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Digital Content for Libraries considering Extended Reality, Physical Interaction Disabilities, Universal Design for Learning and User-Centered Design: A Systematic Review

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ABSTRACT

A systematic review of Digital Content for Libraries, Extended Reality, Physical Interaction Disabilities, Universal Design for Learning and User-Centered Design is presented to find the basis for a software development methodology that covers these characteristics. A protocol oriented to studies in software engineering is used, which consists of the following stages: 1. Defining research questions, 2. Conducting the search for articles, 3. Selecting inclusion and exclusion criteria, 4. Keywords for abstracts, and 5. Data extraction and mapping process. This review is performed through search engines such as Google Scholar, Science Direct, IEEE Xplore, and ACE Library and is limited to publications between 2016 and 2021. Results show an incremental trend in Extended Reality articles but low scientific productivity in

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Digital Content for Libraries, demonstrating the availability of services that consider the previously exposed topics. Finally, the article defines elements aiming to a future methodological proposal for the construction of Digital Content for Libraries and Extended Reality.

Keywords: Digital Content for Libraries; Extended Reality; Physical Interaction Disabilities; Universal Design for Learning; User-Centered Design

Contenidos digitales para bibliotecas desde las perspectivas de la realidad extendida, las discapacidades físicas de interacción, el diseño universal para el aprendizaje y el diseño centrado en el usuario: una revisión sistemática

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Resumen

El artículo presenta una revisión sistemática sobre contenidos digitales para bibliotecas, realidad extendida, discapacidades físicas de interacción, diseño universal para el aprendizaje y diseño centrado en el usuario para encontrar las bases de una metodología de desarrollo de *software* que cubra estas características. Utilizamos un protocolo orientado a estudios en ingeniería de *software*, el cual consta de las siguientes etapas: 1. Definición de las preguntas de investigación, 2. Realización de la búsqueda de artículos, 3. Selección de criterios de inclusión y exclusión, 4. Palabras clave de los resúmenes y 5. Proceso de extracción y mapeo de datos. Esta revisión se llevó a cabo a través de motores de búsqueda como Google Scholar, Science Direct, IEEE Xplore y ACE Library y se delimitó a publicaciones entre 2016 y 2021. Los resultados muestran una tendencia incremental en la generación de artículos de realidad extendida, pero una baja productividad científica en contenidos digitales para bibliotecas demostrando la disponibilidad de servicios que consideran los temas antes expuestos. Finalmente, definimos elementos para la elaboración de una futura propuesta metodológica para la construcción de contenidos digitales para bibliotecas y realidad extendida.

Palabras clave: Contenidos digitales para bibliotecas; Realidad extendida; Discapacidades físicas de interacción; Diseño universal para el aprendizaje; Diseño centrado en el usuario

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Introduction

Digital Content for Libraries (DCL) based on mobile technology is a novelty and an opportunity for information centers to provide services to their remote users (McKiernan, 2010). Taking into account how important the development of DCL is, we intend to know their scientific production with topics such as Extended Reality (ER), Universal Design for Learning (UDL), and User-Centered Design (UCD) to find the basis of a methodology that covers these characteristics and to offer alternatives to improve library services for people with disabilities through the above-mentioned approaches.

ER is renewing how people experience physical and virtual environments from observation to immersion (Chuah, 2019). In fact, ER is an umbrella term that encompasses Augmented Reality (AR), Virtual Reality (VR) and all technologies that provide some form of immersion. These are not new, but several limitations have prevented their actual adoption; however, recent technological advances, coupled with the proliferation of hardware and software, have made them more viable and desirable in many fields, including education (Elmqaddem, 2019).

AR is an experience that superimposes virtual 3D objects on the user's direct view of a real environment around them (Azuma, 2017). While VR can be described as a multimedia or computer-simulated immersive reality that reproduces an environment and simulates a physical presence in real or imagined world locations (Velev and Zlateva, 2017), ER has been applied in different areas to help improve activities for people with Physical Interaction Disabilities (PIDs) (Matthews, See and Day, 2021; Bozgeyikli et al., 2018; Bannink Mbazzi et al., 2021; Götzelmann and Kreimeier, 2020; Edler et al., 2019; Park, Cha and Im, 2019; Özüağ, Cantürk and Özyilmaz, 2019), since with ER they can access to places and experiences they have never had before (Chad, 2019). The interest in researching the disabled population has increased in recent years (Córdoba and Soto, 2007; Suriá Martínez, 2015). This growth is consistent with the current prevalence of this topic, as about 15% of the world's population (more than one billion people) live with some form of disability (OMS, 2017). Based on the extensive relationship between ER and people with disabilities, we propose a methodology for DCL implementing ER for people with some type of PID (autism, deafness, blindness, elderly, dyslexia, among others).

