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Toward the Consolidation of Filming Simulators: A Systematic Literature Review of Virtual Environments for Audiovisual Learning and Practice

Andres Forero-Serna

Communication, Universidad de La Sabana, Chía, Colombia

ABSTRACT

In recent decades, virtual reality (VR) learning environments have expanded across various fields, promising procedural knowledge acquisition. While health and engineering have extensively explored these spaces, the audiovisual production domain has received comparatively less attention. Conversely, the entertainment and media sectors aim to reduce costs in immersive production, leveraging advancements in 360 cameras, VR headsets, and 3D visualization. This systematic literature review covers 14 years, aiming to comprehensively address this gap. Initially identifying 319 references, 33 were meticulously selected for analysis. The review elucidates key themes regarding needs, implementation strategies, and outcomes. While tool development prioritizes enhancing accessibility and affordability, applications remain confined to experimental pilots. This review highlights the need for further investigation of virtual environments for audiovisual learning and practice, with future research prioritizing broader implementations integrated into curricula or full-scale productions, as well as comparative studies to comprehensively assess the benefits of virtual environments.

KEYWORDS

Film production; screen education; virtual classrooms; simulated environment; computer simulation

1. Introduction

The manner in which virtual reality (VR) technologies will cause considerable disruption in education, owing to their ability to develop simulation-based education has been discussed during the last three decades (Jensen & Konradsen, 2018). Educational virtual environments are spaces where, based on a specific pedagogical objective, an experience is designed in a virtual environment, which may or may not be immersive and presents characteristics that, in some cases, emulate a real experience and at other times provide options that are impossible to develop in a physical situation (Mikropoulos & Natsis, 2011). Despite the emergence of the more affordable generation of virtual reality headsets represented in HTC Vive and the Oculus Rift, the interest of academics has increased, considering the possibility of achieving enhanced immersion. Despite substantial research into educational applications of different areas of knowledge, beyond specific fields such as aviation, military training, and, more recently, surgery, it is difficult to consider such disruptions as testable (Jensen & Konradsen, 2018). Further studies crossing technological and pedagogical perspectives distinguishing the specific features of virtual reality that allow concrete learning outcomes remain lacking (Mikropoulos & Natsis, 2011).

Particularly considering audiovisual teaching, we can assume that it has as much opportunity to develop education mediated by ICT and specifically by virtual environments as any other. However, owing to its characteristics, audiovisual has always been crossed by technique and technology as part of the contents viewed and skills to develop. Particularly, we can group some factors within this evolution of the technological aspect of the industry that affect the way in which production processes are learned: the demand for multimedia skills, the inclusion and popularization of previsualization and virtual production processes, and the proximity to gamer phenomena, such as machinima.

To begin with, the need to know and master technical processes and technological aspects has become more latent if we consider that the industry has experienced significant disruptions owing to the digitalization of production processes from registration, information processing, and exhibition, primarily during the present century. In this way, the traditional film production workflow has begun to approach other media, such as design, animation, and video games, not only blurring the boundaries of these media but also demanding a new range of broad digital production skills from filmmakers, both in training and professional practice.

Additionally, owing to the growing inclusion of digital effects in production, even beyond science fiction and fantasy, specialized processes such as previsualization are increasingly demanded and common in the industry to help the effective communication of a creative vision (Harvey, 2010). Previsualization is a process in which, from pre-production, the final result is prototyped and reviewed in advance to make better decisions and avoid excessive corrections in post-production, and has been integrated into the layout formats that were already built, such as the

CONTACT Andres Forero-Serna andres.forero1@unisabana.edu.co; anfose@gmail.com Communication, Universidad de La Sabana, Chía, Colombia

storyboard or the animatic, complementing, and strengthening them.

The pinnacle of combining real images with animation and visual effects throughout the entire production process can be found in iconic industry productions such as Avatar (Cameron, 2009), The Lion King (Favreau, 2019) and The Jungle Book (Favreau, 2016), where people began to talk about virtual production as a new form of audiovisual production. Virtual production combines virtual reality (VR) and augmented reality technologies, motion capture, and video game engines to achieve real-time results (Kavakli & Cremona, 2022; Pires et al., 2022). Similarly, virtual production poses a different approach to camera and cinematography with its novel digital possibilities, (Bédard, 2022; Maddock, 2019) as well as to the reinvention of other roles and processes from new workflows.

However, at the beginning of this century, the same uses of gamers began to expand the limits of animated audiovisual production by allowing them to develop audiovisual productions from the same machines and games in an independent movement that grew and attracted attention outside the entertainment industry called Machinima. Soon, this phenomenon would attract the attention of both teachers in the audiovisual field and other academics who saw in this form of production the possibility of accessing means of production that took advantage of cultural references shared with students, such as fandom culture and the interest and competition of gamers (Payne, 2011), and placed them at the service of other pedagogical objectives.

In this particular context, academia in the audiovisual field must focus on training its students for a new production landscape that demands competencies to work and produce in virtual environments. Faced with this evolution of production forms, the university has not yet dealt with training for virtual production, and formal courses on the subject have not yet been identified (Kavakli & Cremona, 2022). Simultaneously, audiovisual students are susceptible to similar situations of disinterest or demotivation as students in other areas; consequently, they can also benefit from the characteristics of virtual environments to access other ways of understanding theoretical concepts, increase their possibilities of practice in spaces designed for this purpose, or strengthen their decision-making before facing professional practice.

In both professional production and educational settings, incorporating virtual technology presents a promising but challenging panorama (Harper, 2019). The industry sees potential for greater democratization of technology in independent filmmakers' workflows, allowing for faster iteration and lower costs (Liu et al., 2023). This includes integrating new disciplines into audiovisual production (Dooley & Emery, 2023) and making digital storytelling more accessible to more untrained people (Ramsbottom, 2015). Academically, there is an opportunity to balance theory-heavy training with practical experience (Morago et al., 2021), despite lengthy and complex learning processes (Sears, 2020) and a widening skills gap due to technological advances (Willment et al., 2024). However, research on the impact and effectiveness of these technologies is insufficient (Liu et al., 2023). Therefore, this study highlights the importance of analyzing current research to recognize progress and identify opportunities for improvement.

For the reasons aforementioned, the present study aims to identify and analyze the status of the use of virtual environments for audiovisual from a literature review, as a method that seeks to answer specific questions about a field from the collection and analysis of data, when in such a case, it is considered that past reviews have not yet fully resolved the issue or at least, from a particular perspective (MacKenzie et al., 2012). Although a literature review is often used to synthesize or re-conceptualize the knowledge of a widely studied field, it is also used to determine the progress and consolidation of emerging or consolidating topics, which can benefit from a more holistic exploration and analysis of referents, with the objective of finding the framework for its understanding and definition (Ramdhani et al., 2014).

This study particularly aims to characterize the state-of-the-art based on the following primary research question:

What patterns identified in recent research on virtual environments for audiovisual training and practice can guide future studies to explore their potential for enhancing traditional teaching methods and promoting broader adoption among educators and students?

