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ORIGINAL

Smart Learning Environments and Ergonomics: An Approach to the State of the Question

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ABSTRACT

Educational technology evolves constantly, in line with the innovative technologies we implement, but always catering for the improvement of teaching and learning. For this, Smart Learning Environments (SLE) emerge as an optimal alternative to traditional teaching as, through ergonomics, an inclusive outlook which is bound to enhance the educational experience of every student is provided. The method utilized is based on a systematic review of the existing literature which has allowed us to analyze in depth a final sample of 19 documents after an initial review of 633, being these all the works published between 2013 and 2019.Therefore, the principal objective of the present work is carrying out an analysis of the state of the art in relation to ergonomics, inclusiveness and the SLE. The analysis of results is performed utilizing a semantic network, generated through atlas.ti. v.8, by means of which 3 categories, 10 codes and 33 quotes are extracted. Namely, the results reveal the emerging nature of the thematic line researched and how ergonomics is linked to inclusiveness and stands out as one of the most defining components when designing an educational proposal based on SLE.

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1 INTRODUCTION

It is a fact proven in national and international reports (INE., 2019; UIT., 2015) that technologies permeate all spheres of the society of the 21st Century; something which can be easily seen in the evolution which has taken place in densely populated cities, as Buchem and Pérez (2013) point out. This technology-influenced evolution leads to the concept of smart city, that is, the redefinition of the concept of city, through the implementation of Information and Communication Technologies (ICTs), with the aim of improving its sustainability and quality of life of its inhabitants (García-Rubio, 2014; Sarmiento, 2016).

Likewise, the presence of technologies is widespread in the school context, a palpable fact due to the implementation of digital resources (hardware and software), but also to methodological changes and technology-supported educational innovations (Cabero & Barroso,

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2016; Martínez-Sánchez, 2009; Prendes-Espinosa, 2018). On the other hand, the sole fact of considering the use of digital tools in the classroom, both on a regular basis or occasionally, does not necessarily imply a significant improvement in the teaching and learning process (Cariaga, 2018; Luque, 2016).

The curricular integration of ICTs is the basic principle for their reorientation and, thus, prevent inappropriate uses in the classroom. Over time, this objective has been attempted by- among other possibilities- defining a given school as tech-rich, or technology-enhanced space. However, nowadays we have the possibility of progressing in said area, evolving towards what we know as Smart Learning Environments (From now on, SLE). This concept directly stems from Smart Learning, which not only deals with the digitalization of education or progressing towards 100 % online training (Ordov, Madiyarova, Ermilov, Tovma, & Murzagulova, 2019), but also considers face-to-face education, where the interconnection between students is crucial (Achenkunjujohn & Venkatesh, 2020).

In their work, Zhu, Yu, and Riezebos (2016) state that the concept of SLE involves a new educational paradigm which can be used to define learning in today's digital era, as new learners demand the new competences of the 21st century (Prendes-Espinosa, Castañeda, Gutiérrez, & Sánchez, 2017), in line with the concept of Technology Enhanced Learning (TEL) and the educational applications of artificial intelligence, mobile devices, data mining or the Internet of Things, among other technological developments.

Through the development of SLE, it can be said that learning is not exclusively limited to a single context; we could instead talk about learning settings or environments. This is possible thanks to the opportunities provided by technological advances in relation to shortening distances and making training accessible anytime and anywhere (Norris & Soloway, 2013; Prendes-Espinosa, 2004; Tikhomirov, Dneprovskaya, & Yankovskaya, 2015). Moreover, the use of digital devices as it is conceived in the SLE will also provide the necessary information to assess and give feedback about the teaching and learning tasks (Koper, 2014; Simonova, 2019).

There are a number of fundamental principles on which any teaching and learning environment which aims to qualify as "smart" should be grounded. Bautista and Borges (2013) lay out nine: flexibility of physical features, adaptability, comfort, connectivity, personalization, order/organization, opening and security.

More concisely, Bdiwi, de Runz, Faiz, and Cherif (2019) point out that it is necessary to meet three requirements in order to implement a Smart Learning Environment: technology and connectivity, the appropriate educational methodologies and, finally, ergonomics.

