations, 16 in Scopus, 9 in WoS and 16 in IEEE Access. But there was one article, ''Mobile technology: Creation and use of an iBook to teach the anatomy of the brachial plexus'' by Stewart and Choudhury [75], with a total of 42 citations, but only indexed in two databases: Scopus with 22 citations and WoS with 20 citations.

The best classified articles (Q1/Q1), according to the publication quartile of SJR and JCR, were eight: ''Mobile technology: Creation and use of an iBook to teach the anatomy of the brachial plexus'' of Stewart and Choudhury [75]; ''Explore the ubiquitous learning on Campus: A friendship-based knowledge diffusion approach'' of Zheng *et al.* [70]; ''Evaluation of app-based serious gaming as a training method in teaching chest tube insertion to medical students: Randomized controlled trial'' of Haubruck *et al.* [76]; ''Mobile technology in e-learning for undergraduate medical education on emergent otorhinolaryngology-head and neck surgery disorders: Pilot randomized controlled trial'' of Lee *et al.* [77]; ''Recommending Personalized Summaries of Teaching Materials'' of Cagliero *et al.* [71]; and ''Using a Google Glass-Based Classroom Feedback System to Improve Students to Teacher Communication'' of Zarraonandia *et al.* [72]; ''A blended learning system to improve motivation, mood state, and satisfaction in undergraduate students: Randomized controlled trial'' [78], and ''C-POS: A Context-Aware Adaptive Part-of-Speech Language Learning Framework'' [73]. Table 7 analyzes the country/nationality of the first author of the articles.

It is important to define and keep in mind that the country with the most presence in this analysis is the USA with seven initiatives, one in 2015 [79], another in 2017 [17], two in 2018 [80], [81], one in 2019 [82], and finally two in 2020 [83], [84]. Researchers from the USA have had initiatives for each year of our analysis, except for the year 2016. This is followed by Spain with five articles, one in 2016 [28], another one in the year in 2019 [72], and three in 2020 [78], [85], [86], and United Kingdom (UK) with three articles, the first one in the year 2015 [75], another one in the year 2016 [87], and the last one in the year 2018 [88]. These results demonstrate the surprising interest in adoption and innovation in education through mobile devices in these two countries (USA and UK).

On the other hand, there are contributions from China [65], [70], Australia [76], [89], and Taiwan [77], [90] which present two studies each. All these findings contrast with the research of Traxler [1], who points out in his research that learning with mobile devices in UK universities is not a recent practice, since mobile learning has been practiced for a decade, as in universities in other parts of Western Europe, America and Asia [1], [91].

As the results indicate, throughout these years, projects have been implemented focusing on mobile technologies, formal and informal, short-term, and institutional implementations and deployments. The definitions centered on the learner and learning mobility and its characteristics allow crossing contexts, for example, from home to school, formal to informal, and from the library to a park.

2) OBJECTIVE 2

After presenting the initial findings, a more in-depth investigation was conducted based on multiple aspects previously defined as dimensions of educational innovation (see Table 2). Table 8 illustrates the dimensions identified in each work or initiative reviewed. For the construction of this table, a literature review matrix was created, which is a visual presentation used to demonstrate, understand and compare the ideas of each author [92].

In the fourth section, a new model was proposed with 5 dimensions that representing all the other models analyzed in the initiatives that discuss innovation in higher education, as can be seen in Table 2. All the dimensions suggested by the authors can be characterized by these five chosen. Kozma [47] proposes four specific dimensions that all innovation research using IT must fulfill. In our research, one more dimension was added (evidence of results), which is defined in most articles of this work.

The most discussed and evidenced dimensions in the articles were the purpose of learning (38 articles) and the role of the learner (34 articles). The second most discussed

dimension was the evidence of results in 32 articles, followed by the context of learning in 21 articles and finally in 18 articles, the least discussed dimension was the role of the teacher in the innovation of education using mobile devices. All dimensions will be described in detail in Table 8.

D. DIMENSIONS OF EDUCATIONAL INNOVATION WITH MOBILE DEVICES

1) THE PURPOSE OF LEARNING

This dimension contains everything related to the curriculum, including the learning objectives and challenges to be achieved using innovative practices, and the nature of the task or activity linking and integrating mobile devices. This dimension is extremely important because the purpose of learning must be clear and specific; of the 42 articles, only four do not describe it in depth. In other words, 90.5 % of the papers include the purpose of the work in their initiatives, for example, Kali *et al.* [24] uses innovative mobile technologies and local resources intending to develop skills needed to analyze works of art. On the other hand, Stewart and Choudhury [75] creates a digital book for use on an Apple iPad, to enhance and promote students' deep learning. One of the most innovative ways of teaching which have been studied are serious games, and in their topic, Haubruck *et al.* [76] uses a serious game that can be used with mobile devices (smartphone and tablets) and also with a laptop or a PC that has a webcam [76]. The purpose of this serious game in learning was to train students with the skills necessary for the insertion of a chest tube in a patient as an emergency procedure. All of these publications had positive results and met the proposed objective.

