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Systematic Review

A Systematic Review of the Literature on Maker Education and Teacher Training

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Abstract: This systematic review aims to analyse the existing research on the introduction of maker education in teacher training and continuous professional development. There is a growing interest in defining the state of the art on this topic. Using the WOS database, 20 empirical studies published in peer-reviewed journals between 2019 and 2023 were further analysed. The studies were systematically examined to identify the general characteristics related to the type of maker education training intervention. The principal findings of this review indicate that the majority of training programmes are primarily aimed at pre-service and in-service teachers, and the number of articles published has increased significantly in recent years; moreover, the characteristics of these programmes vary considerably across the studies identified, indicating an uneven distribution of research activity. Despite the growth in the literature, there is still a notable gap in terms of the specific knowledge acquisition that teachers require in order to effectively implement maker education. While many studies emphasise equipping educators with both practical skills and theoretical knowledge, fewer focus solely on knowledge acquisition. This review emphasises the value of immersive experiences for training teachers, demonstrating the positive impact such experiences can have on their confidence and mindset. Additionally, the potential of virtual training programmes to create collaborative, supportive learning environments represents an innovative approach to enhancing teacher preparation in maker education. Based on the findings, it must be emphasised that there is still a need for the further research and development of maker education training models specifically designed to facilitate the integration of making approaches into formal education.

Keywords: maker education; pre-service teaching; in-service teaching; professional development

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1. Introduction

Research into makerspaces in higher education needs to start with a deep understanding of the maker movement and its impact on formal settings. The first Maker Faire was held in 2006, and since then, the maker movement has been introduced into both formal and informal learning environments for its potential to enhance learning [1].

This literature review provides valuable insights to inform professionals and educators seeking to understand the current state and dynamics of maker education at university level and professional development. While the existing literature on university maker education and makerspaces [2,3] is extensive and covers a wide range of disciplines and their impacts [4,5], this study primarily contributes to the field of education and the humanities. Specifically, our review examines the types of maker education programmes, their duration, their target audiences, and the main aims and characteristics of these programmes.

1.1. Background

The maker movement is seen as a phenomenon where different agents come together to create communities where they can tinker, create, and build unique creations and artefacts [6]. It derives its name from the do-it-yourself mindset [7]. Transforming education would be one of the main challenges that maker education has [8]. Pedagogically, its origins can be traced back to the ideas of John Dewey and Seymour Papert. Dewey championed the idea that active participation in one's own learning is essential [9], and Papert emphasised the importance of construction over the simple transmission of knowledge [10]. Maker education aims to bridge the gap between formal and informal learning, encouraging individuals to consider the various places and methods through which they can learn [10].

The concept of maker education combines the terms "maker" and "education" with "maker literacy", which is defined as the deep demonstration of one's skills. Research has established the educational significance of making [1]. The term "constructionism" is related to a learning theory that links learning with hands-on creation [11]. Constructionism is a theory derived from Piaget's constructivism. It asserts that active engagement in the creation of tangible artefacts promotes effective learning. This allows for the sharing, discussion, exploration, and appreciation of the objects created. According to constructionism, the artefacts are pure manifestations of knowledge and understanding. When making, knowledge is reconstructed [12].

Maker education combines various teaching approaches, including project-based, inquiry-based, and collaborative learning [13]. It is viewed as a blend of information and communication technology (ICT) and active teaching methods, primarily utilizing technological tools and online environments [14]. Maker education is seen as a means of cultivating a maker mindset in learners, encouraging ongoing development, and facilitating inquiry-based learning. Furthermore, maker education promotes innovation and entrepreneurial awareness as additional key components [14].

A makerspace is a learning environment where students engage in creative activities and learn through exploration, design, play, and experimentation with a variety of tools and materials. They collaborate, ask questions, solve problems, and develop their own inventions [15] using techniques such as analysis and problem-solving [16]. Makerspaces are recognised for their potential to foster creativity, entrepreneurship, and other skills in a global and technological learning environment equipped with various materials and tools [17].