Regarding the last component, which is the focus of the present work, it is worth highlighting that ergonomics is the discipline which guarantees the adaptation of an environment- physical or virtual- to the individual characteristics of its users (Reyes & Piñero, 2003). By means of ergonomics, not only are the flexibilization and personalization of the learning or working environment favored, but also the individual's wellbeing and security (Giakoumis et al., 2019). For this reason, ergonomics is as well directly linked with the design of school furniture, as this leads to improving the comfort of the students and teachers in the physical environment and, subsequently, the inclination towards the educational activity (Alibegović, Hadžiomerović, Pašalić, & Domljan, 2020).

The concept of ergonomics can expand the inclusive approach of the teaching and learning process in a SLE, since it is devised as an area in which its distribution, its resources and the use made of these will promote the development of an optimal smart environment for every individual –a fundamental goal of these technology enhanced environments.

There are some definitions of Smart Learning Environments which stress their inclusive nature, as through SLE, an optimal attention to diversity in order to attain an increasingly functional and efficient learning is guaranteed. An example of this type of definitions is the one put forward by Gambo and Shakir (2019), who understand SLE as spaces where technology becomes relevant as it contributes to creating learning experiences which are personalized and inclusive for every individual, anytime and anywhere.

Other works claim that it is necessary for SLE to rely on assistive technologies (Bakken, Varidireddy, & Uskov, 2019) and adaptative technologies (Spector, 2014), as it will be impossible to generate an effective experience for every student in a smart learning environment otherwise.

2 METHODOLOGY

2.1 Problem and Objective

The present work intends to answer the following research question: has ergonomics been analized in works related to SLE? And if so, how does ergonomics influence the Smart Learning Environments? Consequently, the principal objective we set out is to analyze the relevance of ergonomics in the research and experiences on smart learning environments.

2.2 Method

For this, a method based on a systematic literature review (SLR) is selected. This way, a first approach to the scientific information available about the subject study is ensured. Through this initial review, we will be able to identify if it is an area of interest which requires a more in-depth insight, in line with the thought of González, Urrútia, and Alonso-Coello (2011).

2.3 Stages of the Research

Firstly, it is necessary to set the criteria that determine which productions will be selected as part of the final sample and which will be discarded. For this, the principles compiled in the PRISMA statement (Urrútia & Bonfill, 2010) and the SALSA framework (Codina, 2015) are taken into consideration. Besides, in order to guarantee a systematization of the process, the strategy PICoS (Pertegal-Vega, Oliva-Delgado, & Rodríguez-Meirinhos, 2019), consisting of four elements- population, phenomena of interest, context, and study design- is implemented.

In line with the authors mentioned, the process implemented in the research period is supported on the following filters: search through different database, in this case, two worldwide references (WoS and Scopus) so as to prevent potential biases and identify the greater number of scientific files related to the systematic review; use of bilingual descriptors (English and Spanish), removal of duplications; narrowing down the area, language and time.

Moreover, we have employed Boolean operators. The configuration of bilingual descriptors and Boolean operators implemented has been the following: first, "smart learning environments OR smart classrooms AND ergonomics", and the second search has been "smart learning environments OR smart clasrooms AND inclusive education OR special needs education", "smart learning environments OR smart clasrooms AND inclusive education OR special needs education". All the descriptors have been searched as well in Spanish and in both cases, referring to the title, summary, or key words. Two Boolean searches have been carried out, with the aim of including a larger number of works related to educational inclusiveness in the SLE, but which were not linked with ergonomics due to the specificity of said concept.

Regarding the temporal dimensioning, this has been focused on the last 6 years- that is, during the 2013-2019 period-, as we have observed that the bibliography prior to that period is minimal and we intend to favor up-to-date publications. In relation to the two remaining limitations, that is, the type of document and the field, we have selected articles, book chapters and conference papers of the Social Sciences discipline, both in English and Spanish.

Once the definitive sample has been extracted, the qualitative analysis of results is structured following a graphic representation (semantic network) designed with Atlas.ti V8. In it, the different information units which are more significant in each document are coded and categorized. In total, there are 33 quotes associated with 10 open codes, which are related to the three contexts identified (physical, virtual and physical-virtual context).