To answer this question, we propose approaching the analysis from the specific identification of the expressed needs of the field, the forms of implementation used, and the results applicable to audiovisual teaching achieved by the research collected through the following specific questions:

1. What needs are identified in the training or practice of audiovisual production that are susceptible to improvement through the implementation of virtual environments?
2. How have the proposals for virtual environments for the teaching or practice of audiovisual production been implemented?
3. What results have been obtained from implementing virtual environments in the teaching and practice of audiovisual production?

2. Method

This study adopts a systematic literature review methodology that considers qualitative documentary research. This approach is widely used in the social sciences and is understood to be rigorous because it follows systematization parameters and a previous plan that undergoes clear stages of inquiry, identification, selection, classification, and analysis (Gómez Vargas et al., 2015).

Particularly, through a systematic literature review, this study aims to characterize and examine what has occurred in the field of film education through the use of virtual environments in recent years. To this end, we focus on the past decade and the first years of the current decade, that is, from January 2010 to September 2023.

Owing to the emerging nature of the field under study, it was decided to include rigorous research works with review or socialization processes, beyond scientific journal articles, meaning that book chapters, doctoral dissertations, and conference articles in academic congress proceedings were included, with the latter being the most prolific source. This determination of a broader look for the inclusion of references is supported by other widely cited literature review works within the field of educational virtual reality, such as those conducted by Radianti et al. (2020), Jensen and Konradsen (2018) and Mikropoulos and Natsis (2011). The decision to include articles from conference papers is supported by the conclusion of the study by Randolph et al. (2007), in which no significant or statistical differences were identified when comparing the methodological quality of studies from journal articles and conference papers after analyzing a random sample of 352 articles from the field of computer science education. Similarly, by adopting a more holistic literature review that includes material from certain types of conferences, it seeks to avoid possible publication biases that may exist in scientific journals, such as in experimental studies versus negative or partial results (Kitchenham, 2004).

One of the initial steps of the review was a bibliographic search, resorting to scientifically reliable databases in which keywords were defined to allow initial access to a relevant and sufficiently broad sample. Thus, an initial search of the Web of Science scientific database was proposed. To obtain a larger amount of material for filtering, it was later expanded to Google Scholar. As general educational virtual reality is a broad field, it was necessary to create combinations of terms that would appropriately narrow the search to the objectives of this study. Thus, we searched for "virtual reality" combined with other terms such as "film education," "previsualization," "film," "education," "machinima," and "3D."

It is noteworthy that for this study, we considered studies in which virtual reality and virtual environments were used as tools for teaching, strengthening competencies, and/or transforming workflows and work tasks in film or audiovisual production. In this sense, works in which virtual or mixed reality was only considered as a final medium (360 videos, cinematic virtual reality, and immersive narratives) or that used film or media as an educational strategy for the training of areas of knowledge other than audiovisual production itself were discarded.

It is also important to point out that the selection criteria for this study assume that education and professional practice are linked to the extent that changes in one inevitably have an impact on the other; in other words, the way in which teaching and learning occur impacts the processes of the industry, as much as the evolution of the medium demands an adjustment in training. Additionally, in an industry where technological advances are diverse and constant, it is inconvenient to consider the training process completed by professionals who feel the demands of a constantly changing context.

Relevant information was systematically extracted from the selected papers for subsequent analysis and adapted from the review protocol proposed by Kitchenham (2004). Based on this information, a qualitative categorization and interpretation process was conducted, which allowed the construction of results and conclusions that serve as a proposal for understanding the field in future studies.

3. Results

A total of 319 references were found, of which 250 were from Google Scholar and 69 were from Web of Science. After the review process, a selection was made based on the relevant criteria to include or reject the references that would finally constitute the sample studied (Izaguirre Remón et al., 2010). The following exclusion criteria were applied:

1. The reference is repeated.
2. The material is not available for downloading or reading.
3. It is in a language different from English or Spanish.
4. The theme is considered far from the field (after reading titles and abstracts).
5. The reference is a summary of a paper and does not have a complete structure of a research article (previous review of the article).
6. It does not present an experimentation (after reading the article or chapter).

Thirty-eight filtered references were obtained after applying the first four exclusion criteria. Additionally, the selected group was completed with additional research identified using the snowballing method from the authors, citations, and references of the initially selected studies. Consequently, the number of references increased to 55. Finally, the last two exclusion criteria were applied: after reading the selected articles, those that did not have a complete article structure that did not present results after implementation in the experimental phase or that were reflection articles were discarded. Thus, 22 conference articles were discarded, leaving a final sample of 33 (Figure 1).

The final sample is comprised of 18 conference papers, 13 scientific journal articles, one doctoral dissertation and one book chapter. Although Spanish was included as a possible second language for the review, 33 selected papers were written in English. As presented in Figure 2, 38 participants from different countries were identified in the sample, within which Europe stood out as the region with the most research participants, with 21 from 9 different countries. The country with the most research is Germany with 7 participants, followed by the United States and Australia with 4. It should be mentioned that 4 of the German studies came from the same institution and research group: the Center for Computing Technologies (TZI) of the University of Bremen, which was developed within the context of its Empowering Digital Media research line, and the European project First Stage, concluded in 2019, which had an alliance of partners from the hardware and software development industry.

Two large groups were identified in terms of research area and discipline. Those interested in the media production

