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Characterization of STEM teacher education programs for disciplinary integration: A systematic review

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Abstract

STEM education is established as an alternative for developing 21st century skills, with the premise of integrating its component disciplines. Although numerous studies exist on the subject, STEM teacher training programs are not widely discussed. Therefore, a systematic literature review was conducted in Scopus and Web of Science to identify the intentions of the training and the design and implementation of such teacher training programs. Among the 15 articles identified, there are three groups of intentions: Improving knowledge, developing competencies and skills, and changing attitudes and perceptions. Five methodological strategies were identified: project-based learning, problem-based learning, collaborative learning, ODR (observation/discussion/reflection) approach, and design-based learning. Disciplinary integration can be achieved through content or competencies. It is concluded that design-based learning is the most appropriate strategy for disciplinary integration. It is recommended that research be conducted to measure the impact of modality and time of training on the development of STEM competencies.

Keywords: STEM education, teacher professional development, STEM competencies, design-based learning

INTRODUCTION

Improving the quality of educational processes depends largely on teachers (Harris & Sass, 2011) and the training processes they have undertaken (Acosta Poveda, 2020). Education systems face the challenge of determining the most effective method to equip new teachers and enhance the competence of existing educational institution staff (Calvo, 2008). Similarly, individuals must address the demands of modern society, which requires individuals with the ability to solve problems, produce and evaluate scientific evidence, work in teams and, above all, understand and act upon the world and the phenomena that make it up (García et al., 2017). In this context, the STEM (science, technology, engineering, and mathematics) approach has emerged as a proposal to strengthen education in these skills (Mahecha et al., 2021).

Although this approach is increasingly popular, it is challenging to establish a unified concept (Breiner et al., 2012; Martín-Páez et al., 2019). For instance, Hsu and Fang (2019) categorize it as an educational approach in which the subjects' contents can be viewed as a collection of distinct concepts (multidisciplinary) centered around solving real-world problems (interdisciplinary and transdisciplinary). Kelley and Knowles (2016), Moore et al. (2014), and Sanders (2009) define STEM education as a teaching approach that integrates two or more disciplines, using real-world contexts, with the intention of linking these disciplines to improve student learning. In this sense, Sanders (2009) emphasizes that STEM education is a pedagogical approach based on technological or engineering design that intentionally integrates conceptual and procedural content of science and/or mathematics education with concepts of a practical nature.

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Contribution to the literature

- A characterization of the STEM teacher training programs that are implemented in pre-service and in-service teachers of secondary and secondary education is carried out, where the intentions, methodological strategies and integration strategy are identified.
- The main intentions of teacher training programs are identified: Improving knowledge, developing competencies and skills, and changing attitudes and perceptions.
- The main methodological strategies used in teacher training programs focusing on STEM are project-based learning, problem-based learning, collaborative learning, ODR approach (observation/discussion/reflection), and design-based learning. Out of all these strategies, design-based learning seems to be the most appropriate for disciplinary integration.
- In teacher training programs related to STEM education, two competencies are critical: design thinking and computational thinking. These competencies are considered transversal, meaning they are relevant in this process.

Table 1. Guiding questions for chosen documents analyzed

Guiding questions
What is the intentionality of STEM teacher training programs?
What are the methodological strategies used, the type of training and the target population?
How is the integration of STEM disciplines proposed?

As a result, it has become necessary to add qualifiers in an attempt to clarify the meaning (Aguilera et al., 2021), such as "integrative STEM education" (Sanders, 2009) or "integrated STEM education" (Thibaut et al., 2018). Similarly, additional fields of study, including the arts (STEAM) (Yakman & Lee, 2012) and inclusive and accessible education supported by robotics (STREAMS: Science, technology, robotics, engineering, art, and mathematics) (Krug & Shaw, 2016), have been incorporated.

However, STEM approach presumes that the unified curricula create associations between curricula, overcoming the division of traditionally constructed knowledge and promoting meaningful learning (Arguedas-Ramírez & Camacho-Oviedo, 2022), regardless of the qualifier. In addition, curricular integration allows teachers to contextualize the curriculum and actively intervene in its design and organization (Illán & Molina, 2011).