2.4 Sample Selected

The flow chart (see Figure 1) features the initial population (N= 633) and the resulting sample (n= 19) after applying the different criteria specified in the PICoS strategy: population (Boolean search following dimensioning of time, type of document and languages), phenomena of interest (reading of titles and keywords to identify the subject study), context (reading of summaries to determine how pertinent the content is and whether this is centered on ergonomics or the inclusive outlook of SLE) and study design (works endowed with rigorous methodology, both quantitative and qualitative). Even though a dual search was carried out, once the duplications were removed, these are unified, generating this way a joint analysis of the publications through the mentioned stages.

One of the stages where more documents have been removed from the initial population- more specifically, 387- has been that of the phenomena of interest, as all of the works moved away from the research problem analyzed. The next stage (context) has ruled out 30 works due to different reasons: examples related to the occasional use of "smart" tools for students with special or specific educational needs, but without being implemented in a Smart Environment (Ekin, Cagiltay, & Karasu, 2018); the absence of elements related to ergonomics or educational inclusiveness (Thomas, Parsons, & Whitcombe, 2019) and its coverage of smart environments not related to education (Kumar et al., 2019).

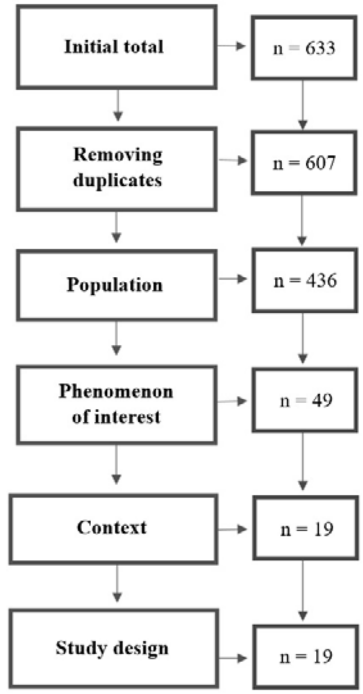

Figure 1 Flow chart of the sample selected

In the table, sorted chronologically, the 19 manuscripts which represent the sample selected are featured (see Table 1).

Also, in the Figure 2 a stacked bar chart is featured; it represents the sample in relation to its year of publication and the type of scientific document each one is (article, book chapter or conference paper)

Of the sample finally selected, eight documents come from Higher Education, one from Secondary Education, two documents from Primary Education, and eight of them do not correspond to any of the educational stages, but deal with the subject matter from a general perspective.

3 RESULTS

The continuous publication of scientific papers related to Smart Learning Environments (SLE) and ergonomics reflects the emerging nature of this line of research (Figure 2). However, eight of the selected papers do not feature any educational implementation nor the exposition of design criteria for smart classrooms from an ergonomics perspective; they instead present the research problem in a generic manner. The works centered on the different educational levels (Childhood, Primary and Secondary Education) do not abound, either. The only exception is higher education, as it is a stage which different articles and conference papers have been focused on.

Table 1 Distribution of the sample by year and type of work

N.	Citation	Type of paper
Paper 1	Gelsomini (2019)	Proceedings
Paper 2	Gambo and Shakir (2019)	Proceedings
Paper 3	Bakken et al. (2019)	Artículo
Paper 4	G. Liu et al. (2019)	Proceedings
Paper 5	Tissenbaum and Slotta (2019)	Article
Paper 6	Chorfi and Al-hudhud (2019)	Article
Paper 7	An (2019)	Proceedings
Paper 8	Kanagarajan and Ramakrishnan (2018)	Article
Paper 9	Wang and Yeh (2018)	Proceedings
Paper 10	Ani et al. (2018); Elkoubaiti and Mrabet (2018)	Proceedings
Paper 11	Elkoubaiti and Mrabet (2018)	Proceedings
Paper 12	Anderson (2018)	Proceedings
Paper 13	Sutjaritthamm et al. (2018)	Proceedings
Paper 14	Miraoui (2018)	Article
Paper 15	Zhong et al. (2017)	Proceedings
Paper 16	Soliman and Elsaadany (2016)	Proceedings
Paper 17	Avdeeva et al. (2015)	Chapter
Paper 18	Pesare (2015)	Proceedings
Paper 19	Bouslama and Kalota (2013)	Proceedings