Now, the wide spectrum of disabilities impedes making a design for each one and requires knowing the problems associated with each disability in depth to produce accessible software (Molina-Lopez and Medina, 2021). For this reason, we have considered that the methodological proposal should use the UCD approach, which is a discipline that bases the design of an innovation using information from the people who will ultimately use it (Dopp et al., 2019). In this

type of approach, the facility with which intended users can understand the system, complete tasks, and the degree of satisfaction with its usage become key measures of design success (Lanter and Essinger, 2017).

At the same time, the inclusion of UDL is raised, since this system improves and optimizes teaching and learning for all people, based on scientific knowledge about how humans learn (CAST, 2021). Therefore, this article, as a first step in the construction of this future methodological proposal, has the purpose of carrying out a Systematic Literature Review (SLR) with the objective of analyzing the existing scientific and academic production to find foundations for constructing a model or methodology of development applying DCL, ER, UDL, and UCD considering PID. This study was performed following the process of Petersen et al. (2008), who defined a protocol for the execution of SLR oriented to software engineering studies.

Initially, we collected publications ranging from 2016 to 2021 to which inclusion, exclusion and quality assessment criteria were applied, obtaining a reduced number of publications to answer research questions and, then, we established objectives. The results were described according to research questions; the studies that helped to answer them were included. In addition, the results visualized during the process of this SLR are shown. Moreover, an area of application was observed given the scarce scientific production related to DCL, ER, UDL, and UCD.

This study is organized as follows: Section 2 establishes the methodology used to carry out the SLR, Section 3 displays the results obtained from the SLR, Section 4 develops the elements for a future methodological proposal, then, Section 5 discusses the obtained results. Finally, Section 6 offers the conclusions and future work.

Systematic review methodology

This work is based on the methodology proposed by Petersen et al. (2008), who defined a protocol for the execution of SLR oriented to software engineering studies (*Figure 1*).

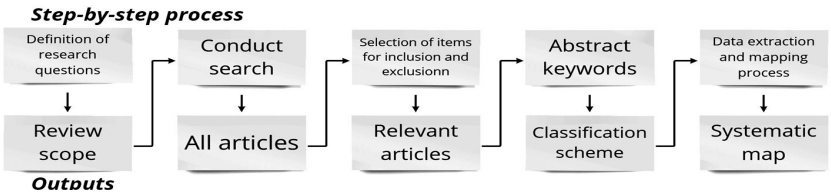

Figure 1. Process to implement the SLR
Source: Petersen et al. (2008)

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Definition of Research Questions

The main objective of this study was identifying existing and related research for the construction of a model or methodology for the development of ER considering PID, UDL, and UCD. In this respect, we defined the subsequent research questions:

1. What are the main research studies that propose a model or methodology applied to DCL, ER, UDL, and UCD considering PID?
2. What are the main attributes or patterns observed in models or methodology applied to DCL, ER, PID, UDL, and UCD?
3. What are the evaluation mechanisms or methods found to validate applications that implement ER, UDL, UCD, and DCL that can be used for a future methodological proposal?

Based on these results we intend to find answers to previously defined questions. Figure 2 shows the structure used to determine these:

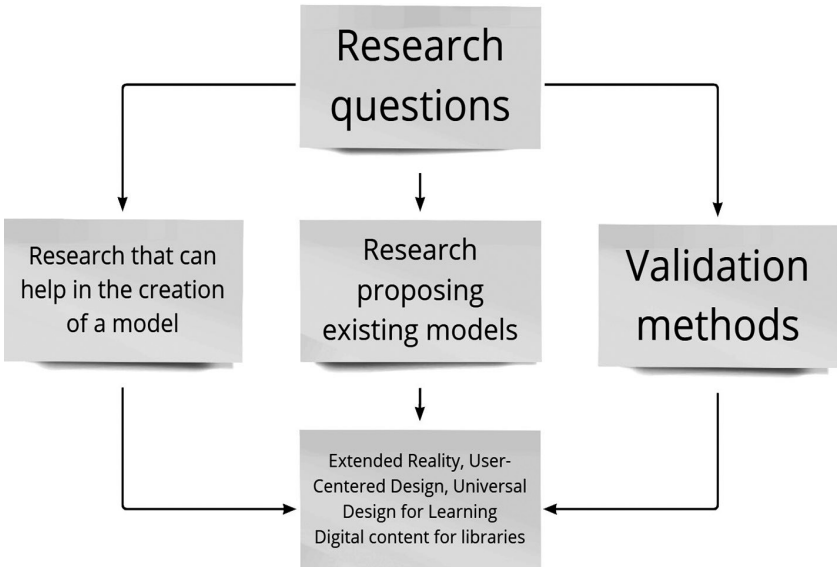

Figure 2. Structure of research questions
Source: Authors' elaboration

Conducting the Search for Articles

The first searches were performed in September 2021 employing different search engines such as Google Scholar, Scopus, Science Direct, and IEEE Xplore. It

was decided to use these engines due to the large collection of scientific articles to which they have access, also because they allow using logical operators for an accurate search. Additionally, it must be mentioned that they have been applied in similar studies in information technology (MacHado et al., 2021; Ribeiro et al., 2018). Different categories were created considering the project keywords to construct the search strings (*Table 1*).

Categories	Search String
ER, DIC, UCD	("User") AND ("centered design" OR "center design" OR "Centered focus") AND ("Extended realities" OR "Extended reality" OR "Immersive Technology") AND ("Digital library content" OR "Digital content for libraries")
ER, DIC, UDL	("Universal Design for Learning") AND ("Digital library content" OR "Digital content for libraries") AND ("Extended realities" OR "Extended reality" OR "Immersive Technology")
DIC, UDL	("Universal Design for Learning") AND ("Digital library content" OR "Digital content for libraries")
UCD, ER	("User") AND ("centered design" OR "centric design" OR "center design") AND ("Extended reality" OR "Extended realities" OR "Immersive Technology") NOT Cognitive NOT Mental
Software Model or Methodology, ER	("Software model" OR "Software development model" OR "Software development methodology" OR "Software methodology" OR "proposed methodology") AND ("Extended realities" OR "Extended reality" OR "Immersive Technology")
PID, ER (without considering cognitive problems)	("Physical") AND ("disabilities" OR "disability" OR "impairment") AND ("Extended realities" OR "Extended reality" OR "Immersive Technology") NOT Cognitive NOT Mental
UCD, evaluation	("User" "centered evaluation" OR "center design evaluation") AND ("Software evaluation" OR "Methodology Evaluation")
Evaluation tools, ER	("Evaluation tool" OR "Evaluation instrument" OR "Usability instrument" OR "Experience evaluation") AND ("Extended realities" OR "Extended reality" OR "Immersive Technology")
UCD, PID, and ER	("User") AND ("centered design" OR "center design" OR "Centered focus") AND ("Physical") AND ("disabilities" OR "disability" OR "interaction disability" OR "interaction impairment") AND ("Extended reality" OR "Extended realities" OR "Immersive Technology") NOT Mental NOT Cognitive
UCD, UDL, PID	("User" AND "centered design" OR "center design" OR "Centered focus") ("Universal Design for Learning") ("Physical" "disabilities" OR "disability" OR "interaction disability" OR "interaction impairment")
ER, UDL	("Extended realities" OR "Extended reality" OR "Immersive Technology") "Universal Design for Learning"

Table 1. Categories and search strings performed
Source: Authors' elaboration

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Selection of Articles for Inclusion and Exclusion Criteria

In this section, we established the criteria for inclusion and exclusion of the selected articles retaking Buela-Casal (2003) and Humanante-Ramos, García-Peñalvo and Conde-González (2017):

- Inclusion criteria

1. Articles in English addressing ER, PID, UDL, and UCD.
2. Articles published between 2016 and 2021 in peer-reviewed journals, conferences, congresses or prestigious workshops.
3. Includes one or more search terms in the title in accordance with the topics stated in the research questions.
4. Presents technologically coherent conclusions.
5. They must be duly justified critical reviews of one or more search terms in accordance with the topics stated in the research questions.