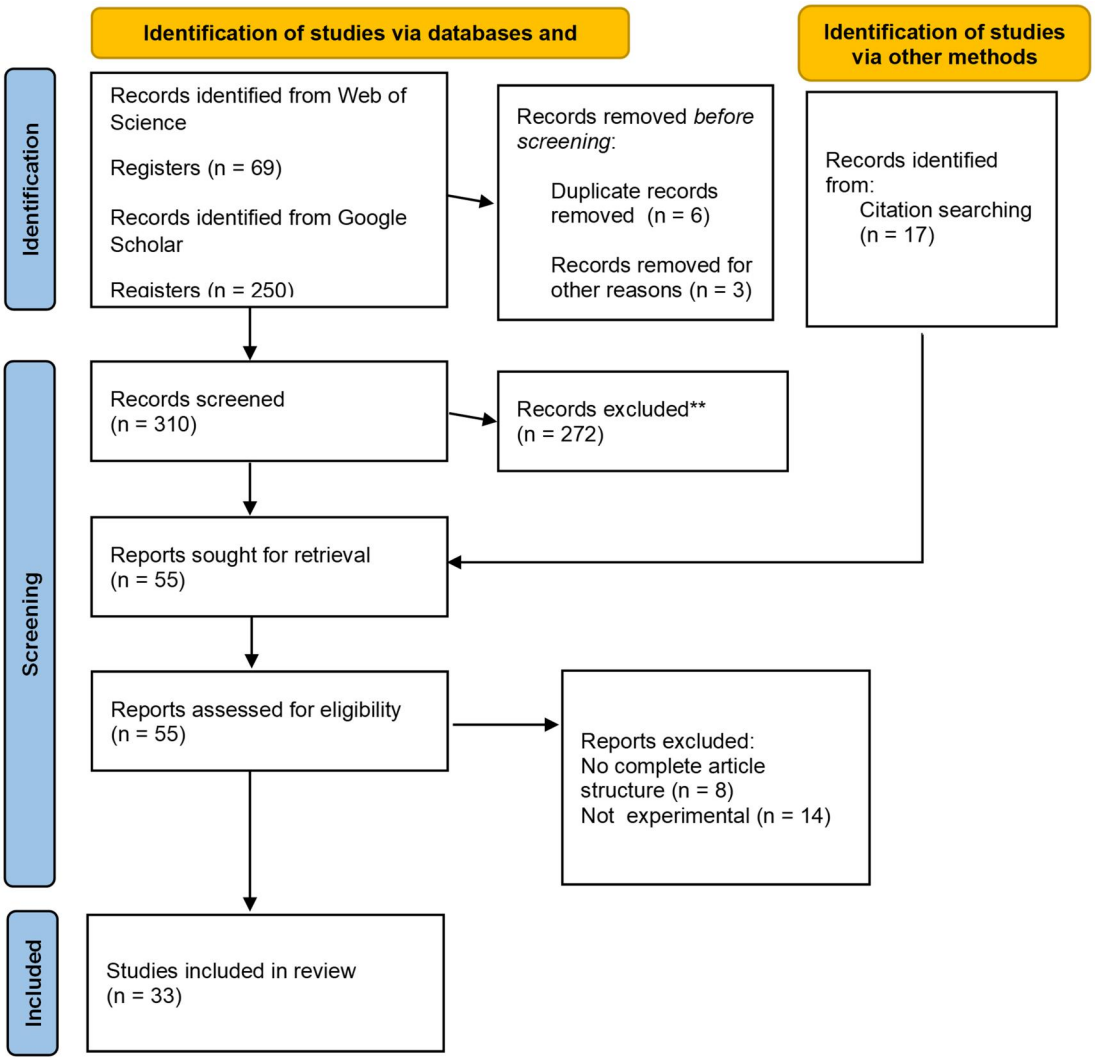

Figure 1. PRISMA 2020 Flow diagram (Page et al., 2021).

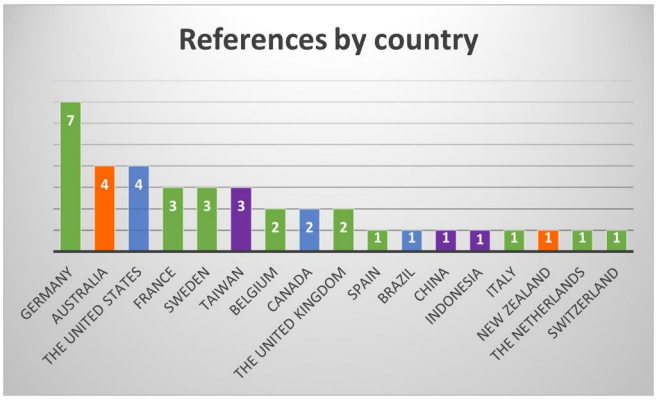

Figure 2. Country of origin of the references.

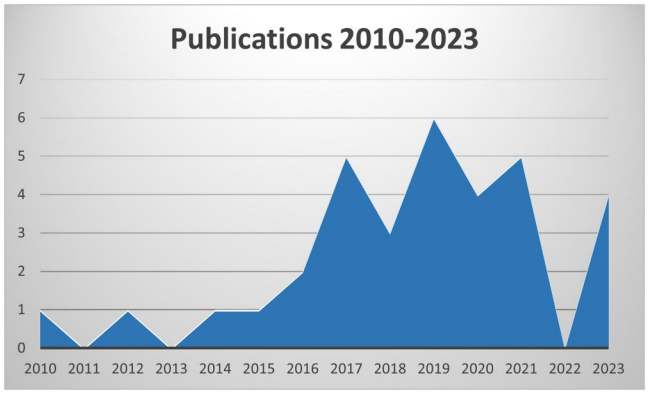

Figure 3. Number of publications per year.

processes, animation and screen production comprised 19 references, and those from technological development, including informatics, computer science, and human-machine interaction, comprised the remaining 14 references.

Of the 14 years of the selected period, as presented in Figure 3, the distribution of publications per year demonstrates a considerable increase in number of papers, from 7 papers in the first half of the period (2010–2016), to 27 in the second half (2017–2023). These last data may be consistent with the greater popularity of technologies such as Head-mounted display (HMD) VR headsets with milestones, such as the appearance of Oculus in 2013, resulting in a considerable reduction in the costs of this type of hardware, (Liu et al., 2023) and a bet by figures such as Mark Zuckerberg in the development of content for this platform from Oculus Story Studio between 2014 and 2017 (Ziemsen, 2017).

The analysis matrix, adapted from Kitchenham's (2004) review protocol, included the following information for each reference: title, author, country of origin, research question, hypothesis or assertion, theoretical framework, methodology, gap or justification, and conclusion. This information was grouped according to the searches proposed to understand the phenomenon based on the research questions of this study.

The first question corresponds to the identification of the needs in which scholars insert their work, as extracted from the revisions of the research question and justification. The second question, related to the ways in which the developed proposals were implemented, was answered by analyzing the methodology. For the third question associated with identifying the achievements of these studies, the hypotheses, statements, and conclusions were reviewed. Finally, the origin of the studies and the theoretical framework were not included in the categorization because they were considered not to be directly related to the questions posed or did not provide any relevant perspective in terms of findings, considering the trends or associations identified after the analysis.

3.1. Types of needs

After reading and analyzing the questions and justifications, three types of expressions of research needs were identified depending on whether the focus was on people's experience, the technological context, or the criteria for automation development, as well as five different expressions of needs (Table 1).

Therefore, 21 of the 33 studies were oriented toward the experience of individuals. However, to achieve greater discrimination of this group, it was decided to separate the studies clearly aimed at students from those that were oriented toward professionals. Thus, 9 studies were classified as specifically or primarily aimed at students, indicating that students require friendly and optimized environments for learning and practice. The other 12 studies, aimed at professionals, were concerned with the need for accessible technologies specifically for previsualization or virtual production. This does not imply that no studies mentioned the identification of weaknesses or opportunities shared by the two audiences; however, it was evidenced that development was primarily focused on one of the two, and on some occasions, the other was mentioned as an additional possibility of scope.

Similarly, several studies began with the expression of needs and opportunities from the technological feasibility of the current context of audiovisual production. In summary, immersive technologies have opened the door to the evolution of production processes and new audiovisual language options. In this group, 10 works were classified, of which 8 were in the first subgroup, where immersive technologies lead to changes in work dynamics and roles; and 2 were in the second subgroup in which these technologies allow valid expressive possibilities that require attention and development.

To a lesser extent, studies that focused on virtual environments related to the development of automated production systems were identified. However, this potential, derived from the digitalization and virtualization of the production process, means that audiovisual automation requires the application of theoretical criteria to improve its results. Thus, two investigations were conducted by this group.

In the larger group, which focused on the learning or production experiences of students and professionals, much attention was paid to the complexity and costs of the processes involved in producing animation or mixing real and digital images. For example, in studies aimed primarily at industry professionals, the identification of previsualization and virtual production as processes with high technological demands in terms of costs and knowledge is repeatedly observed, therefore, it is challenged by the possibility of facilitating access to such work for a large group of audiovisual professionals who are not specialists in animation, special effects, or who do not have the resources to hire such services (Aguilar et al., 2019; Bodini et al., 2023; Galvane et al., 2019; Grau et al., 2017; Hawes et al., 2019), and who would benefit from possibilities such as remote collaborative work (Ardal et al., 2019; Nebeling et al., 2020), intuitive manipulation of motion capture systems (Kammerlander et al., 2021), tangibles, (Muender et al., 2019) or natural interfaces (Malaka et al., 2021; Muender et al., 2018; Volkmar et al., 2020).