1.2. Teaching Approaches for Maker Education: Making as a Pedagogical Practice

In higher education, maker culture has the potential to promote a holistic approach to science, technology, engineering, and mathematics (STEM) education, as well as other fields such as social sciences and the humanities. Maker activities, which involve hands-on activities in the classroom, have been shown to improve students' skills in science, technology, engineering, arts, and mathematics (STEAM) [18]. Incorporating maker technologies in the classroom is thought to enhance students' knowledge and skills in STEM subjects, which are crucial for fields such as industry, higher education, entrepreneurship, and innovation [19]. Engaging in makerspace activities has been shown to improve comprehension of STEM [20]. However, teachers may face challenges in teaching STEM in makerspaces due to the new content, delivery methods, and physical space. Therefore, teacher training programs could address the unique preparation and experience required for teaching in such environments [21].

Empirical research has demonstrated the necessity for educators to utilise a learning-through-making framework in order to comprehend and integrate maker education into their teaching practices more effectively. To establish a framework for implementing maker education, three key elements must be considered [22]: firstly, it is essential to provide access to the necessary tools and technologies that facilitate making; second, there should be a community infrastructure that supports learning and encourages collaboration between makers, and this community should be located within the institution where maker education is implemented; finally, it is important to cultivate a maker mindset, which involves approaching learning through making in a playful, collaborative, and experiential way. To cultivate a maker mindset, teachers need to understand the importance, significance, and relevance of making things and act on this understanding [23]. They should also be given the opportunity to gain first-hand experience, possibly in real maker learning environments such as makerspaces, in order to achieve a positive change in their mindset [24]. Cultivating a maker mindset and empowerment is not limited to students alone; it is equally important for educators to feel and be makers themselves [25]. Despite this growing interest and the pedagogical benefits of integrating making activities into formal educational settings, there is currently a lack of evidence to support effective methods of teacher development in this area.

Makerspace activities should incorporate time for reflection. The essential elements for maker professional development include working on teaching and learning strategies, practicing what you preach, and exposure to technological equipment, not only machines but also in the making process. Additionally, makers should have time to share what they have made and consider shared knowledge construction [26]. Collaboration through making is a fundamental aspect of maker education. In a study conducted by Cohen et al. [27], both in-service and pre-service teachers engaged in making activities for a semester. The study concluded that collaboration was essential in creating a community of makers, and that the opportunity to tinker was also important. The maker-centred learning environment should ideally include features related to the community, process, and environment [25]. A supportive network is necessary to provide meaningful experiences and assist teachers in effectively introducing maker principles into the curriculum [28]. Professional learning that includes exposure to tools and the co-designing of curricular aspects can foster novice maker teachers' confidence and self-efficacy [29]. Teachers should receive training in both pedagogical procedures and technological tools to deliver appropriate instruction in makerspaces effectively. Educators who possess theory, knowledge, and skills about making are crucial to maximise the potential benefits of maker-centered learning activities for K-12 contexts [27]. Developing a maker identity aligns with the concept of comprehending the practical applications of maker pedagogy and integrating it into daily classroom practices [30]. Introducing maker pedagogies in pre-service teaching programmes makes them more representative and easier to integrate post-graduation [31].

As previously mentioned, the maker pedagogical approach has gained importance in formal education in recent years due to its potential to foster 21st century skills [17,32]. However, there is still a lack of research in terms of literature reviews in the areas of teacher training, higher education, and continuous professional development. This knowledge gap emphasises the limited understanding of training and supporting teachers to implement making practices [33]. Therefore, there is a need to further explore and develop professional development models specifically designed to facilitate the integration of making practices in formal education. It is essential to provide formal training and ongoing coaching opportunities for teachers and to take on the role of makerspace teachers [34].

This systematic review emphasises the necessity of incorporating structured maker education to bridge the gap in teacher training and enhance understanding of the key elements of these programs. This approach could support the development of future teacher training initiatives, enabling the more effective application and integration of maker pedagogies into educational practices.

2. Research Questions

RQ1. How has maker education been introduced in teacher training?
RQ2. What is the gap that exists in the literature on maker education in teacher training?
RQ3. What are the characteristics and main objectives of training and professional development programs related to maker education?

