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M-learning and Augmented Reality: A Review of the Scientific Literature on the WoS Repository

M-learning y realidad aumentada: Revisión de literatura científica en el repositorio WoS

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ABSTRACT

Augmented reality emerges as a tool, on which it is necessary to examine its real educational value. This paper shows the results of a bibliometric analysis performed on documents collected from the Web of Science repository, an Internet service that concentrates bibliographic information from more than 7,000 institutions. Our analysis included an overall universe of 12,000 indexed journals and 148,000 conference proceedings. From those, we selected a sample targeting the terms "mobile-learning" or "m-learning" and "augmented reality" as descriptors or components of titles of scientific works. The analysis on journals (n=741) and in conference proceedings (n=913) reveals a differentiated perspective in each area in the last two years. A qualitative analysis of 67 scientific productions addressing these subjects complements the research. This highlights five themes: conceptualization of the phenomenon, development of new methodologies, motivation, spatial delocalization, and implementation in subject-matter areas. The research highlights logical changes, such as greater and differentiated access to information; transcendent innovations, such as increasing informal and ludic activities, insertion into virtual environments, membership of specific groups, and networks of friendly interaction, along creation of new scales of values. These elements are now beginning to constitute fundamental parts of teaching methodologies. Education appears to be subsidiary to technical advances, thus imposing a drastic methodological change.

RESUMEN

La realidad aumentada surge como un útil sobre el que se precisa examinar su real implementación educativa. Esta investigación hace un análisis bibliométrico sobre documentos del repositorio Web of Science. Este servicio ofrece en Internet la producción científica de más de 7.000 instituciones de todo el mundo. Se toma como base un universo de 12.000 revistas indexadas y 148.000 actas de conferencias y se selecciona una muestra centrada en los términos «m-learning» y «augmented reality» como descriptores o componentes de títulos en trabajos científicos. El análisis sobre revistas n=741 y actas n=913 en los dos últimos años muestra una perspectiva diferenciada por áreas. La investigación se complementa con un análisis cualitativo de 67 producciones científicas sobre estos descriptores en ese periodo de tiempo. En el estudio sobresalen cinco temáticas: la conceptualización del fenómeno, el desarrollo de nuevas metodologías, la motivación generada, su deslocalización espacial y las materias objeto de implementación. Las investigaciones destacan cambios lógicos, como un mayor y diferente acceso a la información, junto a innovaciones trascendentes, como el incremento de actividades informales y lúdicas, la inserción en ambientes virtuales icónicos, la pertenencia a grupos específicos, y redes de interacción amistosa dentro de nuevas escalas de valores. Todo ello hace que estos instrumentos pasen a ser partes fundamentales en las metodologías. La educación parece subsidiaria a estos avances técnicos y a sus requisitos, imponiéndose un drástico cambio metodológico en nuevos escenarios formativos.

KEYWORDS | PALABRAS CLAVE

Ubiquitous learning, education, online education, mobile devices, e-learning, digital literacy, m-learning, augmented reality.
Aprendizaje ubicuo, educación, educación en línea, dispositivos móviles, e-learning, alfabetización digital, m-learning, realidad aumentada.

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1. Introduction

The high variety and penetration of mobile devices in society impacts young users, who are also students at education centers. Portable devices have encroached into our daily lives (Weiser, 1991), thus fostering u-learning. Learning using portable digital devices, or m-learning, has now reached our regular activities linked to knowledge (Castro & al., 2016). The use of m-technologies represents a challenge for educators (Burden, & Hopkins, 2016). Therefore, research alerts about the need to continuously explore the benefits or interest that drive their use. In view of that, we review relatively recent research on m-learning and augmented reality (AR), in education. Relevant work in the first decade of the century is represented by Hwang & Tsai (2011). Toh & al. (2015) have also contributed. More recent investigation into this matter has been performed by Amara & al. (2016). All of them recognize an increase in technology development, enticing particularly younger generations, who have also become its most akin users.