2) THE CONTEXT OF LEARNING

This dimension contains everything related to the place or time where learning takes place, pedagogical practices, spatial delocalization, and classroom connectivity. The spaces and places where learning occurs with the help of mobile devices are variables especially addressed due to the characteristic of ubiquity provided by mobile technology. Likewise, innovative pedagogical practices and the necessary technological resources must be part of mobile learning initiatives. The use of mobile applications on smartphones has great potential to support field learning. Wang *et al.* [93] demonstrates a theoretical design of a mobile application called GeoFARA that uses augmented reality and would serve for university students to gain a better geographical understanding of an urban area in fieldwork (away from the classroom). Zheng, Pan, and Peng proposes a knowledge dissemination model using mobile devices along with WiFi networks for use in a smart campus [70]. This initiative moves knowledge and the way it is transmitted away from the classroom and creates a need for mobile connectivity access technologies within a university campus.

3) THE ROLE OF THE TEACHER/PROFESSOR

The role that the teacher plays in educational innovation using mobile devices is a topic that has been least involved in the research reviewed; only 40.9 % of the analyzed works take this dimension into account. Most innovation initiatives include the use or design of a mobile application and do not take into account the teacher's perspective or whether he/she is trained to lead the use of mobile devices in the classroom. The findings obtained in this dimension prove mobile devices are widely used in informal learning, but there are very few experiments of mobile learning guided by teachers, as indicated by Hao *et al.* [60]. When the teacher is a key part of the innovation initiative they can influence the engagement of their students and encourage independence and peer collaboration, they are also more likely to be involved in the learning process and integrated into the class, as Hegarty and Thompson successfully achieved and describe in their publication [94]. Timely feedback is also important, Zarraonandia *et al.* [72] supports constant monitoring and effective feedback using a wearable device and mobile devices in their classroom. This initiative allows improving the teacher-student relationship which can result in motivation to learn.

4) THE ROLE OF THE LEARNER

This dimension expresses whether the student's perspective as the main element of the educational process was considered. In other words, the innovation initiatives in teaching practice focused on the student to be developed. The results indicate this dimension, together with the purpose of learning, is the most analyzed in the articles found. Some educational uses of mobile devices result in negative experiences for students who have difficulties with technological tools [24], [95]. Also, mobile devices can become a distractor due to access to social networks and the Internet [29]. Consequently, mobile pedagogical initiatives should be student-centered and achieve improvements in perceptions and collaborative learning [96].

The work presented by Valenzuela-Valdés *et al.* [28] provides students with ubiquitous learning environments and with the necessary material to implement free learning. In addition, it allows students to take advantage of the capabilities of their mobile devices. Uncertainty and fear of failure can cause students to underperform and drop out of college [97]. This is why Nguyen, *et al.* developed a mobile application, with various pedagogical approaches, to guide students in their careers [97]. This app features innovative augmented reality themes and gamification of education.

5) EVIDENCE OF RESULT

This dimension is the second most studied in the selected articles, 32 investigations show a piece of the results that the proposed innovative practice provoked in the students. Neufeld and Delcore present the results of survey analysis, a photo journal, and focus groups to better understand the phenomenon of technology acceptance [80]. This institution designed a program called "DISCOVERe" in 2014 with the intention of developing ways of teaching that involve tablets as a teaching and learning tool. The results are positive and

TABLE 6. Relevant studies on innovation education with mobile devices (2015-2020).