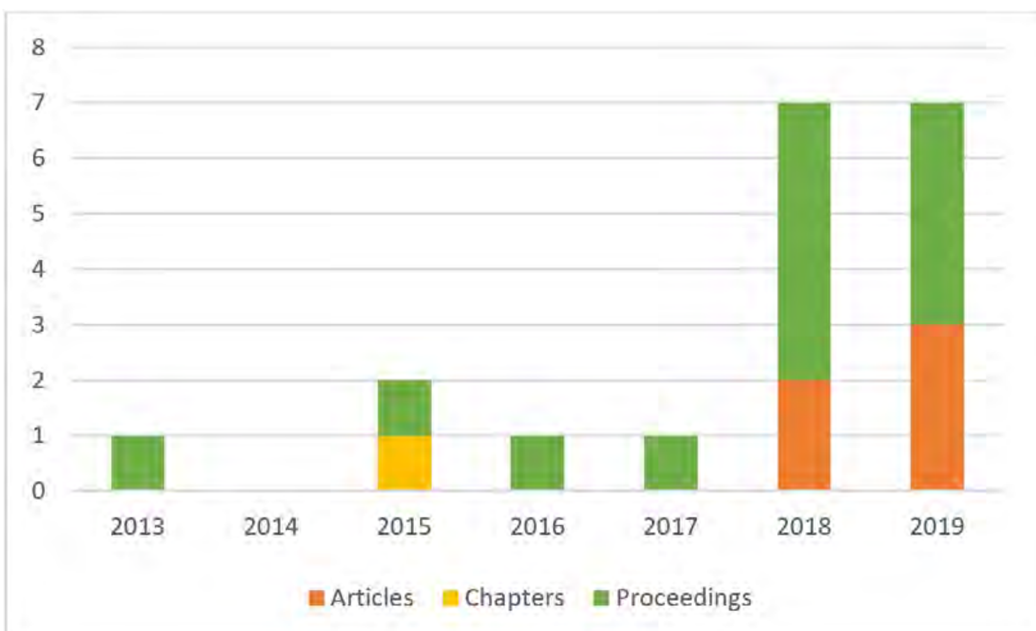

Figure 2 Figure 2. Distribution of the sample by year and type of work

The 19 articles of the sample consider directly or indirectly different aspects which promote the ergonomics of SLE, making this Smart Learning Environment a more accessible and beneficial space for all the agents involved.

As we have explained, it has been stated that these environments foster the fusion between face-to-face and online teaching and learning. Therefore, when analyzing the results, three categories related to the teaching and learning environments and their ergonomics were set: physical environment, virtual environment, and physical-virtual environment. The first two are largely referenced in the literature about the topic of SLE (D. Liu, Huang, & Wosinski, 2017; Serrano-Iglesias, Bote-Lorenzo, Gómez-Sánchez, Asensio-Pérez, & Vega-Gorgojo, 2019), while the latter deals with the link between the face-to-face and virtual environments, the one which includes the codes that encompass aspects that need to be interrelated both virtually and face-to-face.

The different codes are units of text information which have been directly extracted from the content analysis of the ergonomics outlook of SLE. Once the data that reflect any aspect related to the promotion of educational inclusiveness have been compiled, they have been reduced to significant information units to facilitate their accommodation to the categories established.

Finally, the quotes which are linked to each of the codes represent the bibliographical references which justify them.

In Figure 3 the semantic network extracted with the mentioned categories and their respective codes and quotes is presented. Likewise, said graphic representation is complemented with Table 2, which reflects the absolute frequency of the codes associated with their categories.