Widespread use of m-learning is correlative to demographic factors, such as age, gender, and family income (Mazaheri, Mohamed, & Karbasi, 2014). Cantillo, Roura and Sánchez (2012) have drawn a below-to-media rate, at 13 years old, when adolescents pick up mobile devices. An advanced trend of m-learning is the technique known as AR. AR superposes digital information on real imagery captured on mobile devices. AR is driving spectacular innovation. It allows to aggregate data, 2D and 3D images, or allows Internet access to sites or sources, creating interactions with any environment. M-learning and AR appear as intrinsically related, and their novelty make them the object of multiple research in aimed at understanding their educational possibilities (Cabero & Barroso, 2016; Ávila & Bailey, 2016). These are emerging phenomena with implications that reach beyond the pure technological facts, that impact on methodologies, habits of students, and that have the potential of transforming our understanding of learning processes in their spatial, temporal, generational, cultural and geopolitical spheres, thus transcending the merely un-localization element of the formative framework (Vázquez-Cano, Sevillano, & Fombona, 2016). This fast evolution creates some unfilled spaces in our knowledge about how to appropriately take advantage of these tools. It creates a need to develop robust theories about learning and their underlying models. The scientific community is in need to provide answers to those questions and is urged to verify if we are facing a socio-educational problem, or a new culture-enriching phenomenon.

2. Materials and methods

The common use of these devices by students, and their innovative and highly attractive features are characteristics that open multiple educational options. This potential generates a hypothesis for effective implementation in any educational setting. In this regard, this research brings together international researchers of the National Autonomous University of México (UNAM), and of the University of Oviedo in Spain, with the purpose of clarifying the didactic possibilities of m-learning and outlining concrete expectations generated by AR technology.

Therefore, this work seeks to understand where this phenomenon is heading considering previous scientific research. To attain that objective, we undertake a descriptive analysis of current findings, considering robust references, non-biased by market/commercial factors, in a time range that does not go beyond a five-year, period. This because of the high risk of theoretical and practical obsolescence of technological meanings (Martínez & Bello, 2001). We worked on the repository for scientific research Web of Science (WoS), indexed by Thomson. WoS catalogues scientific references with high impact. It comprises more than 12,000 journals and 148,000 conference proceedings. References in WoS are grouped by sciences, social sciences, arts and humanities. Although this review is not extensively based on it, we also considered Scopus which is further analysed in a different document.

For the qualitative design, we implemented a simultaneous contrast between UNAM´s and University of Oviedo´s teams, the latter acting as a double expert. According to literature on evaluators reliability, we followed Cohen´s kappa, yet details of this specific analysis are not further described here. The approach implemented permitted a deep review of contents, and also, the use of a high number of WoS documents: books, chapters, articles, communications and presentations in key relevant conferences. 67 documents were reviewed using the key terms under research in the Topic and in the Title, see table 5. A pair of tools supported the analysis: Codification of WoS database, and Atlas.ti-7.5.12. Due to a high number of records obtained, we

Table 1. Number of documents in WoS records

M-learning	**Topic**	**Title**
Total	1,110	381
Mobile learning	**Topic**	**Title**
Total	25,560	2,910
Augmented reality	**Topic**	**Title**
Total	10,155	4,262

incorporated temporality and appropriateness criteria to obtain a selection of samples. This approach is widely accepted, in cases that entail dealing with plenty of information (Avila, 1999).

The analysis considered the terms involved in two instances: records related to the subject, that is, terms were included in the topic (title, abstract or descriptors words). On the other hand, we looked at records where key terms were substantial to the document and appeared in the titles. Therefore, the exercise quantified the variables topic and title, searching for the terms "m-learning" and "mobile learning", both with sufficient range, and using complementary and exclusive elements. "Augmented reality" or "realidad aumentada" was also reviewed placing the reduced results in Spanish, within its meaning in English. Search operators "and" for records with all terms and "or" were used to locate records within the appropriate scope.