Table 1. Needs by focus.

Focus	Expression of the need	Amount	References
People experience	Students need friendly and optimized environments for practice and learning	9	Bennett and Kruse (2015); Burn (2016); Carter (2012); Harkema and Rosendaal (2020); Harvey (2010); Lin et al. (2018); Liu et al. (2023); Morago et al. (2021); Dooley et al. (2020)
	Practitioners need accessible previsualization or virtual production technologies	12	Aguilar et al. (2019); Ardal et al. (2019); Bodini et al. (2023); Galvane et al. (2019); Grau et al. (2017); Hawes et al. (2019); Kammerlander et al. (2021); Malaka et al. (2021); Muender et al. (2018); Muender et al. (2019); Nebeling et al. (2020); Volkmar et al. (2020)
Changes through technology	Immersive technologies lead to changes in work dynamics and roles	8	Bennett and Carter (2014); Cannavo et al. (2019); Dooley and Emery (2023); Hach et al. (2017); Hendry et al. (2023); Kang and Li (2021); Nguyen et al. (2017); Vogel et al. (2018)
	Immersive technologies allow for valid expressive possibilities that require attention and development	2	Wastyn et al. (2021); Ziemsen (2017)
Automation improvement	Audiovisual automation needs applied theoretical criteria to improve its performance	2	Fanani et al. (2016); Galvane and Ronfard (2017)

Regarding the subgroup focused on the students' experience, there is a concern for training students in nonlinear production logics from processes such as previsualization, virtual production, and motion capture, (Bennett & Kruse, 2015) considering that it can facilitate learning processes, experimentation of roles, and understanding of concepts (Harvey, 2010; Lin et al., 2018), or specific aspects, such as a greater possibility of playing with the camera (Morago et al., 2021), and even an alternative way to traditional face-to-face and tactile exploration (Harkema & Rosendaal, 2020). Moreover, there is research concerned with establishing differences between immersive and non-immersive environments to support student training in different ways (Liu et al., 2023). However, in addition to the aforementioned previsualization and virtual production processes, machinima is identified as a cultural phenomenon of interest to consider as a possible bridge between tradition and the technological uses of students (Burn, 2016) and to seek, for example, through its practice, the strengthening of the understanding of texts and theoretical concepts by way of performativity (Carter, 2012). It is noteworthy that only one study identified in this group inquired about the role of immersive production in relation to educational perspectives on the problematization of teaching and learning processes (Dooley et al., 2020).

Proceeding to a group of works focused on the changes in dynamics, roles, and expressive possibilities made possible by technology, there is an interest in the possibility of improving and facilitating production flows from different aspects, which are becoming increasingly viable technologically. In this way, production processes would benefit either through the possibility of real-time interaction of digital models (Hendry et al., 2023), manipulation of models in more intuitive interfaces (Vogel et al., 2018), motion capture as a facilitator of production processes (Bennett & Carter, 2014), camera depth information to simplify post-production (Hach et al., 2017), the possibility of assuming more than one role by the same person in iterative production logic (Kang & Li, 2021), or the strengthening of the understanding of space owing to immersion as an enabler of better creative decisions in production (Cannavo et al., 2019) or editing (Nguyen et al., 2017).

Of the works identified as being concerned with the development of new artistic and expressive possibilities derived from technological advances, we have, for example, Ziemsen (2017), who suggested that the state of maturity of machinima proposes that we should consider it as a valid production technique and form of expression, with clear advantages for experimentation and, therefore, training. Similarly, Wastyn et al. (2021) considered that virtual space lends itself to improvisation in states of collaborative flow, adding a component of performativity to production, which opens a greater dialogue between filmmakers and the audience.

Of the two works that focused on improving the automation process, there are studies that explore the location of the camera. Galvane and Ronfard (2017) were concerned with how to relate the role of point of view and focalization, as well as the proximity to a subject or object, according to its relevance at a moment in the story (mentioned as Hitchcock's rule) with the proposed direction of photography and editing, aiming to allow that through automatic cinematography a screenwriter can see different versions of films derived from the changes he suggests in the script. According to a study by Fanani et al. (2016) there is also an inquiry into rules that allow an automatic system to better determine and define the shot value and angle for different moments of a machinima animation. Both projects force us to consider the place of film analysis theory, which is usually relegated to criticism as a reflective exercise for the audience, as a necessary criterion for making assertive decisions in production. The configuration of variables and rules for the creative decisions of automatic systems necessarily leads us to discern how we make decisions, such as camera placement, movement, and blocking, in terms of the narrative.

3.2. Implementation approaches

After reviewing the methodological definitions of each reference in the sample, three approaches were identified to implement and validate the research proposals. The first and most widely used method (18) was to test end users, divided between evaluations by experts or professionals (11), novices or students (3), or both audiences (4) (Table 2).

Similarly, a second current is presented, in which 9 of the studies opted to propose production exercises. Of these, two specifically stated that they were identified with practice-based research, although there were differences in methodological design and tools. For example, Ziemsen (2017) turns to an external peer review with the content produced, whereas Bennett and Carter (2014) use reflective analysis to reach conclusions.

As a third trend, it was found that 6 works conducted the design of exercises implemented in the curriculum in specific classes. Additionally, 2 papers (Aguilar et al., 2019; Nebeling et al., 2020) from the content production group specified students' chief tasks in the production process. If we added this group to the 7 investigations in which students were used as evaluators of the prototypes, we found that 15 of the 33 works were directed at or implemented directly with students within the academic environment.

Additionally, 21 studies developed prototypes, of which 7 reported using post-surveys to collect user experiences. However, only in Volkmar et al. (2020) the use of standardized questionnaires was specified. Similarly, 4 studies from the group of 21 prototype developers mentioned the interview as the tool used to collect usage information, whereas three other studies mentioned it as part of other methodological designs. Finally, 7 references described the design of experiments with specific conditions or tasks to be developed or fulfilled by users, as opposed to the free practice of the prototypes.

In addition, of the remaining 12 projects that did not develop a prototype, 6 designed didactics were adapted to a classroom curriculum, 5 of which used off-the-shelf software tools rather than developing their own. The remaining

Table 2. Method of implementation.

Method	Implementation and validation	Amount	References
User tests	Expert/professional evaluation	11	Ardal et al. (2019); Hendry et al. (2023); Kammerlander et al. (2021); Kang and Li (2021); Malaka et al. (2021); Muender et al. (2018); Nguyen et al. (2017); Vogel et al. (2018); Bodini et al. (2023); Muender et al. (2019); Volkmar et al. (2020)
	Novice/student evaluation	3	Morago et al. (2021); Liu et al. (2023); Wastyn et al. (2021)
	Expert and novice evaluation	4	Cannavo et al. (2019); Galvane et al. (2019); Hawes et al. (2019); Lin et al. (2018)
Production exercises	Content production with the prototype	9	Aguilar et al. (2019); Dooley and Emery (2023); Fanani et al. (2016); Galvane and Ronfard (2017); Grau et al. (2017); Hach et al. (2017); Nebeling et al. (2020); Ziemsen (2017); Bennett and Carter (2014)
Implementation into the curriculum	Classroom exercises	6	Bennett and Kruse (2015); Burn (2016); Carter (2012); Harkema and Rosendaal (2020); Harvey (2010); Dooley et al. (2020)

Table 3. Types of results.