3. Method

To conduct the research, a search was performed in the Web of Science (WOS) database between 2019 and 2023 using the terms "makerspace" and "education" in peer-reviewed manuscripts. The database contains 359 articles from various disciplines, including education, making it comprehensive enough to cover the primary literature on maker education and higher education. The search was initiated on 19 April 2023.

The following lines provide a brief description of the search procedure used to include as many relevant studies as possible. A search was conducted using the keywords "makerspace" and "education", with duplicates removed using Zotero 6.0.26 software. The title of each article was then read to avoid the possibility of excluding relevant articles from the search. If the title did not provide sufficient information, we then read the abstract. If the abstract was also insufficient for exclusion, we proceeded to read the full article.

The systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [35], which are considered the most innovative method for this type of analysis (Figure 1). A total of 359 results were identified in the WOS database after the first search, which were then refined by language, leaving 353 articles. The study applied exclusion criteria to select records published between 2019 and April 2023 (n = 96), excluding those published before 2019. To be included in this review, studies had to focus on maker education in higher education or professional development (excluding public library or museum makerspaces); they had to be be full-text, peer-reviewed articles reporting empirical research; and they had to be published in English.

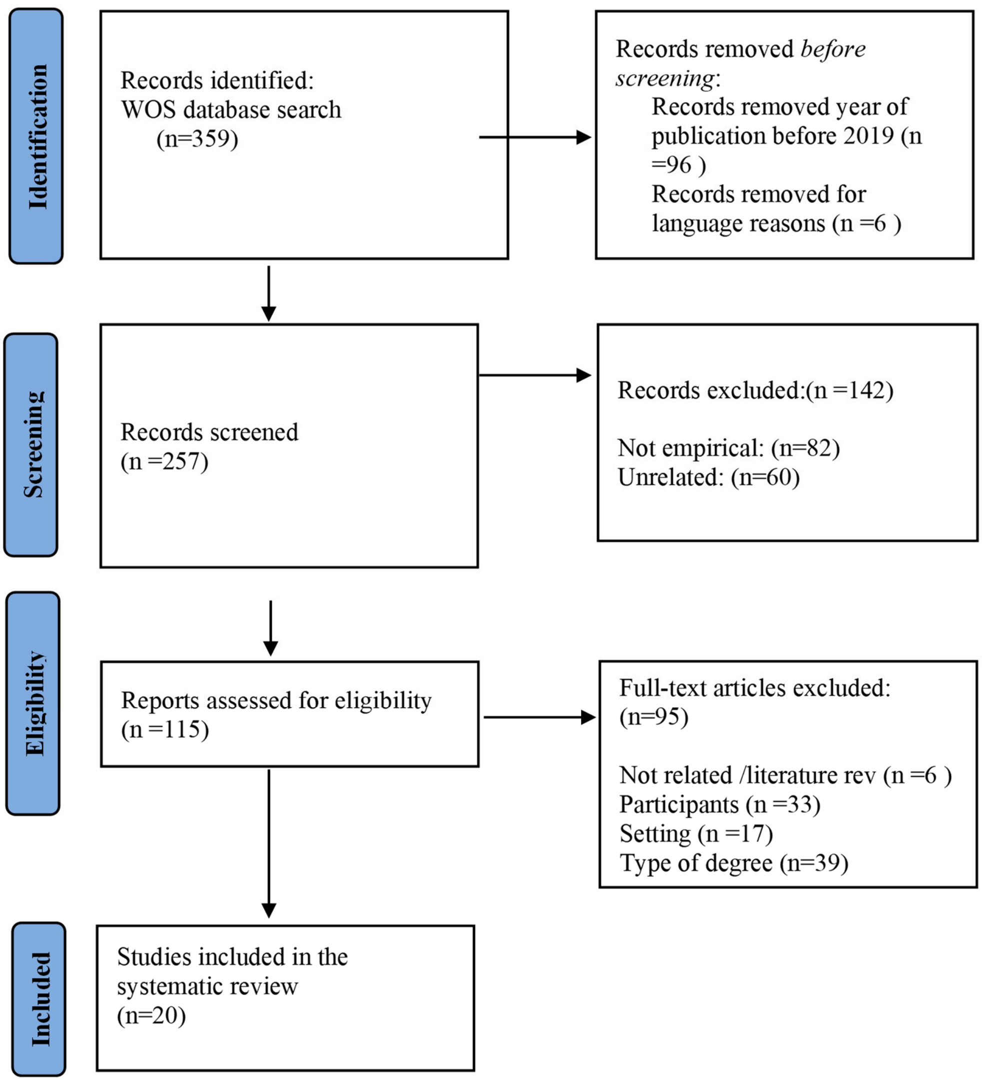

Figure 1. PRISMA flow diagram. Note: adapted from Moher, Liberati, Tetzlaff, Altman, and Prisma Group (2009) [35].

The remaining 115 studies were transferred from Zotero to Microsoft Excel. Each title was read, and, if necessary, the abstract or full article was reviewed. The articles were examined using the inclusion and exclusion criteria listed in Table 1.

Table 1. The summary of the process of review.

Aim	To search empirical articles related to maker education in higher education so as to provide a suitable answer to the three research questions.
Search Strategy	Boolean search using "makerspace" and "education" in Web of Science (WOS).
Inclusion Criteria	Research focused on a deep analysis of: a. Maker education in higher educational institutions or professional development (not a public library or museum makerspace); b. Full-text, articles, peer-reviewed articles; c. Empirical research; d. Published in English.