Article	First Autor	Journal	SJR/JCR	Citations S/W/I
[75]	Stuart Stewart	Anatomical Sciences Education	Q1/Q1	22/20/0
[79]	Robert Robinson	PeerJ	Q1/Q2	13/7/0
[89]	Janie Brown	Computers Informatics Nursing	Q2/Q4	20/16/0
[74]	Didac Gil de la Iglesia	IEEE Transactions on Learning Technologies	Q1/Q2	16/9/16
[24]	Yael Kali	IEEE Transactions on Learning Technologies	Q1/Q2	4/6/9
[87]	Kieran Mcdonald	Research in Learning Technology	Q2/NO	8/7/0
[28]	Juan Valenzuela	IEEE Transactions on Learning Technologies	Q1/Q2	7/5/6
[98]	Sertac Arabacioglu	Journal of Baltic Science Education	Q2/Q3	11/9/0
[93]	Xiaoling Wang	International Journal of Geo-information	Q2/Q2	1/0/0
[65]	Wang Lin	International Journal of Emerging Technologies in Learning	Q2/NO	4/3/0
[17]	Jean Gambo	Computers Informatics Nursing	Q2/Q4	0/6/0
[70]	Wei Zheng	IEEE Access	Q1/Q1	2/1/0
[97]	Nguyen	International Journal of Educational Technology in Higher Education	Q2/Q2	5/5//0
[90]	Shu-kung Hu	Sustainability	Q2/Q2	7/6/0
[76]	Patrick Haubruck	Journal of Medical Internet Research	Q1/Q1	13/10/0
[99]	Tsoghik Grigoryan	Research in Learning Technology	Q2/NO	4/2/0
[88]	Roxie Christ	Plos One	Q1/Q2	7/9/0
[80]	Philip Neufeld	Journal of Information Technology Education	Q2/NO	4/4/0
[77]	Li Ang Lee	Journal of Medical Internet Research	Q1/Q1	7/0/0
[81]	Mina Makary	Academic Radiology	Q1/Q2	2/1/0
[71]	Luca Cagliero	IEEE Access	Q1/Q1	5/2/0
[72]	Telmo Zarraonandia	IEEE Access	Q1/Q1	5/2/2
[94]	Bronwyn Hegarty	Journal of Information Technology Education	Q2/NO	8/5/0
[19]	Carol Choo	International Journal of Environmental Research and Public Health	Q2/Q2	0/0/0
[100]	Oscar Herrera	Sensors	Q1/Q2	4/3/0
[66]	Mohammed Abugohar	International Journal of Emerging Technologies in Learning	Q2/NO	8/4/0
[82]	Emily Johnson	Journal of the Medical Library Association	Q1/Q2	3/2/0
[67]	Jairo Eduardo Díaz	International Journal of Emerging Technologies in Learning	Q2/NO	0/0/0
[78]	Mario Lozano-Lozano	Journal of Medical Internet Research	Q1/Q1	2/2/0
[101]	Marc Levin	Perspectives on Medical Education	Q1/NO	1/0/0
[85]	Dolores Parras-Burgos	Applied Sciences	Q1/Q2	1/1/0
[83]	Julia E.Winter	Journal of Chemical Education	Q2/Q3	0/0/0
[86]	Vicente Camacho	Electronics	NO/Q2	0/0/0
[84]	Amy H. Deeken	Histopathology	Q1/Q3	4/2/0
[102]	Samad Sepasgozar	Applied Sciences	Q1/Q2	6/4/0
[103]	Vivian Wing Yan Lee	International Journal of Mobile Learning and Organisation	Q1/NO	2/0/0
[68]	Binar Kurnia Prahani	International Journal of Emerging Technologies in Learning	Q2/NO	2/1/0
[64]	Camilo Lellis-Santos	Advances in Physiology Education	Q2/Q4	1/0/0
[104]	Manbir Nagra	Journal of Medical Systems	Q2/Q2	2/1/0
[69]	Pangkuh Ajisoko	International Journal of Emerging Technologies in Learning	Q2/NO	1/0/0
[73]	Shazia Maqsood	IEEE Access	Q1/Q1	0/0/0
[105]	Ruti Gafni	Journal of Information Technology Education	Q1/NO	0/5/0

* S: Scopus, W: WoS, I: IEEE Xplore

recommend the use of mobile devices in education. Another research shows the result of the analysis of a mixed research method (observation of teaching and learning in the classroom & surveys and interviews) for the use of mobile devices and virtual reality (VR) [103]. The findings allow educators to reflect on how to design new learning experiences through mobile devices and VR that allow better assimilation of educational content. On the other hand, Gafni *et al.* [105] presents the results of the analysis of surveys to groups of people who studied foreign languages and used the MALL Duolingo on a mobile device. The results suggest that users of the Duolingo MALL app find the mobile learning assistant useful and accessible. In addition, it is easy to use, and using it enhances and stimulates language learning.

TABLE 7. First author, country, database and years of selected articles (2015-2020).