Type of result	Synthesis of the result	Amount	References
Usability improvement	Offer a more usable, easy-to-learn environment with natural or intuitive interface	13	Aguilar et al. (2019); Bodini et al. (2023); Cannavo et al. (2019); Galvane et al. (2019); Hach et al. (2017); Malaka et al. (2021); Muender et al. (2018); Muender et al. (2019); Nguyen et al. (2017); Volkmar et al. (2020); Wastyn et al. (2021); Vogel et al. (2018); Grau et al. (2017)
Change in the work dynamics	Enable iterative workflows, with collaborative, remote dynamics and reduction of processes and costs	7	Ardal et al. (2019); Dooley and Emery (2023); Lin et al. (2018); Nebeling et al. (2020); Kammerlander et al. (2021); Bennett and Carter (2014); Grau et al. (2017)
Camera experience	Allow another way of approaching framing, movement and camera placement	6	Bennett and Kruse (2015); Vogel et al. (2018); Fanani et al. (2016); Galvane and Ronfard (2017); Hawes et al. (2019); Morago et al. (2021)
Training for new media	Conducive to the formation of new skills and other forms of expression	4	Dooley et al. (2020); Kang and Li (2021); Bennett and Carter (2014); Grau et al. (2017)
Simulation space	Suitable for the development of simulation strategies to experiment and strengthen decision making	4	Harvey (2010); Morago et al. (2021); Hendry et al. (2023); Ziemsen (2017)
Theoretical comprehension	Facilitates understanding of concepts by making them more practical and experiential	4	Burn (2016); Carter (2012); Bennett and Kruse (2015); Harvey (2010)
Emulation of the physical experience	They generate a novel experience through presence, embodiment and tangibility	3	Harkema and Rosendaal (2020); Liu et al. (2023); Kammerlander et al. (2021)

research (Dooley et al., 2020) focuses more on presenting the importance of the inquiry-based learning perspective and its relationship with immersive production teaching than on the technology used.

3.3. Types of result

Finally, 33 selected papers were reviewed based on their hypotheses, statements, and conclusion sections to determine coincidences and trends in the types of achievements reached by the proposals. Despite studies focused on industry or education for industry, the approach to virtual environments was primarily divided into areas such as previsualization, virtual production, machinima, animation production, and the construction of automatic cinematography systems. Thus, we grouped the types of achievements into 7 categories by the type and synthesis of the results found for each group. Of the 33 references, 26 were located in a single category, 6 in two categories, and 1 in three categories, for a total of 41 types of results identified in the sample, which are discriminated and presented in the following Table 3.

The group with the largest number of identified works was related to the possibility of more usable learning or production experience. Here, we highlight the first subgroup of research that demonstrates the effectiveness of virtually replicating the traditional method of producing audiovisual content from the creation of natural interfaces for previsualization, which are nourished by our real-world actions and make a more effective translation of the results, facilitating the processes to a wider audience that does not necessarily have to be an expert in 3D animation (Malaka et al., 2021; Muender et al., 2018, 2019; Volkmar et al., 2020).

Another subgroup of studies demonstrated the benefits of visualizing and experimenting in real time with the results of digital actions from pre-production to post-production. Here, we conducted experiments that achieved user-friendly virtual environments for pre-production tasks such as storyboarding and audiovisual prototyping (Galvane et al., 2019), facilitating activities such as location scouting (Bodini et al., 2023), 360 content editing from virtual interfaces (Nguyen et al., 2017) and virtual studio prototypes that simplify the production of visual effects, allowing independent or novice producers to include this type of content in real time (Aguilar et al., 2019; Grau et al., 2017) achieving aspects such as the inclusion of dynamic shadows, occlusions, and semitransparent screens (Hach et al., 2017). Similarly, studies that achieved faster and easier learning of 3D animation

processes from virtual puppets or armatures emulated the work of a puppeteer more than a digital animator (Cannavo et al., 2019; Vogel et al., 2018) and with a more immersive and tangible experience benefited by immediacy (Wastyn et al., 2021).

Although also related to the improvement of working methods, a group of 7 research studies with results on the flows and dynamics of production processes were found. Here, we see the relevance of the implementation of technologies, such as video game engines (Ardal et al., 2019; Dooley & Emery, 2023), motion capture, (Bennett & Carter, 2014; Kammerlander et al., 2021) and the capture of depth information in real time, (Grau et al., 2017) enabling other skills that bring audiovisual production closer to the logic of multimedia production.

It is noteworthy the research group that aimed to generate a contribution from virtual environments to the manner in which the camera and framing work. Here, we initially identify works that contribute to strengthening directors' core competencies, since they present proposals that facilitate learning, understanding, and decision-making related to the camera (Hawes et al., 2019; Morago et al., 2021; Vogel et al., 2018). However, there were those that made use of the possibilities of the virtual environment experience to consider transferring such decision-making direction competencies of the point of view to an automatic system (Fanani et al., 2016; Galvane & Ronfard, 2017) or the viewer himself (Bennett & Kruse, 2015) in an environment, which again approximates and blurs the boundary with video games.

4. Discussion

In general, studies are perceived to aim at transforming teaching or production processes using virtual environments, declaring the need for greater affordability and accessibility. This is evident despite their initial focus on individual experiences or proposed technological modifications at the onset of research. Notably, these efforts are characterized by reduced costs, user-friendliness, and seamless integration with industry-specific utilities and contemporary work dynamics, enabling iterative, collaborative, and remote experimentation. All of the above goes hand in hand with the common idea of adapting technological advances to greater democratization a few years after their appearance.

The analysis of the methodological proposals identifies that most studies developed prototypes and consequently opted to test them directly with users, surpassing those that opted for more direct implementations in the natural environments of the proposals, either the classroom and integration into the curriculum from those focused on educational processes, or within content productions by those focused on media industry processes. A possible explanation for this finding may emerge from the nature of most of the samples, as they are projects that present partial results at academic conferences and, therefore, can be considered in a pilot stage. Thus, the emerging nature of the study area is reinforced by the fact that most studies have tested small groups of users in experimental spaces.

With regard to the study of training gaps in the current technological context, we see studies such as that of Willment et al. (2024), which, in relation to the UK audiovisual production industry, identifies that, beyond traditional skills, there is a growing need for enhanced communication, teamwork, flexibility, and the ability to apply knowledge in an ever-changing work landscape. This coincides with the industry's interest in successfully adapting the creative sector to the new dynamics of immersive technology production, as demonstrated by initiatives such as the Virtual Production Skill Report (Bennett et al., 2023), which uses surveys, interviews, and case studies of the industry in the UK to identify training gaps, challenges, and opportunities for the sector. In their findings, they advocate a consolidation of communication based on a common language, greater openness to democratization, not only by making tools cheaper, but also in terms of ease of understanding and access by all actors involved in the chain.