Table 2. Number of documents 2015-2016		
M-learning	**Topic**	**Title**
Total	246	73
Mobile learning	**Topic**	**Title**
Total	5,213	668
Augmented reality	**Topic**	**Title**
Total	2,107	913

The analysis included the number of titles within WoS All Databases for all collections. For the terms "m-learning" and "mobile learning", the number of records resulted uneven, and warranted a differentiated handling (Table 1).

We obtained 26,670 documents related to m-learning, and 10,155 for augmented reality. Records for these documents include dates of registration. With that information, we considered only the most recent. Then, we refined the search with the variable "records made between January/1/2015 to November/16/2016". We obtained 913 titles for "augmented reality". Using AR as a descriptor resulted in 2,107 documents. M-learning yielded 73 titles and 246 documents, whereas mobile learning yielded 668 titles registries and 5,213 documents when using it as descriptor.

3. Analysis and results

Table 3 includes the type and number of scientific papers where the terms are included as descriptor or in the title of a document. It is worth noting that some cases are included in more than one category, and that the total numbers may exceed total number of documents (n).

The period under review represents a 20% of the total number or registries of the last 24 years for both, m-learning and AR, and the production includes more articles and presentations than books, which is the least prolific product. Table 4 below features subjects and numbers of documents in each case. In some cases, records can be associated to several subjects.

When using: Theme: ("m-learning" OR "mobile learning" OR "mobile-learning") AND "augmented reality" (Table 5) (see next page), we obtained null recent reviews on these themes altogether. Note that social sciences include education.

Quantitative details for "m-learning" and "augmented reality" in the titles and period reviewed are available here: https://goo.gl/H5BjSh Results included there show a strong connection of these terms with Education and Research, and with Medicine and Engineering.

Table 3. Type and number of documents						
Topic	**Mobile learning**		**M-learning**		**Augmented reality**	
Type of document	**n= 5,213**	**%**	**n=246**	**%**	**n=2,107**	**%**
Article	2,877	55.18	113	45.93	1,110	52.68
Presentation/Communication	2,525	48.43	135	54.87	1,110	52.68
Review	77	1.47	3	1.22	57	2.70
Summary	21	0.40	5	2.03	19	0.90
Editorial	36	0.69			29	1.37
Other	182	3.49			34	1.54
Title	**Mobile learning**		**M-learning**		**Augmented reality**	
Type of document	**n= 668**	**%**	**n=73**	**%**	**n=913**	**%**
Article	346	51.79	35	47.94	452	49.50
Presentation/Communication	318	47.60	40	54.79	500	54.76
Review	15	2.24			12	1.31
Summary	7	1.04			12	1.31
Books	5	0.74			18	1.97
Other	16	2.69			62	6.70

4. Qualitative analysis

Contents analysis resulted in five major subject-matter areas differentiated and contrasted by the two teams. These areas are the following: a) Conceptualization and typology; b) Methodology; c) Factors of use and the ludic-motivational dimension; d) Spatial delocalization; e) Educational subjects for AR implementation.

4.1. Records on conceptualization and typology

The work of Toh & al. (2015) constitutes a salient piece of scientific literature in m-learning. Yousafzai, Chang, & Gani (2016) present a taxonomy of technical variables on m-learning applications with multi-media capacities, linkage to heterogeneous devices, network needs, user´s expectations typology and characteristics of contents.

In this context, m-learning represents an advance of portable technology and a manner to introduce resources in an online environment. Richardson (2016), and Kim & Hyun (2016) feature a clear relationship between AR and the potential of intelligent portable devices and smartphones. Delocalization demands a new denomination for learning in undefined spaces and timing. Students now have access to a myriad of digital services when and where they need them. They can use video, multimedia and AR, a mixed-reality where you can interact with objects. Research show new virtual rooms with tools created and managed by students and instructors like in-real- life practice. Heradio & al. (2016) review virtual labs and the reduction of costs in equipment, space, maintenance, security enhancement, micro or macro experiences and accessibility to people with disabilities. Tools for flexible and comfortable learning with multiple support, whether they are portable computers, tablets, smartphones or multimedia players. El-Kabtane & al. (2016) highlight a rapid change of meaning for e-learning after the emergence of the Internet. Before that, the term meant any kind of learning with electronic machines; currently, it is associated with online learning. In that context, it is necessary and also appropriate to redefine categories, distance learning, open courses MOOC, etc. All that configures new models that begin to be systematized (Potkonjak & al., 2016).