Exclusion Criteria	a. Not related to the research questions (conceptual and theoretical articles on maker education); b. Set in non-higher education learning environments (informal learning environments, museums, libraries. . .); c. Type of university degree (e.g., engineering, nursing, arts. . .); d. Participants of the study (articles that focused on K-12 students or pre-K-12. . .).
Data Extraction	Read the studies and collect the relevant information in Excel.
Synthesis of Data	Identify the study categories, authors, year of publication, population (pre-service or in-service, other agents), and study characteristics.
Report	The results have been analysed and summarised to provide relevant information about the empirical research on maker education in the context of teacher training and professional development.

Own production.

Out of the 115 articles, a few were excluded because they were not related to the research topic (n = 3) or they were literature reviews or reviews of the state of the art (n = 3). Additionally, research participants in primary education and school-based makerspaces (n = 25) or those in secondary education (n = 8) were also excluded. Regarding the setting for the study and the type of makerspace, the articles that dealt with an out-of-school or urban makerspace (n = 3), as well as cases where the research was conducted in a library makerspace (n = 11) a museum-based makerspace (n = 3), were not included.

From the remaining 66 full-text articles, 39 were excluded due to their relation to specific university degrees: engineering education (n = 21); arts or design education (n = 4); science and maths (n = 4); biology (n = 3); industry and electronics (n = 3); or nursing education (n = 2). The remaining 20 articles underwent further analysis and were included in the review.

Coding

This literature review comprises twenty studies. The coding was conducted based on the following variables: characteristic of research (author, research location, year of publication); the number of participants of the study; in-service (n = 7) or pre-service (n = 7) populations; various agents (n = 6); and outcome data (type of research).

This categorisation was crucial in identifying the challenges that teacher preparation may face in effectively incorporating maker-based teaching and learning practices. Additionally, the training experience was described, including the main goals, objectives, and duration of the maker education training intervention.

4. Results

Table 2 provides a summary of the study descriptions included in this review. The studies are listed alphabetically, and the table includes the authors, the year of publication, the total number of participants, the type and duration of makerspace training, and the main training characteristics.

Table 2. Reviewed articles.