It is also noteworthy a more noticeable approach to proposing solutions from new technologies and software tools, where an advance in terms of usability prevails over the evaluation of the results, either of learning or of the language itself and its expressive possibilities. In this sense, there is limited intention of analyzing the role of virtual environments in the way we learn to produce content, in a contrasting manner or in more rigorous comparative studies, compared with other traditional teaching and production alternatives. If we also consider that in a post-pandemic world, adapting to digital spaces and a landscape with changing challenges, researchers such as Henry and Maric (2023) have pointed out the need to establish transversal reflections and debates between different isolated experiences of teachers and institutions, in order to recognize good educational practices mediated by technology for the field of teaching audiovisual production.

However, if we focus only on the projects aimed at teaching and learning, it is evident that the starting point is rarely established from diagnosed curricular or educational problems. Similarly, there is limited reflection on the articulation of technologies in teaching or learning processes, and even in the methodological descriptions of most of them, there is an absence of a position in terms of the pedagogical approach. As mentioned, in a few cases, studies are related to educational methods and strategies, such as inquiry- or problem-based learning (Dooley et al., 2020), or particular perspectives on approaching knowledge, such as practice-based research (Bennett & Carter, 2014) and a/r/tography (Ziemsen, 2017).

In terms of the analysis of results, the two largest groups are related to achievements in usability and effectiveness improvements. This aims to make audiovisual production more accessible by simplifying complex technical procedures through natural and intuitive interfaces, as well as making production dynamics more cost-effective.

In contrast, the following two trends (camera experience and training for new media) suggest expanding the scope of audiovisual production in the context of the new digital characteristics and possibilities, either by exploring new

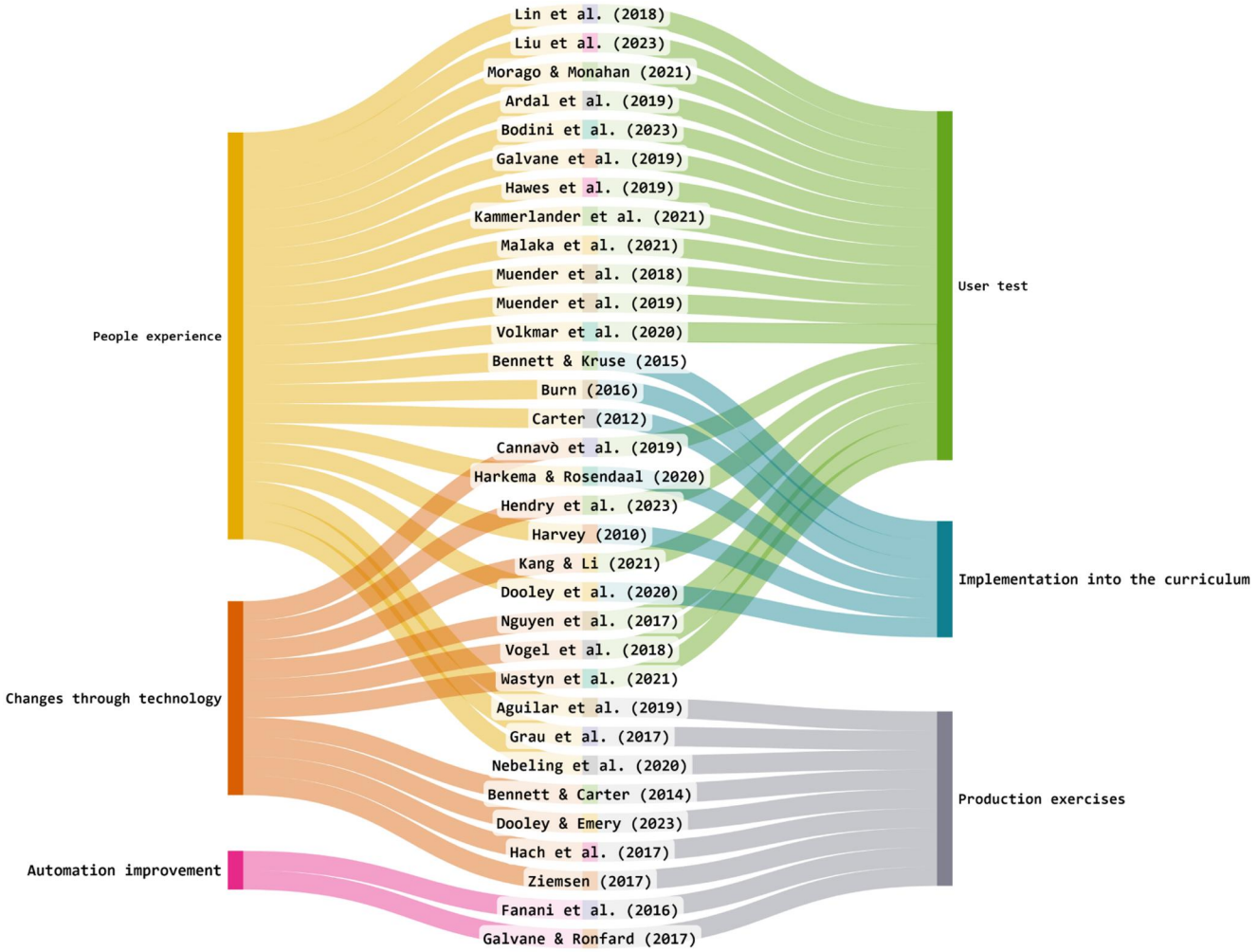

Figure 4. Focus of the needs to implementation method.

ways of approaching the camera or by acquiring new skills that allow a wider range of expression. Indeed, examining the changing dynamics of the creative industries in light of evolving roles is consistent with recent work by researchers such as Maddock (2019), who focuses on cinematographers in mixed real and virtual environments, or Carvalho et al. (2024), who assess the impact of cyberperformance scenarios on actors.

Likewise, although more distributed in other types of results, it is important to highlight that the next 3 groups (simulation space, theoretical comprehension and emulation of the physical experience), with 10 related references, are associated with the characteristics of virtual environments with the potential to contribute positively to educational outcomes (Mikropoulos & Natsis, 2011) such as the possibility of designing models that strengthen competencies that would later be applied at the moment of real practice, the option of experiencing a virtual space and body as if it were real, and the ability to translate abstract theoretical concepts into a practical experience, also mentioned as virtual reality's properties of simulation, presence, embodiment, and reification. The Virtual Production Skill Report also calls for greater research attention to the practical and theoretical implications of virtual production, both for filmmakers at the creative stage and for actors and technical personnel on the set.

An examination of the relation between the focus of needs and the forms of implementation (Figure 4) and between the expressions of needs and the forms of implementation (Figure 5) shows that most user experience concerns opt for user testing, while production exercises are found in all three types of focus. However, there are also peculiarities, such as that curricular implementation is used only by studies focused on the student experience, but this group does not explore production in academic spaces as a form of implementation.

An analysis of the interrelations between the need focuses and the types of results (Figure 6) reveals that the majority of studies concerned with user experience achieve findings in terms of usability improvements. However, it is also evident that within that group of research concerned with user experience, there are results in the other six types of results.