- Exclusion criteria

1. Duplicated work.
2. Works where the research topic is rendered superficially.
3. Failure to correctly include search terms.
4. Types of studies for discussion or available only in the form of presentations or abstracts.
5. Types of studies in books or book articles.

Information Extraction and Synthesis Procedure

Once the consultation was done, 721 publications were obtained. A first evaluation was made based on the previously defined inclusion and exclusion criteria. For this purpose, we prepared a matrix consisting of Title, Abstract, Keywords, Year of publication, Authors, and Type of document (Article, Book, Report). Resulting from this evaluation matrix, we selected 77 final articles and evaluated them on a scale of 1 to 5 according to the criteria proposed by Humanante-Ramos, García-Peñalvo and Conde-González (2017) (*Table 2*).

Score	Quality Evaluation Criteria
1	They are descriptive bibliographic studies without greater depth.
2	These are theoretical contributions that propose new approaches or trends.
3	They include design proposals and/or duly substantiated implementations.
4	They present practical implementation experiences in real learning contexts.

5	In addition to what is contemplated in level 4, they evaluate applications with clear and reproducible results.

Table 2. Criteria for evaluating the quality of publications
Source: Authors' elaboration

Then, after attending the guidelines and once the documents were scored, we selected only those that reached values greater than or equal to 3.

Presentation of results

This section displays the results obtained during the application of this SLR. First, a flow chart shows the findings results, then appears the distribution of the initially filtered articles by year and then the percentage of publications by category. Finally, the research questions of this project are answered. *Figure 3* exposes how this SLR flow consisted of four stages: 1. Obtainment of 721 articles from different search engines, 2. Reducing of the number of articles to 77 considering inclusion and exclusion criteria, 3. Obtainment of 37 articles applying quality evaluations, and 4. Reaching of 26 articles by analyzing their contribution to the research questions:

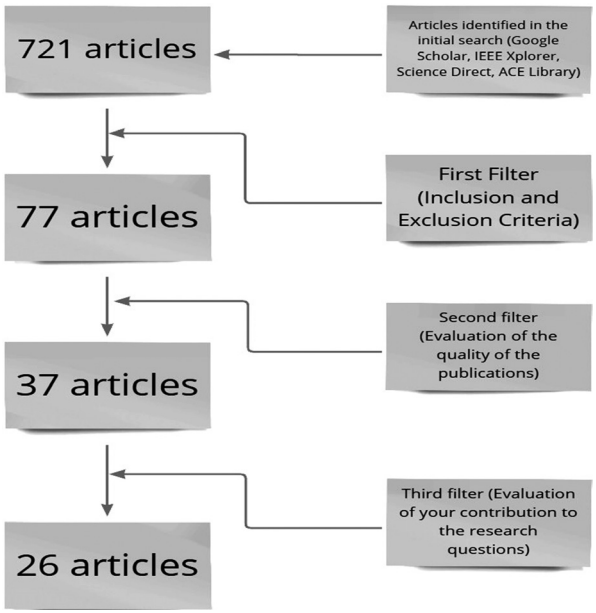

Figure 3. Flow of results obtained from the SLR
Source: Authors' elaboration

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The distribution of initially filtered articles by year (721) are exposed in *Figure 4*, where an upward growth can be observed from the year 2018 onwards, being 2021 the year when publications surpassed by 13 times those of 2016:

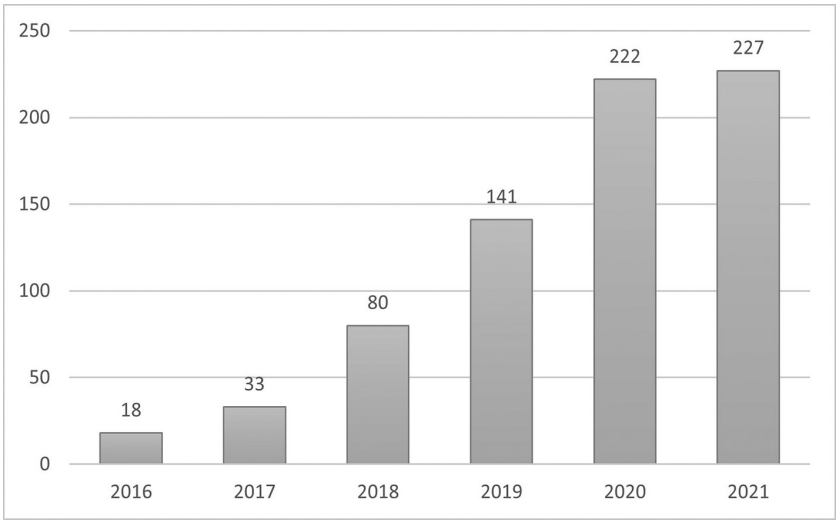

Figure 4. Trend of publications per year
Source: Authors' elaboration

A total of 26 articles were obtained to answer the research questions. *Figure 5* shows the distribution of the final articles by specific category:

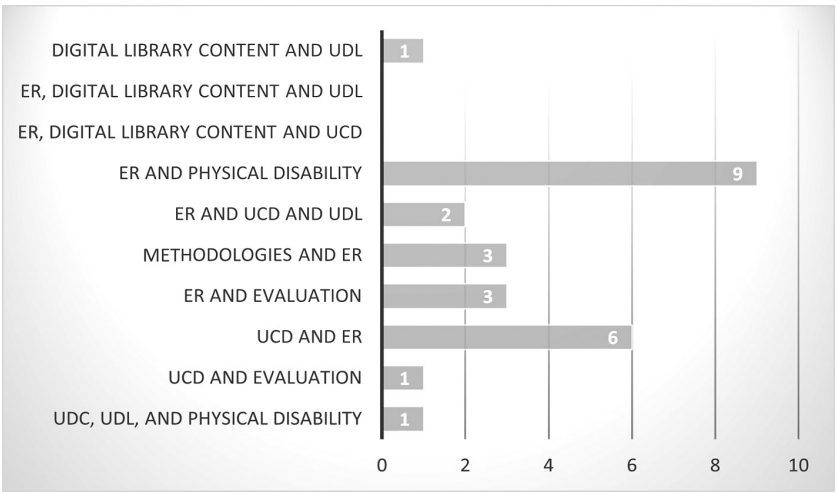

Figure 5. Final publications by specific categories
Source: Authors' elaboration

Distribution by specific categories shows that most publications are found in Evaluation Tools and ER with 26%. Meanwhile, PID and ER (without considering cognitive problems) is the second category with the highest percentage (54%). An important aspect to highlight is the null production of DCL related to ER, UDL and UCD, since it represents less than 1% of all evaluated articles, as portrayed in *Figure 6*:

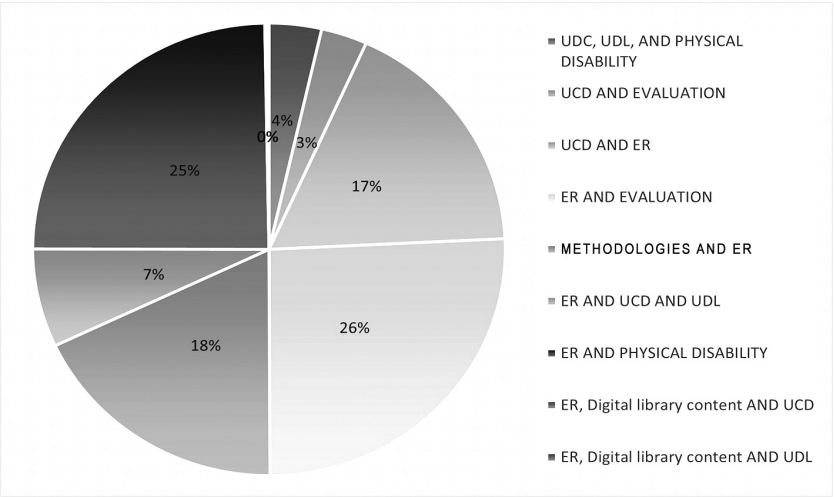

Figure 6. Percentage of publications by category
Source: Authors' elaboration

To conduct this SLR, the terms "Mental" and "Cognitive" were omitted in the categories that included the characteristic "Physical Disability" to access only those articles involved with interaction disabilities. In this way, it was possible to reduce 2 233 articles to 721 for the first stage of the SLR. These results demonstrate the strong inclination towards mental and cognitive issues by employing ER, UDL and UCD; however, they also show little attentiveness towards the treatment of physical disabilities of interaction with these types of technologies. Furthermore, 25 final articles were distributed among the three initially posed research questions and even more than one article was contemplated for one or more research questions.