Study Authors	Participants	Type of Training (RQ1)	Duration	Maker Education Training Characteristics Scope/Objective (RQ3)
[36]	43 in-service teachers	Virtual professional development		To improve K-12 teachers' knowledge, attitudes, and beliefs.
[37]	53 pre-service teachers	The World Café method	5 weeks	To demonstrate the suitability and effectiveness of the World Café method as a means of meaningful learning for maker education.
[21]	2 pre-service teachers	STEM-focused pre-service teaching preparation	A semester	To integrate planning and teaching for a STEM makerspace; To provide intellectually and socioemotionally rich first-hand experiences; To plan, teach, and peer-teach lessons as part of the experience.
[38]	Pre-service teachers	Virtual professional development		To participate in makerspace activities using digital and technological tools to develop computational thinking skills.
[39]	5 pre-service teachers	University-based makerspace apprenticeship program.	A semester	To learn about makerspace tools and technologies, to develop a maker mindset, and to build a community.
[40]	2 in-service teachers	A course in the Masters of Education program.		To comprehend how two classroom teachers interpreted the three-course tenets of making: maker as learner; making as iterative; and making as equitable and consequential.
[41]	7 graduate students	Making for learning course	A semester	To capture students' perceptions of making in relation to their class experiences and to identify any tensions they faced when applying their conceptual knowledge of making to practical lesson plans.
[42]	23 in-service teachers	Professional development	Summer (8 weeks)	To expose teachers to the key principles of the maker movement with the goal of helping teachers integrate maker-centered learning elements into the curriculum. The focus was on fostering self-efficacy, confidence, and interest in making activities, all of which are linked to the maker mindset.
[43]	8 in-service teachers	Professional development		To participate in maker activities and integrate a maker identity into teaching practices.

Table 2. *Cont.*

Study Authors	Participants	Type of Training (RQ1)	Duration	Maker Education Training Characteristics Scope/Objective (RQ3)
[44]	15 in-service teachers	Professional development	8 weeks	To introduce in-service K-12 teachers to making and to help them consider how to integrate maker-centered learning activities into their curriculum; To reate one meaningful artefact.
[45]	13 facilitators			To explore attitudes, experiences, and needs; To assist pre-service and in-service teachers to become better equipped, motivated, and confident in the use of makerspace technology.
[46]	7 different agents	Virtual making experience		To explore the possibilities of the virtual maker learning environment; To discuss the following: rethinking assessment in making; reframing teaching through making; exploring mobile making for rural and remote communities.
[47]	28 different agents	Professional development	4 h	To investigate changes in the safety perceptions of educators.
[48]	17 academic makerspace leaders	Description		To understand how makerspace leaders envision makerspaces regarding the tools, people and behaviours involved.
[49]	A team of 4 maker-lab researchers	Virtual professional development	12 weeks	To analyse best practices, technical support, activities, resources, and adaptability.
[50]	4 pre-service teachers	Workshop	8 weeks	To guide in the design, planning, and facilitation of a maker workshop.
[51]	6 pre-service teachers	Internship	A Spring internship	To design and implement making activities for students in grades 3–5 at a local elementary school.
[52]	15 pre-service teachers			To analyse the pedagogy for inclusive making with regards to maker practices, expertise, mutual learning, and resources.
[53]	27 in-service	Blended professional learning programme		To explore teachers' confidence, enthusiasm, skills, and beliefs after being exposed to practice-based, theoretically grounded learning.
[54]	252 participants			To explore the factors that influence makerspaces; maker activity, maker subject, and resources.

4.1. The Main Characteristics of the Research

General trends are found regarding the main characteristics of the research that examine maker training in higher education and professional development. The selected studies were primarily from institutions located in the following countries: the United States (n = 10); Canada (n = 3); Taiwan (n = 1); and China (n = 1). In the case of the rest of the articles, the location was not identified. In the last four years, the articles were published as follows with regards to their publishing date: in 2019 (n = 1), 2020 (n = 4), 2021 (n = 5), 2022 (n = 8), and up to April 2023 (n = 2). Upon analysis of the publication years, it can be concluded that the majority of the articles were published in recent years.

Out of the 20 selected studies, research was published in various journals. Three of the studies were published in *Techtrends*, two in the *Journal of Research on Technology in Education*, and two in the *British Journal of Educational Technology*; the remaining journals published only one article.

4.2. The Number of Participants in the Study

The number of study participants varied considerably, with a range of 2 to 252. Five studies included participants who were not pre-service or in-service teachers, with some of them examining a variety of stakeholders and others focusing on a single specific stakeholder.