Finally, an analysis of the interrelations between implementation methods and types of results (Figure 7) identifies particularities. For instance, the findings in terms of theoretical understanding are exclusively derived from curricular implementation exercises conducted within the educational environment with students.

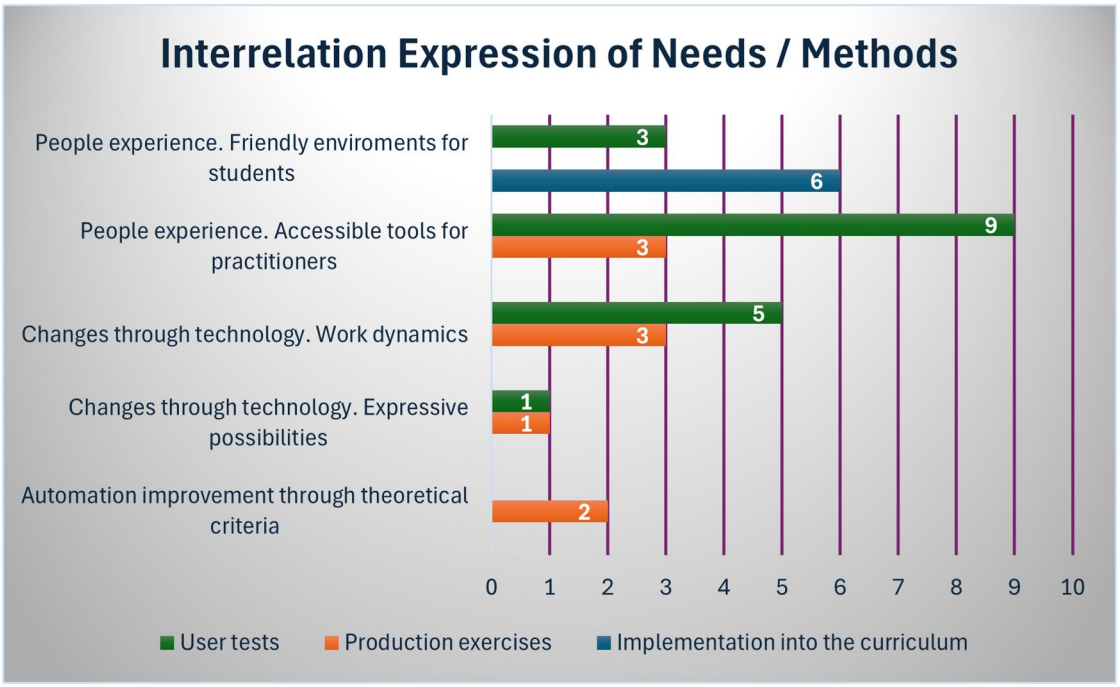

Figure 5. Interrelations expression of the needs and implementation methods.

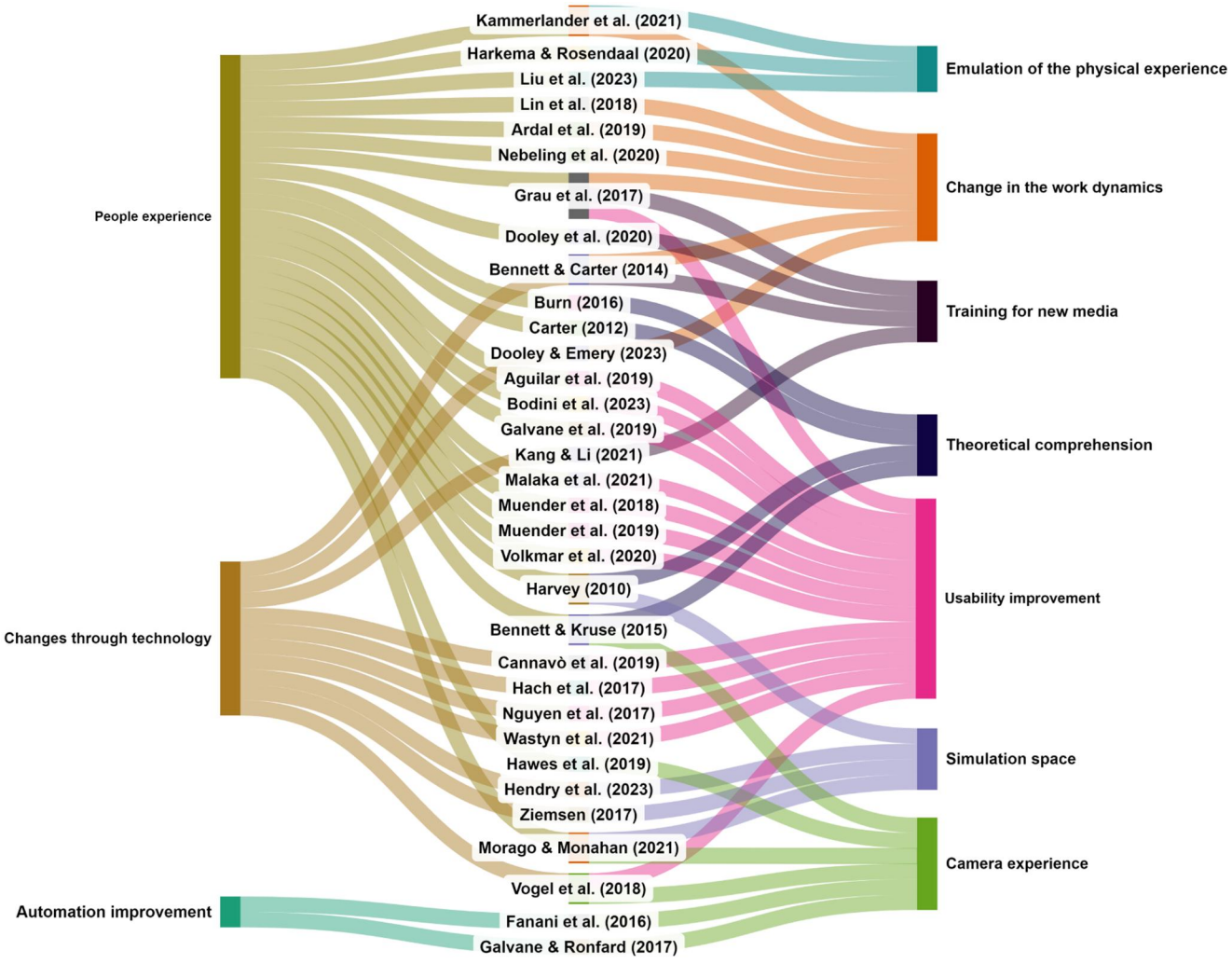

Figure 6. Focus of the needs to results.