Below, we show how the research questions were answered with the selected articles.

1. What are the main research studies that propose a model or methodology applied to DCL, ER, UDL, and UCD considering PID?

No research that proposes a model or methodology applied specifically to DCL, ER, UDL, UCD and PID was identified. This may be a result of

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the specific search that was conducted in this SLR. Nevertheless, articles that follow a methodology or development process for their ER products that can help in the methodological structure for a future methodological proposal for DCL were found (Krajčovič et al., 2021; Afnan et al., 2021; Hamzah et al., 2021; Zucchi et al., 2020; Van Wyk and De Villiers, 2019; Rodríguez-Cano et al., 2021; and Rechowicz et al., 2019).

2. What are the main attributes or patterns observed in models or methodology applied to DCL, ER, PID, UDL, and UCD?

We identified attributes and patterns of inclusive design, ER, design in children with autism, video games and 360º videos that may help in the construction of a future methodological proposal for DCL (Vi, Da Silva and Maurer, 2019; Gomes et al., 2020; Caggianese, Gallo and Neroni, 2018; Sweetser and Rogalewicz, 2020; McMahon, 2019; McMahon and Walker, 2019; Bauer, Bouchara and Bourdot, 2021; Zucchi et al., 2020; Van Wyk and De Villiers, 2019; Krajčovič et al., 2021; Rechowicz et al., 2019; Matthews, See and Day, 2021; and Mustafa and Aldein, 2020).

3. What are the evaluation mechanisms or methods found to validate applications that implement DCL, ER, UDL, and UCD that can be used for a future methodological proposal?

This SLR did not find an evaluation mechanism or method to validate methodologies that apply DCL, UDL, and UCD (Méndez, 2006; Giugni and Loaiza, 2008; Guedes, Marques and Vitório, 2020; Neira-Tovar and Castilla Rodriguez, 2017; Parras-Burgos et al., 2020; Sukotjo et al., 2021; Nguyen et al., 2021; Salomoni et al., 2017; AlMuraikhi et al., 2021; Dayarathna et al., 2021; Costa et al., 2016; and Hamzah et al., 2021).

Basis for a methodological proposal

As a result of the research questions, we recognized some elements that can be part of future methodologies for the creation of DCL implementing RE, UDL, and UCD.

Identification of a Methodological Structure

The methodological structure oversees defining the stages from beginning to end in the construction of an ER application. The following are the methodological structures found through this SLR. Hamzah and Rizal (2021) present a methodological structure composed of the stages: problem identification, planning, design, testing, implementation, and evaluation of the system. As well as

Afnan et al. (2021), both researches recur to a methodological process that can help structuring the designing stage. In contrast, Krajcovic et al. (2021) demonstrate a methodological process for the creation of user interfaces divided by the stages: analysis and collection of references, creation of resources, virtual environment and creation of game scenarios, use, and testing. This is also the case of Zucchi et al. (2020) and Rodríguez-Cano (2021), who execute a methodology that uses UCD, an approach based on ISO 13407. Finally, Van Wyk and De Villiers (2019) present a methodological structure composed of the stages: problem analysis, solution design, solution development, evaluation in practice and reflection. The projects above-mentioned put into effect development methodologies to generate ER products, so they can be useful starting points to structure a future methodological proposal.