Table 4. Subjects and number of documents

M-learning	**Topic**	**Title**
Social Sciences	182	56
Technological Sciences	152	52
Engineering and Computing	137	46
Sciences	11	4
Biomedicine	21	10
Arts and Humanities	15	2
Mobile learning	**Topic**	**Title**
Social Sciences	2,372	423
Technological Sciences	4,405	468
Engineering and Computing	4,023	416
Sciences	1,047	53
Biomedicine	916	87
Arts and Humanities	203	42
Augmented reality	**Topic**	**Title**
Social Sciences	755	319
Technological Sciences	1,888	811
Engineering and Computing	1,694	726
Sciences	302	174
Biomedicine	464	105
Arts and Humanities	158	66

4.2. Records on educational methodology

M-learning represents a shift in teaching methodology, reaching beyond a purely instrumental component of technology for education. It facilitates the use of strategies based on a myriad of learning theories, such as constructivism (Sun & Shu, 2016), connectivism, or conceptual maps techniques, among others (Marzal & Pedrazzi, 2015).

As more ergonomic equipment is built and pedagogic use is facilitated, new user-friendly interfaces surge (Navarro & al. 2016). On the one hand, m-learning creates collaborative dynamics to learn and interact, which are basic elements in teaching. These options open possibilities and yet they bring procedural issues. (Al-Emran, Elsherif, & Shaalan, 2016). On the other hand, learning at a personal, informal, spontaneous and creative learning is fostered (Gimhyesuk, 2016). This, enhanced by commonalities such as accessibility, motivation, self-control and enjoyment. This suggests learning traits (Castro & al., 2016). Research has documented methodological implications in different areas and levels. Castro & al. (2016) review m-learning in secondary education, math methodology using SMS, social networks such as Facebook and Twitter, and learning objects (LO) looking at new styles and learning contexts. Rodrigo (2016) reviews tablets and makes a difference in elementary and secondary school methodologies. He discusses that their use is conditioned by their initial purpose for purchase, by pedagogical strategies in the classroom, by educational level, and by resources utilised. In more basic levels, tablets are used in a more traditional fashion, more centered in activities than in contents, and competencies are left aside. Games are part of the learning process, project method and new opportunities where tablets

Table 5. Search ("m-learning" OR "mobile learning" OR "mobile-learning") AND "augmented reality"

	Topic		**Title**	
Type of document	n=59	%	n=8	%
Article	31	52.54	7	87.50
Presentation/comunication	32	54.24	1	12.50
Book	2	3.39	1	12.50
Subject	**Topic**		**Title**	
Social Sciences	46		6	
Science and Technology	39		5	
Arts and Humanities	7		1	

may reach beyond traditional strategies (Suarez-Guerrero, Lloret-Catala, & Mengual-Andres, 2016). AR calls for a more appropriate use of methodology to attain effective implementation (Chen, Chou, & Huang, 2016). Pejoska & al. (2016) place the narrative component of AR in purely audiovisual language.

The benefits of virtualization seem more evident in self-formation (Hackett & Proctor, 2016), and in collaborative interaction, from person-to-person in or out of the classroom, or from a person to groups (Lindsay, 2016). Amara & al. (2016) call this Mobile Computer Supported Collaborative Learning (MCSCL). They underscore the lack of systematic analysis on methodologies in group interaction and in solutions that could be generalized. Technology can increase the drive to learn more about environments; however, the use of technology may come along with issues when used in the classroom. M-learning may disrupt normality in this setting, more often in exams as reviewed by Kaiiali & al. (2016). Use of mobile phones at school is problematic and many instructors are unwilling to use them because of attention deviation, cyberbullying and other issues.