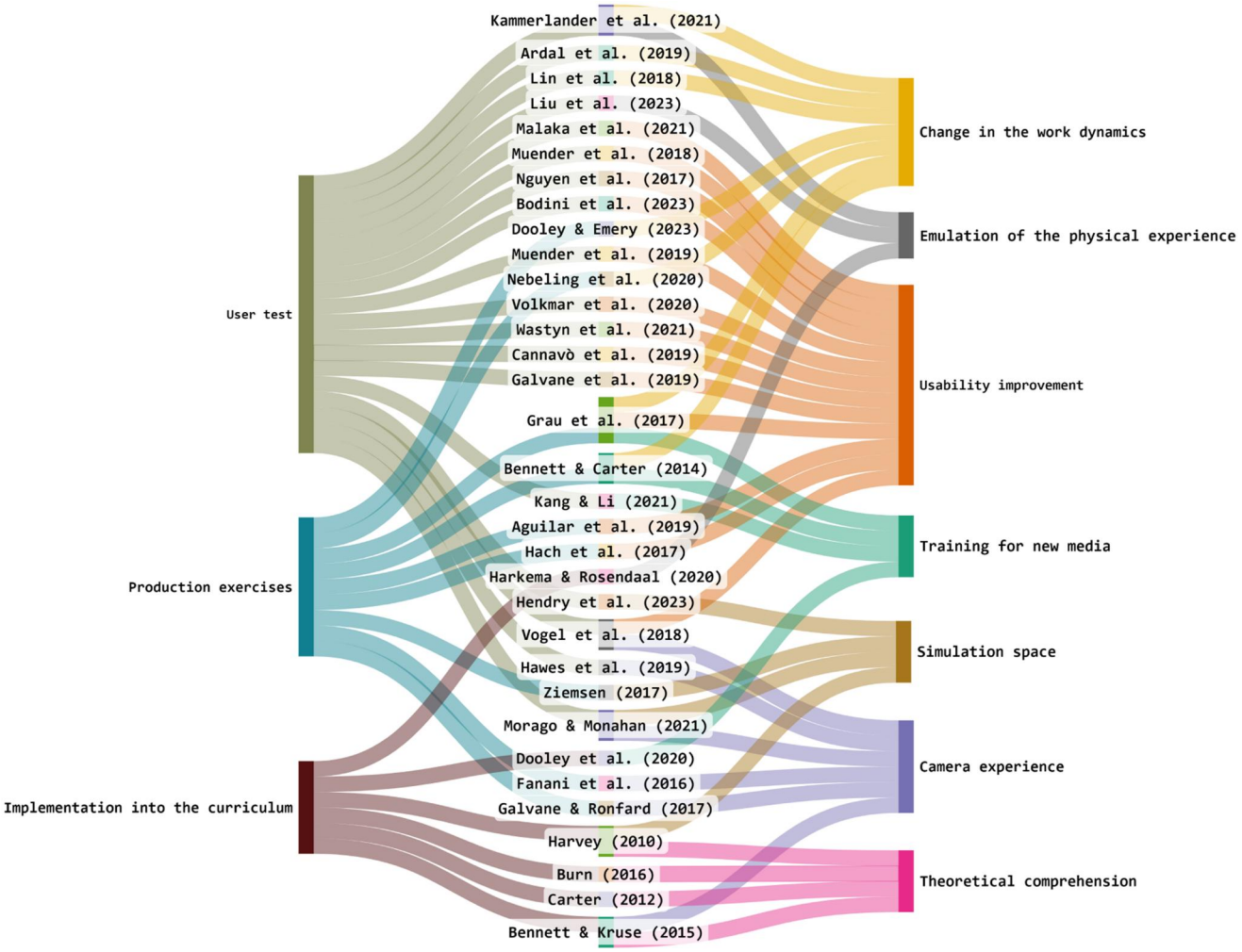

Figure 7. Implementation method to results.

5. Conclusion

Regarding the objective of the present study to identify patterns that emerge from the literature review to characterize the use of virtual environments for teaching and practicing audiovisuals, and projecting future research for the field, the following conclusions are presented based on the analysis of needs, implementation methods, and results, as well as their interrelation, as the axes of the three specific questions formulated. While this study initially aimed to identify the use of these virtual environments to support their use among students and teachers, the findings may also interest those examining gaps between training and practice, as well as the role of academic research in evolving production dynamics.

The analysis begins by acknowledging technological context. This context presents an opportunity for change in the dynamics of work and the expressive possibilities of the audiovisual industry. However, it highlights concerns regarding the difficulty of processes related to digital production, 3D animation, and the inclusion of special effects. This concern often leads to a focus on affordability and accessibility with the desire for easier and more democratic production processes. The need to facilitate, simplify, or reduce the cost of technical processes is partly explained by the fact that much of the research in the sample focuses on previsualization, virtual production, and 3D animation projects. Conversely, concerns about technical and procedural aspects also prevail over other starting points, such as identified barriers to learning or industry entry gaps, as evidenced by the UK Virtual Production Skill Report in relation to general communication skills.

Similarly, in accordance with the growing focus on people's experiences, the prevailing approach to implementation involves the creation of technology-based tools evaluated through usability testing. However, it can be challenging to track these studies as many use non-standardized tests with small groups of evaluators and rely on isolated usage experiences.

In addition, the results of most studies are associated with greater ease of learning or use, efficiency of processes, adoption of more collaborative workflows, and optimization of resources. Although only four studies from the University of Bremen directly address natural interfaces, other studies approach usability through intuitive actions that tend to relate to characteristics defined as natural semantics in virtual learning environments.

Although there are few of them, researchers who focus on practical and theoretical implications of virtual,

interactive, or automated aspects in relation to specific audiovisual features, such as camera representation, should not be overlooked. These features are related to other characteristics of virtual environments, such as presence, immersion, or autonomy, as well as the evolution of traditional production roles or of the audience itself towards more active roles.

In conclusion, the presented analysis suggests opportunities for future research in virtual environments applied to audiovisual learning and practice, which could help further consolidate the field. One approach is to begin with inquiries involving more complex questions based on reliable diagnoses of learning difficulties and joint academia-industry studies on barriers for field staff. Furthermore, it also entails the methodological consideration of larger-scale study designs. This means moving beyond simply facilitating learning and production processes with pilot tools in small experiments on the margins of everyday life to implementing projects that aim for a deeper impact, such as integrating them into the curricula of various classes over multiple academic periods or testing them in full-scale productions across different case studies. Additionally, extending the evaluation period can help minimize potential bias in the assessment of a technology owing to its novelty. In the same sense, it is also necessary to conduct more comparative studies that analyze results in traditional teaching or production processes, compared with the new VR proposals, with broader criteria than simply the perception of user experience, to determine in a more complete and certain way the convenience of using virtual environments for audiovisual learning and practice. Finally, research that addresses student experience can expand the scope of curricular implementations that initially focus on theoretical understanding and academic contexts, such as experimental audiovisual production. This approach allows for further explorations of artistic possibilities and changing dynamics and workflows, while remaining independent of other economic pressures associated with professional production.

It is important to note that this literature review has some limitations. Although this was a systematic review, it was limited to two scientific databases and a period of approximately 14 years. The review also established exclusion criteria to ensure scientific rigor, resulting in the exclusion of other types of publications, such as master's and undergraduate theses and popular science books. It is expected that in the coming years, the amount of scientific research in this field will increase, which will allow us to further enrich the characterization efforts proposed here.

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ORCID

Andres Forero-Serna http://orcid.org/0000-0003-0564-756X

Data availability statement

Data available on request from the authors.

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About the author

Andres Forero-Serna is an Assistant Professor and animator, PhD candidate in Communication at the Universidad de La Sabana. He holds a master's degree in Education and a bachelor's degree in Film and Television. His research interests include animation, video games, virtual environments, practice-based research, and film education.