The specialized literature has indicated that STEM teacher training can equip educators with problem-solving skills and a holistic understanding of science, emphasizing its varied and practical applications in the real world (García et al., 2017). At this point, it is important to note that teacher education processes in STEM are relatively new (Carmona-Mesa et al., 2019; Castro-Rodríguez & Montoro, 2021), although since 2009 this approach has experienced a global expansion (Ortega-torres et al., 2019), demonstrating its importance in the formation of citizens with 21st century skills (Castro Inostroza et al., 2020).

For all to the aforementioned reasons, it has been established that the lack of a consensus related to the STEM might be ascribe as one of the main reasons for teacher training programs, which are not devoted to curricular integration. Additionally, since the STEM research has been centered in university teachers, the need of discovering how to integrate the STEM practices in elementary and middle school teachers is an issue that has not been extensively studied (Ferrando et al., 2018).

Furthermore, according to our best knowledge, there are no systematic reviews related to the identification of STEM features for in-service and pre-service teachers training programs dedicated to the integration aspect.

In this matter, the current research analyzes the impact of methodological strategies, type of training (formal or informal), and type of teachers (in-service or pre-service) on the STEM teacher training programs. The proposed main goal is to identify the general characteristics of teacher training programs in education with a STEM approach related to curricular integration.

By knowing the lack of consensus about STEM approach, it is worthy to mention that the research does not use any particular STEM adjective, which could excludes any relevant results or experience for the present literature review. The formulated questions are shown in **Table 1**.

METHODOLOGY

The literature was systematically reviewed, following the PRISMA Statement guidelines (Moher et al., 2009; Page et al., 2021; Urrútia & Bonfilll, 2013).

During the identification phase, Web of Science (WoS) and Scopus were used as databases, applying the search equation ([Teaching AND training] AND [integrated AND STEM]). The selected data bases (Scopus and WoS) were chosen because they published the most important and updated literature in the field as well as the collect the relevant journals of science

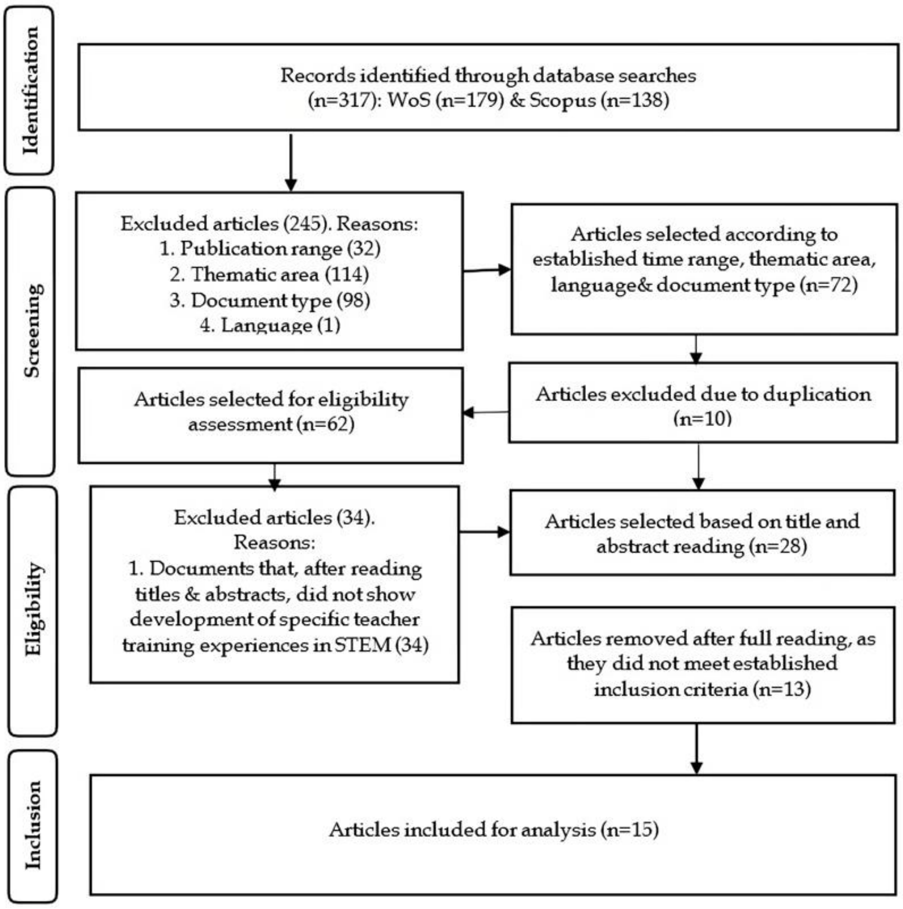

Figure 1. PRISMA methodology flow chart (Adapted from Urrútia & Bonfilll, 2013)

education, which have been publishing papers about STEM education. The search on Scopus comprised the "title of articles, abstracts, and keywords" while on WoS, it covered "all fields". After the general identification of the documents, the following inclusion and exclusion criteria were applied:

Inclusion Criteria

Articles published in open access journals, written in English and Spanish, published since 2013 onwards, were included, where programs or strategies for teacher training in STEM education are described, carried out with teachers in training or in practice who work in basic and secondary education, where it is considered that training programs can have the greatest impact, being these, a possible research niche in the medium term. Research focused on methodological strategies, training types, modalities, and time were considered.

Exclusion Criteria

Conference papers, books, book chapters, systematic reviews, brief surveys, errata, notes, letters, and editorials were excluded as well an article dealing with acronyms other than STEM or lacking a clear description of the teacher training program methodology. Additionally, articles with a sample consisting of university professors not considered for this review, as shown in **Figure 1**.

The materials found in the databases were downloaded in BibTeX format and uploaded into the Mendeley bibliographic manager. Any duplicate documents were automatically detected and deleted. The chosen documents were analyzed to respond to the guiding questions outlined in **Table 1**, which address the intentionality of the training provided, the methodological strategies, and the curricular integration proposal.

RESULTS

Although a significant number of studies were identified at the outset, only a few of them focus on creating a STEM teacher training program that is grounded in curricular integration (as displayed in **Figure 1**).

Table 2 itemizes the analyzed documents, which showcase the intentions and certain aspects of the training programs' design and execution.

In response to the question what the intentionality of STEM teacher training programs is, three categories of intentions emerged among the 15 papers selected. The first one, oriented to knowledge and conceptions; the second one, to competences and skills; and the last one,

Table 2. Documents selected as analysis sample

Authors	Objectives of training process	Design			Implementation	
		Methodological strategy	TT	TTC	TM	TTI
Galadima et al. (2019)	Training participants in iSTEM methodology–Developing skills for iSTEM teaching	Project-based learning in engineering design	F	PS	On-site	5 weeks
Aldahmash et al. (2019)	Training teachers to design & teach an integrated STEM curriculum effectively.	Design-based learning	NF	IS	On-site	6 days
Wu et al. (2019)	Modelling STEM learning design process	Design-based learning	F	PS	Online	Customized times
Alan et al. (2019)	Supporting integrated teaching knowledge for prospective science teachers	Problem-based learning	F	PS	On-site	10 weeks
Kelley et al. (2020)	Training teachers to integrate STEM content using engineering design	Learning on TRAILS design method	NF	IS	On-site	2 weeks
Aydin-Gunbatar et al. (2020)	Developing STEM integrated with LESMeR model	Model based on research practices	NF	PS	On-site	13 weeks
Dinh and Nguyen (2020)	Developing skills in design & organization of STEM experimental activities	Design-based learning	NF	PS	On-site	7 days
Aydin-Gunbatar et al. (2021)	Integrating their knowledge of chemistry with mathematical & technological knowledge and/or practices in an engineering design process	Course was on context integration (Moore et al., 2014)	F	PS	On-site	13 weeks
Wu et al. (2021)	Developing their ability to design an integrated STEM learning unit	Learning design process on reverse design approach & collaborative design	F	PS	Online	8 weeks
Chaipidech et al. (2021)	Implementing an andragogical teacher professional development outreach program	A personalized learning system oriented to TPACK was designed	NF	IS	On-site	2 days
Toma and Retana-Alvarado (2021)	Improving conceptions–Training in use of two pedagogical strategies: Scholarly inquiry and engineering design	Problem situations approach	F	PS	Online	6 weeks
Ciftci & Topcu (2022)	Improving computational thinking of future early childhood teachers	Problem-based learning	F	PS	Online	8 weeks
Pewkam and Chamrat (2022)	Applying framework of computation as an integrative theme with STEM to develop computational thinking of pre-service teachers	Relevance of context & applications of world	NF	PS	Online	2 days
Huang et al. (2022)	Improving teachers' STEM understanding through observation, discussion, & reflection	ODR approach	NF	IS	On-site	2 weeks
Costa et al. (2022)	Providing teachers with knowledge & skills to develop STEM-integrated tasks to be implemented in class	Integrated approach to STEM education on real-life scenarios	NF	IS	Online	26 hours