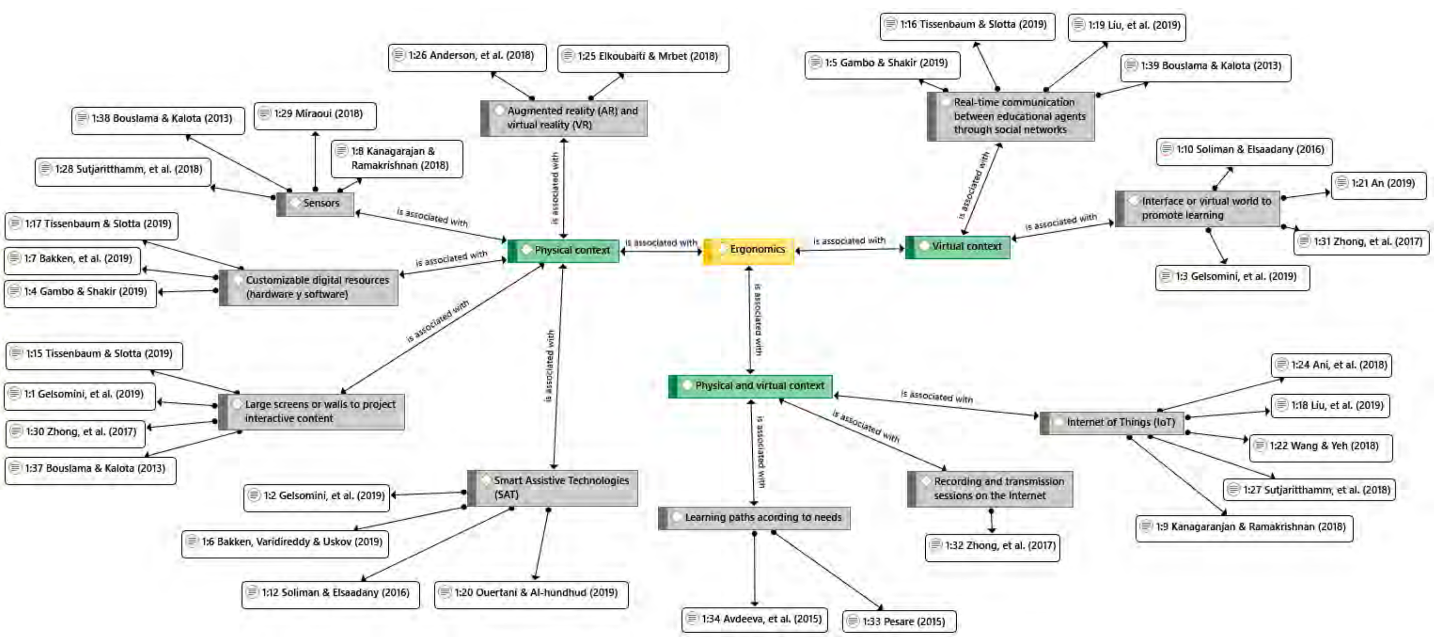

Figure 3 Semantic network of the results

Table 2 Code Frequency

Categories	Codes	f
Physical context	Smart Assistive Technologies (SAT)	4
	Large screens or walls to project interactive content	4
	Customizable digital resources (hardware y software)	3
	Sensors	4
	Augmented reality (AR) and virtual reality (VR)	2
Virtual context	Real-time communication between educational agents through social networks	4
	Interface or virtual world to promote learning	4
Physical and virtual context	Internet of Things (IoT)	5
	Recording and transmission sessions on the Internet	1
	Learning paths acording to needs	2

One of the more obvious codes for improving the information access and management is that of "Smart Assistance Technologies" (SAT). These are connected with the different electronic devices which, through different stimuli, enhance the educational process of any agent, depending on the functional diversity presented (works 1, 3, 6 and 16).

Closely linked to the above mentioned code, the code "adaptable digital resources (hardware and software)" is also aimed at providing support to the person using it, as they are technologies which feature additional improvements to enhance the experience of the users, depending on their individual characteristics (works 2, 3 and 5).

"Large screens or walls on which displaying interactive content" is a code related to the physical enlargement of the information in order to enhance the optimal visualization from any point in the smart classroom (works, 1, 5, 15 and 19).

The use of "sensors" to enhance the automatization of different actions in the classroom, for instance: turning on lights, controlling humidity or temperature, etc., is another code which is frequently cited (works 8, 13, 15 and 19).

The last code related to the category "physical environment" is the least cited; it is both "augmented reality" (AR) and "virtual reality" (VR), defined as a smart digital resource which projects the content to make it more accessible (works 11 and 12).

The category "virtual environment" features only two codes linked, one of which is "communication in real time between educational agents through the social media". By means of it, the inclusive interaction between members of the educative community, provided the appropriate mobile devices and applications are available (works 2, 4, 5 and 9).

Closely connected with the former, the "interface or virtual world to enhance learning" enables the creation of digital environments, by means of which, the teacher will be able to define the learning process of each student according to the information received. Moreover, the interface used must favor personalization and adaptability (works 1, 7, 15 and 16).