Selection of elements to facilitate the design of DCL, ER, UDL, and UCD

Due to the limited production of works related to DCL no elements that facilitate its design were identified; however, the found production related to ER can be applied for a future methodological proposal with these characteristics. If you wish to find characteristics of Inclusive Design (ID) and ER, you can analyze the work of Matthews, See and Day (2021), where they show how diverse users drive innovation and improve everyone's experience. Moreover, Vi et al. (2019) and Gomes et al. (2020) show guidelines to design ER applications, such as ones related to organizing the spatial environment to maximize efficiency, creating flexible interactions or designing according to the hardware. In addition, Van Wyk and De Villiers (2019) and Bauer, Bouchara and Bourdot (2021) mention suggestions, case studies, and discussions to design ER in children with Autism spectrum disorder. Penny and Rogalewicz (2020) use a model for player enjoyment in video games applied to ER where they analyze VR and non-VR versions of the same games to identify enjoyment differences. Similarly, Caggianese, Gallo and Neroni (2018) introduce guidelines for the design of diegetic interfaces with ER. Zucchi et al. (2020) show tools to exhibit a 360-degree video with ER. Finally, McMahon (2019) and McMahon and Zachary (2019) expound considerations to implement UDL in ER tools presenting strategies to provide comprehension, expression, and communication options in applications.

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Selection of Evaluation Instruments for DCL, ER, UDL, and UCD Products

Once the DCL has been built by implementing ER, UDL, and UCD it is important to evaluate different characteristics to know how it performs; the evaluation methods located through this SLR are shown below.

To measure satisfaction, it is possible to use the instrument used by Soares et al. (2020). If you need to measure stress generated at the time of using ER, you can analyze the work of Neira-Tovar and Castilla Rodriguez (2017). In like manner, if an analysis of operation, agility, and interaction is required, it can be found in Parras-Burgos et al. (2020). Moreover, Sukotjo (2021) provides an instrument to measure perception, in the same way, Salomoni et al. (2017) address how an instrument can evaluate graphical interfaces, also, if the user experience needs to be measured, the questionnaire shown by Rechowicz et al. (2019) could be implemented. Finally, system usability can be measured applying a tool called 'System Usability Scale', which has been adopted in several projects with ER (Al-Muraikhi et al., 2021; Dayarathna et al., 2021; Costa et al., 2016; Hamzah et al., 2021; Brooke, 1996).

Conclusions and future work

This paper allowed analyzing scientific and academic production to build DCL, ER, PID, UDL, and UCD. A total of 721 articles were examined in the first section of the SLR, where the inclusion and exclusion criteria were applied to obtain the articles that best met the defined objectives, thus reducing the number to 77 articles.

Subsequently, a new evaluation was carried out by applying information extraction and synthesis criteria; from this new evaluation, 33 articles were obtained and their contribution to the research questions was evaluated, thus generating the final number of 26 articles. Consequently, we were able to answer the research questions posed in this study, therefore, it was discovered the inexistence of a development methodology applied specifically to DCL, ER, UDL, UCD, and PID. Likewise, we identified research, elements, attributes, patterns, and evaluation methods that can help in the construction of a methodology with these characteristics.

As a result, we presented elements for a future methodological proposal, indicating a set of steps, such as identification of a methodological structure, selection of elements to facilitate the design of DCL, ER, and selection of evaluation instruments for ER products. Besides, we found a possible research area as the use of ER for the construction of DCL implementing UDL and UCD, given the almost

null scientific production found in this systematic review. After analyzing the obtained results, we deduce the following observations:

1. The highest growth in the trend of publications on this topic occurs during 2019-2020. In contrast, the lowest growth is observed during the years 2020-2021 with only 5 papers produced.
2. Research that combines the terms ER, PID, UDL, and UCD is scarce; nonetheless, it is possible to find research that mixes one or two of these terms, but it was not possible to find a specific software development methodology for the implementation of ER. Instead, we found adaptations of software processes used by development teams and researchers for the conception of their products.
3. We found SLRs focused on demonstrating ER application to health issues, suggesting the close relationship between both topics, which can be exploited in the future.
4. In relation to DCL, the production of articles was very low demonstrating that it is a topic that can be delved into with the implementation of ER, UDL, and UCD to offer new library content experiences through immersive and accessible experiences for all users, including those with disabilities.
5. The main limitation was found in the search engines implemented because they only allowed a specific number of characters and Boolean operators. Owing this, search strings had to be delimited to ensure greater reliability in the obtained results.

Due to continuous evolution of computer systems and their interaction methods, ER is an interesting area of exploration to different research areas that wish to utilize this technology. This investigation is of great importance for researchers who are planning to put into effect DCL and ER for people with disability or that intend to mix it with UDL and UCD features. The identification of different evaluation methods exposed in this SLR will allow speeding up the search of tools for the assessment of future research that implement DCL and ER.

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