4.3. Records on factors of use and the ludic-motivational dimension

Penetration of ICT is linked to infrastructure. Burden & Hopkins (2016) identify physical contexts and personnel training as barriers to their development, followed by attitudes and beliefs. In upper-level education, classroom management and manager´s traits are crucial (Alrasheedi, Capretz, & Raza, 2016). Chang & al. (2016) discuss a positive correlation between environment perception and creative performance. They establish m-learning generates motivation in educational managers and organizations.

Because of the recreational character that stems of its experience, a fundamental component of m-learning is motivation. Several analysis cross-connect interest, concentration and performance. According to Karimi (2016), individual characteristics drive students to the educational use of these devices, reinforcing their ludic style for learning, in a formal and informal setting. Ruiz & Belmonte (2014) identify that university students at a young age display a positive attitude towards applications downloading, installation and use. Hsia (2016) identifies stress in students for what is expected from them; classroom environment conditions, behavior, and this belief significantly affects their level of achievement.

One cannot leave aside the commercial drive underlying ICT market, this creates more affordable mobile devices with more functionalities, including AR in educational materials, such as interactive publications. This trend grows nurtured by economic investment (Kopecky & Szotkowski, 2016). Kim, Chun & Lee (2014) identify that the extent to which students utilize technology is conditioned by its affordability.

The unyielding environment of traditional teaching contrasts with learning based on games and story-telling as salient strategies to create external motivation. Furio & al. (2015) compare mobile to traditional learning. Although they do not find significant differences, they discuss that a student may feel more suited for learning through games, since it connects ludic challenges to rigidness of the real world, abstract concepts to practical deeds, learning processes in real contexts to virtual contexts in AR. Different research documents give account of the attractive potential of AR for students (Cubillo & al., 2015). Sakr & al. (2016) explore emotional implications of students that learned about Second World War by means of the multimodal approach of AR. Laine & al. (2016) combine these ideas in an AR platform where they develop science learning games that interact with the environment.

4.4. Records on spatial delocalization

A variable specifically reviewed in m-learning is the modification of learning spaces by moving the educational phenomenon outside the traditional classroom. Lin & Yang (2016), and Welsh & al. (2015) review possibilities for mobile devices in field trips. Reychav, Dunaway, & Kobayashi (2015) characterize three types of m-learning use: a) teaching-and-learning activity as an extension to the classroom in outdoor settings where objectives, activities and tools remain similar to those created in a traditional curriculum, b) learning activities set forth by the student that is actively searching for new knowledge; and, c) spontaneous learning created in daily activities occurring in non-planned environments. These synthetize m-learning out of the class as formal or informal; planned or spontaneous; guided by the educator or by the student; in a school or work environment. Often, non-planned learning is driven by commercial interests (Pavlou & Fygenson, 2006). It seems that learning outside formal settings does not create bold changes in behavior and patterns, and it is difficult to control its efficacy. Usually, the researcher uses behavioral patterns of the use of mobile devices in daily activities of the user as a reference. Such patterns, not necessarily educational, are significant since they help draw lines of delocalized learning.

Expected behaviour with these devices seem to be geared at gaming and leisure activities. Agarwal & Karahanna

(2000: 673) introduced the concept of "cognitive absorption". This is defined as a state of deep implication with the tool that could be used a foundational basis for motivation for learning outside of the classroom with mobile devices.

AR emerges as a substitute to outdoor experiences as the device itself (Harley & al. 2016) is used to enter immersive and interactive environments, virtual rooms, or scenarios designed to support learning (Nagata, Giner, & Abad, 2016). Tan & Chang (2015) have put forth a scientific algorithm directed at identifying reality objects that can be utilized along with AR for educational purposes. Also, Tarng & al. (2015) develop a new methodology able to reproduce an ecological system, resembling a garden, where students interact with one another and see insects grow. García, Guerrero, & Granados (2015) identified good formative virtual practices, concluding that students are able to learn, when situated in a place where they can experiment, and achieve a high degree of interaction that can be assimilated as real. These are beneficial common places for social dialogue and playful experience (Tscholl & Lindgren, 2016).