The studies that examined a variety of stakeholders included one that focused on seven different stakeholders, including one librarian, two individuals with doctoral qualifications, two teachers and researchers, one teaching and learning facilitator, and one sessional instructor [46]. Conversely, the second study focused on 28 distinct stakeholders, including administrators, librarians, supervisors of STEM subjects, educators of STEM subjects, educators of computer science, and educators of elementary subjects [47].

In contrast, other studies concentrated on a single stakeholder group, rather than examining a variety of stakeholders. One such study included 13 administrators [45], 17 academic makerspace leaders [48], and 4 maker lab researchers [49].

The number of studies that included in-service teachers (n = 7) is equivalent to those that focused on pre-service teachers (n = 7).

4.3. The Length of the Intervention

The duration of the maker education training programmes was found to vary significantly, with the shortest course lasting only four hours [47] and the longest lasting for the duration of a semester [21,39,41].

Three articles presented findings from eight-week programmes. One workshop provided pre-service teachers with the opportunity to design, plan, and facilitate activities in accordance with the maker principles [50]. Two professional development courses provided in-service teachers with exposure to maker tools and training in the integration of maker activities into the curriculum [42,44]. Another article detailed a five-week experience of the World Café method of teaching maker practices [37]. A period of twelve weeks was dedicated to the analysis of best practices for virtual professional development courses [49]. A spring placement was allocated to the training of pre-service teachers in the design and delivery of making activities for primary students [51]. It should be noted that half of the studies did not report the duration of their interventions (n = 10).

4.4. Outcomes

The majority of studies employed predominantly qualitative methods of analysis (n = 15). Only two studies used quantitative data analysis [37,54]. The suitability of the World Café method for STEM/maker subjects was measured in comparison to other more conventional learning methods. The measurement constructs selected were active, authentic, constructive, cooperative, and personalised.

Two studies were identified that combined both qualitative and quantitative methods: in one case, the TPACK instrument was used to assess teachers' knowledge in the context of maker education [36], while attitudes and beliefs were measured using qualitative methods; in another study, a quantitative analysis was used to assess teachers' confidence and enthusiasm for blended professional learning, while a qualitative analysis was employed to analyse open-ended questions and focus group results [53]. A quasi-mixed design was used to investigate changes in educators' perceptions of safety in 21 school districts [47].

4.5. Characteristics of Pre-Service Teacher Training in Maker Education

In relation to studies on teacher preparation programmes (n = 7), several programmes have introduced pre-service teachers to maker principles, both theoretically and practically.

The type of maker intervention differed significantly between the studies. Four studies trained pre-service teachers to design and plan according to maker principles. One study involved extensive first-hand experience in a makerspace, preparing to teach in one [21]. Another study used an 8-week workshop that involved guided design, planning, and facilitation [50]. A third study implemented making activities for pupils in a primary school during the design and planning phase [51]. Finally, a fourth study examined how five participants in a university makerspace, who were makers-in-residence, learned to integrate making into their future classrooms by focusing on the tools and the maker mindset [39].

Another study examined how 15 pre-service primary teachers leveraged their knowledge resources to implement inclusive making pedagogy. The study concentrated on their expertise, maker practices, learning principles and resources [52].

The only research that included virtual maker training exposed learners to active participation in making activities using technological tools. The objective was to extend the learning community of pre-service teachers through virtual makerspace activities [38]. Finally, from the analysed papers, one of them focused on how undergraduate students were exposed to the World Café method related to maker education to determine its effectiveness compared to other teaching and learning approaches [37].

4.6. In-Service Professional Development Training Characteristics

In the case of studies targeting in-service teachers (n = 7), three articles were written by the same authors. In the first one, the perceptions of 15 teachers who participated in an eight-week professional development programme were identified [44]. During the programme, the teachers engaged in making activities that required them to create at least one meaningful artefact in a commercial makerspace. In the second one, conducted in the subsequent year, 23 teachers were exposed to elements of the maker movement and received assistance in integrating maker elements into the curriculum through a summer professional development course [42]. In the same year, another article was published in which eight participants engaged in making activities and shifted their identity formation between teacher/learner and maker/non-maker [43]. A sense of community was fostered among peers, members, and makerspace staff. Furthermore, the participants were instructed in the incorporation of maker-centred learning activities into their pedagogical practice. With regard to this study, and with a particular focus on the practical implementation of maker pedagogy, the perceptions and tensions that arise when translating conceptual maker knowledge into practice were analysed. In-service teachers were trained to design practical maker lesson plans [41].