Article	First author	Country	Database	Year
[75]	Stuart Stewart	UK	WoS	2015
[79]	Robert Robinson	USA	WoS	2015
[89]	Janie Brown	Australia	WoS	2015
[74]	Didac Gil de la Iglesia	Switzerland	IEEE Xplore	2015
[24]	Yael Kali	Israel	Scopus	2015
[87]	Kieran Mcdonald	UK	Scopus	2016
[28]	Juan Valenzuela	Spain	Scopus	2016
[98]	Sertac Arabacioglu	Turkey	WoS	2016
[93]	Xiaoling Wang	Holland	Scopus	2017
[65]	Wang Lin	China	Scopus	2017
[17]	Jean Gambo	USA	WoS	2017
[70]	Wei Zheng	China	IEEE Xplore	2018
[97]	Nguyen	Finland	Scopus	2018
[90]	Shu-kung Hu	Taiwan	Scopus	2018
[76]	Patrick Haubruck	Australia	Scopus	2018
[99]	Tsoghik Grigoryan	United Arab Emirates	Scopus	2018
[88]	Roxie Christ	UK	Scopus	2018
[80]	Philip Neufeld	USA	Scopus	2018
[77]	Li Ang Lee	Taiwan	Scopus	2018
[81]	Mina Makary	USA	WoS	2018
[71]	Luca Cagliero	Italy	IEEE Xplore	2019
[72]	Telmo Zarraonandia	Spain	IEEE Xplore	2019
[94]	Bronwyn Hegarty	New Zealand	Scopus	2019
[19]	Carol Choo	Singapore	Scopus	2019
[100]	Oscar Herrera	Mexico	Scopus	2019
[66]	Mohammed Abugohar	Saudi Arabia	Scopus	2019
[82]	Emily Johnson	USA	Scopus	2019
[67]	Jairo Eduardo Díaz	Colombia	Scopus	2020
[78]	Mario Lozano-Lozano	Spain	WoS	2020
[101]	Marc Levin	Canada	Scopus	2020
[85]	Dolores Parras-Burgos	Spain	WoS	2020
[83]	Julia E.Winter	USA	Scopus	2020
[86]	Vicente Camacho	Spain	Scopus	2020
[84]	Amy H. Deeken	USA	WoS	2020
[102]	Samad Sepasgozar	Australia	Scopus	2020
[103]	Vivian Wing Yan Lee	Hong Kong	Scopus	2020
[68]	Binar Kurnia Prahani	Indonesia	Scopus	2020
[64]	Camilo Lellis-Santos	Brazil	Scopus	2020
[104]	Manbir Nagra	UK	WoS	2020
[69]	Pangkuh Ajisoko	Indonesia	Scopus	2020
[73]	Shazia Maqsood	Pakistan	IEEE Xplore	2020
[105]	Ruti Gafni	Israel	snowballing	2020

VII. DISCUSSION

The first objective of the research was correctly fulfilled, and the results can be seen in tables 6 and 7. For the fulfillment of the second objective, five dimensions were proposed, which can be used in future analyzes of educational innovation. The most studied dimensions among researchers are in this order:

The purpose of learning, the role of the learner, evidence of results, the context of learning, and the role of the teacher.

The summary of the percentages of papers addressed in the analysis of the research dimensions revealed that 38 out of 42 (90.5 %) studies adequately described the purpose of learning, 34 out of 42 (80.9 %) articles focused on the learner for their development; 32 out of 42 studies (76.2 %) demonstrate qualitative and quantitative evidence of the results obtained by using a given innovative methodology. Additionally, 21 out of 42 studies (50 %) described the learning

TABLE 8. Matrix of dimensions in educational innovation found.

Articles	The purpose of learning	The context of learning	The role of the teacher	The role of the learner	Evidence of results
[75]	X			X	X
[79]	X	X		X	X
[89]	X			X	X
[74]	X	X		X	X
[24]	X	X	X	X	X
[87]			X	X	
[28]	X	X	X	X	X
[98]	X	X	X	X	X
[93]	X			X	X
[65]	X	X	X	X	X
[17]	X			X	
[70]	X	X		X	X
[97]	X			X	X
[90]		X			
[76]	X	X	X	X	X
[99]	X			X	X
[88]	X	X			
[80]	X		X	X	X
[77]	X	X		X	X
[81]	X	X	X	X	X
[71]	X	X		X	X
[72]	X		X	X	
[94]	X	X	X	X	X
[19]	X			X	X
[100]		X		X	X
[66]	X		X		X
[82]	X	X		X	X
[67]	X	X			
[78]	X			X	X
[101]	X			X	
[85]	X			X	X
[83]	X		X	X	
[86]	X	X	X	X	X
[84]		X			
[102]	X	X	X	X	X
[103]	X		X	X	X
[68]	X		X		
[64]	X	X	X		
[104]	X			X	X
[69]	X			X	X
[73]	X				X
[105]	X		X	X	X
TOTAL	38	21	18	34	32