Finally, the third category, that is, "physical and virtual environment" features three codes. The first of them, the most numerous, is "Internet of Things" (IoT). While this code is not as specific as the others, by means of it, the necessary connectivity which needs to exist between the devices utilized in a SLE to ensure the automatization of certain tasks and optimize different processes is exposed. (works 4, 8, 9, 10 and 13).

Next, the least cited code not only within that category, but in all the semantic network is "recording and transmission of sessions on the Internet", in order to create a virtual library with all the sessions carried out in the physical environment (work 15).

The last code within the "physical and virtual environment" is "learning path or trajectory according to necessities". Through this descriptor, the design of different paths to encourage flexibility and personalization in relation to the learning process is intended. These need to be physically present and be transferable to the virtual environment (works 17 and 18).

4 DISCUSSION AND CONCLUSIONS

The present work analyzes the most recent scientific papers on SLE from the perspective of ergonomics, in order to reflect on how this discipline influences the inclusive design of a Smart Learning Environment.

First, we should highlight the lack of research works where SLE are studied from the perspective of ergonomics as an essential component when considering an inclusive outlook. Therefore, it has been necessary to expand the search field to obtain significant results in order to achieve the desired goal.

Notwithstanding this fact, and bearing in mind the relevance of the concept of ergonomics (Alibegović et al., 2020; Giakoumis et al., 2019), it is considered that an inclusive outlook on SLE should accommodate to an ergonomics perspective, since ergonomics allows us to shift the focus to the design of the space, the use of adaptative or assistance technologies, among other factors of interest for this new outlook of inclusive, technology-enhanced environments. In other words, ergonomics is a fundamental discipline in order to ensure that a SLE can be adapted to the specific needs of each student, both regarding the level of access and the development of the educational process.

As it is evidenced in the physical environment category, the SLE involve the possibility of enhancing the teaching and learning process, so long as the necessary adaptative technology and the necessary innovative features are available, so as to transfer this aspect to one group as a whole (Bakken et al., 2019; Spector, 2014).

Also related to the physica environment, the code "Augmented Reality (AR) and Virtual Reality (VR)" is one of the less frequently cited, but it can offer several opportunities for students with functional diversity (Chocarro, Lainez, Busto, & López, 2018; Marín, 2018). Likewise, "large screens where to project interactive content" is a key code when facilitating access to the information and allowing its manipulation using different input devices.

On the other hand, communication (analyzed within the virtual environment category) is also a remarkable element, since different authors (Koper, 2014; Simonova, 2019) stress that, in SLE, constant feedback to enhance the learning environment and benefit both students and teaching staff should be guaranteed. This way, the flexibility, horizontality, and efficiency which should characterize Smart Learning Environments are provided (Escofet, Gros, López, & Marimon-Martí, 2019; Pal, Pramanik, & Choudhury, 2019).

Has it has been exposed, the elements which promote an ergonomics perspective of SLE are largely diverse. For this reason, a possibility for bridging the gap between virtual and face-to-face settings, promoting the smart component and encompassing a large number of variables to consider, could be the implementation of a Learning Management System (LMS).

This digital resource is linked to several works which define the smart tools which need to be present in a SLE (Al-Hamad, 2016; Dascalu, Bodea, Moldoveanu, & Dragoi, 2017), hence, it could also provide an opportunity by means of which the different defining aspects of ergonomics in smart environments could be interconnected.

On the basis of the results shown, we suggest the possibility of expanding this research, applying different descriptors, such as "personalized", "adaptative" or "assistive technology" among others, which could yield results linked to the inclusive outlook of SLE and, thus, construct a solid concept of ergonomics in relation to these.

Additionally, it would be appropriate to research and go further in the development of some codes and their relationship with the SLE to ensure an ergonomics perspective, since their actual implementation is not as widespread as other codes. Some examples include use of sensors in the physical environment to automatize certain actions, in both teachers and students; the personalization through learning pathways, of which there are different experiences in the face-to-face context (García-Tudela, 2019), etc.

In this work we have proven the key role which ergonomics has with regard to the development of a Smart Learning Environment; however, it is deemed necessary to expand on the research, in order to create an optimal model which conceives ergonomics as an essential component of SLE. In conclusion, the implementation of a smart environment from an outlook in which ergonomics is present in the educational activity will benefit teaching, research and innovation in any level and context, key aspects of any experience in the framework of Educational Technology (Prendes-Espinosa, 2018).

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