In relation to the delivery of theoretically grounded maker knowledge and the development of a maker identity among teachers, two professional development courses were the object of study [36,53]. The former was delivered virtually, with a specific focus on improving not only knowledge but also in-service teachers' attitudes and beliefs. The latter course provided teachers with practical hands-on experience and aimed to identify how different participants, including industry experts, school leadership, and colleagues, affected teachers' confidence, enthusiasm, skills, and beliefs when teaching in makerspaces.

Making as a pedagogical practice was also a matter of concern in a research paper that analysed how two in-service teachers positioned themselves as maker-learners, understanding making as a process and approaching making as equitable and consequential [40].

4.7. Other Studies

The remaining six studies identified further aspects related to maker education. One of the studies identified the attitudes, experiences, and needs of both pre-service and in-service teachers with the aim of providing them with the motivation, confidence, and necessary support to enable them to perform their roles effectively [45].

In another study, a questionnaire was employed to gather data concerning three aspects of makerspaces in universities: maker subject, activity, and resources with the aim of identifying the influencing factors of makerspaces related to innovation, teamwork, maker activities, and available resources [54]. Seventeen academic leaders were interviewed to obtain data on the key defining elements of a makerspace. The research focused on exploring how power and politics can influence makerspace design. The interview guide aimed to gain a full understanding of participants' vision of a makerspace from all perspectives [48].

Another research paper addressed the perceived impact of a four-hour professional development course on makerspace safety among a range of educators [47]. The experience involved in-service educators as well as a range of stakeholders including administrators, librarians, STEM supervisors, STEM educators, and computer science educators.

The potential of a virtual making experience with the objective of reconsidering the assessment of making was also the subject of investigation. The principal objective was to reframe the pedagogical approach, primarily through the implementation of hands-on making activities, the exploration of the use of portable making tools and techniques for rural and remote communities, and the promotion of the development of modern skills, with a subject-specific introduction to the curriculum. The participants were afforded the opportunity to explore the potential of a virtual maker learning environment and to engage in maker activities that were unfamiliar to the majority of them [46].

Finally, the best practices of four researchers who were in the process of learning how to effectively create a virtual maker professional learning course were analysed [49]. The analysis included an evaluation of the strengths and weaknesses of the technical support, collaboration, equity, maker activities, and adaptation strategies. The principal findings demonstrate that technical assistance is indispensable, and that activities that are neither excessively complex nor overwhelming are most efficacious in an online learning environment. The provision of an appropriate online collaborative environment and means of sharing is also fundamental to the implementation of maker pedagogy. It is also essential to ensure equitable access to resources through the utilisation of cost-free virtual tools and flexibility and adaptability to the diversity of learners is crucial.

5. Conclusions and Discussion

The findings of this literature review allow us to draw several conclusions, which will be presented and discussed in the following section. In consideration of the characteristics of the study in question, it can be observed that there has been a notable and sustained increase in the number of manuscripts published in recent years, as evidenced by the articles included in this systematic review. An examination of the recent trend of the inclusion and implementation of makerspaces and their popularity in the educational sector, including all age groups from primary to higher education, reveals a clear and consistent pattern [55]. It can be predicted that there will be a significant increase in the publication of similar studies in the future. With regard to the geographical distribution of the published studies, it is notable that approximately half were conducted in the United States, with some others in Canada. This observation may be regarded as indicative of the growing adoption of maker principles for students and makerspace infrastructure, as well as the increasing integration of maker education into teacher training programmes and professional development initiatives.