context in detail, and finally, 18 out of 42 studies (42.9 %) detailed the teacher's perspective on the analyzed topic (see Figure 2). This work reveals different HEIS innovating the teaching model with the strategic implementation of mobile devices. The knowledge created from the results of this work (dimensions) can be used to create initiatives using mobile devices that can support the innovation of academic spaces. Some of the main findings of this research indicate that although there are several initiatives of researchers and educational institutions that seek to adopt mobile technology, these practices, based on the analyzed dimensions, are not completely considered innovative.

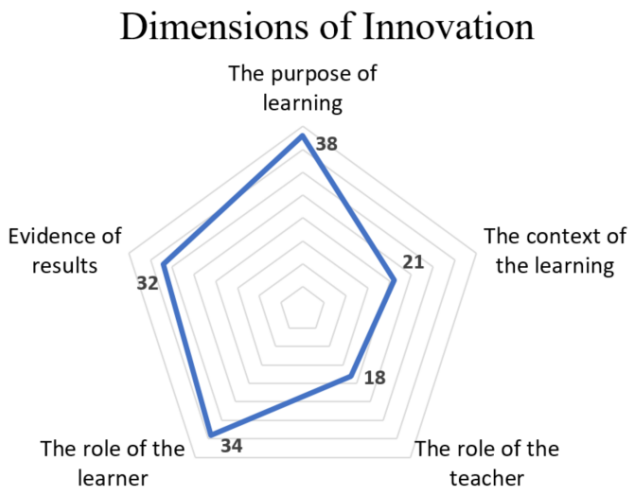

FIGURE 2. Dimensions for the innovation of educational practices using mobile devices.

Similarly, as can be seen in Figure 2, the teacher's perspective or role is the least studied dimension. If the teacher does not lead the process of adopting mobile devices in education, this innovation will not be as successful as expected. Therefore, the active participation of the teacher (perspective, experience and knowledge) is of vital importance for the construction and training of innovative pedagogical practice.

VIII. LIMITATIONS

An SM is always an instant capture of the broad field of knowledge at a particular point in time [8]. Although the literature search followed a very rigorous process, it is possible that some articles may have been overlooked. On the other hand, the exclusion of papers limits the number of possible extra initiatives and may lead to a variation of the obtained result. In this study, only articles written in English were considered, since they were published in specific Open Access journal quartiles (SJR: Q1&Q2). We also did not consider conferences and book chapters, and only three scientific databases (Scopus, WoS, IEEE Xplore) were used for the search.

IX. CONCLUSION AND FUTURE WORK

The proper use of mobile technology in educational innovation could transform the academic world. This innovative and in many scenarios disruptive practice can change the traditional practice and restrict control to educational institutions to involve the student in their academic training process. It is proven that these scenarios generate engagement and motivation, which translates to improved academic performance and learning outcomes [6], [18], [19], [106].

It is well known that one of the main problems and limitations of mobile devices is their small size (small input and output interfaces), thus in some cases, this feature is necessary, especially in a practical educational environment, where learners can choose them for portability and easy adaptation to their pockets [107].

Although mobile devices provide conveniences to people's daily lives, they also associate, in certain cases, a pattern of addictive use involving negative outcomes (loss of control, cognitive relevance, mood regulation) [108], [109]. Much over, the use of mobile devices can result in negative experiences for learners, due to the usability characteristics of technological tools [110].

It is important to have training in the proper use of IT and mobile devices to improve the competencies of faculty and learners. Moreover, mobile technology should be incorporated at the beginning of the curriculum, and gradually review its integration into various subjects of the curricula. This promotes a technological and mobile culture that can be a strong factor to provide student with the necessary skills to exploit mobile technologies for the benefit of education.

As a future work of this research, it is proposed to extend the review time for the SM and to include other types of journals and congresses to enrich the corpus of works analyzed. It would also be interesting to include not only innovation in higher education but also in middle and early education. It would also be interesting in a future study to include educational inclusion as an extension of the current research topic; the search string should be adapted to include innovative educational initiatives with inclusive mobile devices.

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