Qualitative analysis points at five groups of key descriptors in research for m-learning and AR: terminological conceptualization, methodological changes, analysis of use factors, motivational and ludic dimension, delocalization and selected subject-matter with higher implementation of AR. These are references to educative institutions that do not play a key role when confronted to informal actions, use of tools for m-learning, immersive virtual environments outside of teaching guidelines, MOOC courses, hybrid models, and b-learning. In addition to benefits such as quantitative enrichment due to more access to information, this phenomenon creates innovative frameworks for activities such as focused virtual groups, rewarding interaction, and new scales of values, that are situated outside of administrative regulations that nonetheless, can become successful learning experiences.

4.5. Records related with subjects with AR implementation

Not all subject-matter implements new technology at the same pace. We have detected that AR is still scarcely linked with formation and learning, as pointed out by Abate & Nappi (2016), and by García (2016). Tscholl & Lindgren (2016), Laine & al. (2016), Liou, Bhagat & Chang (2016), among others, describe the benefits of AR in learning sciences. Most of the references appear in technology and Medicine. In this, Huang, Liaw & Lai (2016) describe the use of human simulators for patients and systems of virtual environments. Acceptation of these virtual reality (VR) learning environments is high among students, with a positive impact on perceived usefulness and easy-to-use features. Heradio & al. (2016), and Potkonjaj & al. (2016) organize formative experiences in engineering, and analyse literature on virtual laboratories, since its early days to 2015.

Another area where AR implementation has occurred is language learning, Mobile Assisted Language Learning, and notably in English (Gimhyesuk, 2016). Liu, Lu & Lai (2016) reviewed WoS literature through data mining and address specific abilities enhanced in each case. Kim (2016) presents positive results in listening comprehension where levels of interest and motivation, along with autonomy of university students in their own learning, play an important role. Sung, Changb, & Liua (2016) analyse autonomous learning of English and its impact on listening skills. We cannot put aside the great market behind foreign language formation where strong commercial strategies, gaming and the enticing capacity of AR combined are driving components of activities even at upper language levels (Richardson, 2016).

5. Discussion and conclusions

Scientific literature reviewed demonstrates that it is urgent to assemble a theorical and conceptual framework agreed and assimilated by the educational community. Several works, including those of Mohd & al. (2014) call for a reorientation in the realm of Philosophy of Education, seeking not to underestimate creative and ludic drivers of the teaching-and-learning process. We coincide with several authors in witnessing the surge of these instruments motivating methodological changes, and as mechanisms for modulation of the educational interaction, overcoming the mere space-time delocalization (Vázquez-Cano, Sevillano, & Fombona, 2016). In line with Davies & al. (2010), we believe that the overall technological implementation process should not be regarded in a systematic manner, but rather, it should be addressed in perspectives tailored to specific subject-matter.

Data show the situation of the phenomenon at the moment of the review. Because of the importance of the sources reviewed, the trend can be considered as a true image of the level of penetration that m-learning and AR technology have achieved in scientific research, making this paper a timely reference for subsequent sectorial research.

Qualitative analysis points at five groups of key descriptors in research for m-learning and AR: terminological conceptualization, methodological changes, analysis of use factors, motivational and ludic dimension, delocalization and selected subject-matter with higher implementation of AR. These are references to educative institutions that do not play a key role when confronted to informal actions, use of tools for m-learning, immersive virtual environments outside of teaching guidelines, MOOC courses (Aguaded, Vázquez-Cano, & López-Meneses, 2016), hybrid models, and b-learning (Mittag, 2016). In addition to benefits such as quantitative enrichment due to more access to information, this phenomenon creates innovative frameworks for activities such as focused virtual groups, rewarding interaction, and new scales of values, that are situated outside of administrative regulations that nonetheless, can become successful learning experiences.

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