In addition to in-service and pre-service teachers, other researchers included in their reviewed articles other types of stakeholders who were also involved in the workshops and training courses. It is notable that the participants in the studies reviewed [45–49] included a variety of individuals. This may be related to the concept that programmes designed to equip future teachers with the skills to plan, organise, and lead maker activities may wish to circumvent and mitigate the challenges associated with integrating such activities into the conventional classroom setting. One potential strategy for achieving this is through the provision of collaborative support. An additional potential explanation for this emerging phenomenon is the necessity to further delineate a unified framework for maker education. However, defining makerspaces is a complex task due to the varied perceptions of what constitutes a makerspace and the difficulty in clearly delineating the characteristics associated with makerspaces, which are often subjective and emotionally charged [48].

From this systematic review, it can be concluded that there is a lack of articles that focus solely on knowledge acquisition when it comes to equipping teachers with expertise in maker education. In contrast, there is a greater number of articles that focus on equipping teachers with both the necessary practical skills and theoretical knowledge of maker education. In those studies where pre-service teachers were given the opportunity to become makers themselves, they consequently gained an insight that went beyond learning the content of making [56].

Regarding the appropriate integration of maker practices into the curriculum, a lack of research was identified [56], particularly in the area of providing pre-service teachers with the training needed to incorporate maker principles in their classrooms. Several studies have highlighted the importance of teachers experiencing maker learning first-hand in order to design and incorporate maker activities into the curriculum, and that they require support in this regard [44,53,56]. Furthermore, positive changes have been observed in emotions, such as confidence, understanding, enthusiasm, and change in mindset after designing, experimenting, and implementing making as a pedagogical practice [40]. It is widely acknowledged that addressing the social and emotional needs of teachers in training can have a significant positive impact on their future teaching practices and help to alleviate the phenomenon of content dread [21]. To address this lack of confidence, future training programmes could be designed to engage pre-service teachers in meaningful hands-on experiences that not only stimulate their intellect but also support their emotional well-being.

The provision of immersive virtual programmes to replicate authentic makerspace learning environments could be a viable option in certain instances for the delivery of training. These virtual environments provide opportunities for individuals from disparate locations to engage in collaborative work, fostering the formation of a supportive community network that enables all members to collaborate and achieve shared objectives through the use of technology [36,40,46,49]. Such online learning opportunities, designed to promote knowledge and skills, have been shown to enhance positive attitudes and beliefs towards teaching with and through maker technologies [36].

This literature review has revealed a growing trend towards improvement in various areas. For instance, there is a growing focus on identifying and analysing the most effective practices for designing virtual development training [49] and on examining the potential benefits and advantages offered by virtual maker learning environments [46]. It can be concluded that the continuous and effective design of professional development courses is essential for progress. It may be beneficial to continue researching this area, not only in the context of virtual training but also in the context of face-to-face formats.

Limitations and Next Steps

It must be acknowledged that this literature review is not without limitations. The studies were selected and coded on the basis of their focus on maker education in the context of teacher education and professional development in the WOS database. Consequently, only 20 articles pertinent to the subject matter were identified. However, to extend the scope and avoid overlooking pertinent studies of interest, it is recommended that other databases are incorporated into future research. A further limitation of the study is the narrow scope of the search terms employed during the literature review process. Despite the efforts made to capture relevant research within the intersection of makerspaces and education, it is important to acknowledge that restricting the search to only include the terms “makerspace” and “education” was inherently limiting. To enhance the comprehensiveness of the review, it would have been beneficial to incorporate additional search terms, such as "maker education", "teacher training", "makerspace", and "higher education", among others.

Furthermore, it is recommended that future studies should incorporate quantitative and/or qualitative analysis of the quality standards of the training programmes and the perceptions of those involved in them. This would enable a more comprehensive understanding of training interventions and facilitate improvements in the effectiveness of those delivered.

It would be beneficial for future research to investigate the extent to which training courses provide opportunities for teachers to influence and shape educational practices, thereby enabling them to choose and advocate for effective teaching methods. The next steps in advancing maker education could involve replicating similar studies to gain a deeper understanding of the adequacy of training and the expertise of those who deliver it. In addition, capturing the perceptions of teachers who have undergone training could represent a novel approach to conducting future research. Moreover, longitudinal studies could also provide a more robust insight into, and comparison of, the perceptions of educators upon graduation and during in-service periods.

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