Note. TT: Type of training; TTC: Type of teacher; TM: Training method; TTI: Training time; F: Formal; NF: Non-formal; PS: pre-service; & IS: In-service

to perceptions and attitudes. The initial category includes training programs aimed at transforming pedagogical knowledge and conceptions of teaching the STEM approach (Aydin-Gunbatar et al., 2020, 2021; Costa et al., 2022; Toma & Retana-Alvarado, 2021). It also includes the development of knowledge in STEM considered necessary from computer science and the generation of digital content (Pewkam & Chamrat, 2022). Finally, the strengthening of knowledge of integrated teaching for problem solving in local contexts (Alan et al., 2019). It is possible to mention that the emergence of this category might be plausible because of, the need to reach agreements that allow assuming theoretical assumptions in relation to the concept of education with a STEM approach, which must be considered important for the subsequent development of the design of curricula, pedagogical practices, classroom management and assessment.

The second category includes teacher training programs that aim to enhance STEM competencies and skills. These programs cover the design and organization of experimental activities (Dinh & Nguyen, 2020), the creation of learning units (Wu et al., 2021), iSTEM teaching (Galadima et al., 2019), the cultivation of design thinking (Wu et al., 2019), the advancement of computational thinking (Ciftci & Topcu, 2022), and the promotion of STEM comprehension through observation, discussion, and reflection (Huang et al., 2022).

Finally, the third category involves training programs that concentrate on altering attitudes and perceptions, assessing the impact of STEM training on teachers' attitudes (Aldahmash et al., 2019), their perceptions (Costa et al., 2022), and their teaching self-efficacy (Ciftci & Topcu, 2022; Kelley et al., 2020).

Eight programs were found to utilize non-formal training strategies. These strategies are considered permanent or continuously updated and are typically geared towards practicing professionals. Formal training strategies, on the other hand, were utilized for pre-service teachers. At least five distinct methodological strategies were identified in this study: project-based learning (Galadima et al., 2019), design-based learning (Aldahmash et al., 2019; Aydin-Gunbatar et al., 2021; Dinh & Nguyen, 2020; Kelley et al., 2020; Wu et al., 2019, 2021), problem-based learning (Alan et al., 2019; Ciftci & Topcu, 2022; Toma & García-Carmona, 2021), collaborative learning (Costa, 2022), and ODR (observation/discussion/reflection) approach (Huang et al., 2022).

The second question addressed in this research was related to what the methodological strategies are used, the type of training and the target population, it is worth noting that six research programs implemented the strategy of design-based learning. According to Aldahmash et al. (2019), design-based learning enables content and hands-on activities to have multiple connections with both the theoretical and practical aspects of STEM lesson integration and implementation in the classroom. As a result, it facilitates the efficient and effective design of integrated STEM curricula. Wu et al. (2019, 2021), indicate that teacher training that models the STEM learning process promotes the development of teachers' design thinking competence. Furthermore, Kelley et al. (2020) states that preparing teachers for integrating engineering design enables students to engage with prior scientific knowledge, discover new knowledge, and apply it to solve novel problems whereas. Dinh and Nguyen (2020) suggest that the enhancement of design skills improves not only design ability, but also experimental skills.

Problem-based learning programs evaluated the problem-solving capabilities of teachers utilizing scientific knowledge, both in simulated scenarios (Alan et al., 2019) and within problem situations in curriculum-related events (Toma & Retana-Alvarado, 2021), as well as problem-solving based on the development of computational thinking (Ciftci et al., 2022). A similar explanation is given by Costa et al. (2022). They employed an integrated approach to STEM education based on real-life scenarios and in the context of a collaborative professional development program, albeit and Huang et al. (2022) sought to improve teachers' STEM understanding through observation, discussion, and reflection. The training programs that used a project-based learning strategy, managed a model from practical research exercises, which sought context integration (Aydin-Gunbatar et al., 2020, 2021).

The third question addressed in this research was related to how the integration of STEM disciplines is proposed. For this document, it is considered important to determine aspects linked to the implementation of teacher training programs. Regarding the implementation of the teacher training programs, the documentary sample shows that half of them were exclusively face-to-face. The duration of the training programs ranged from two days to 18 weeks. Some programs connected STEM disciplines based on the necessary competencies of real-world application in the construction of STEM learning activities (Aydin-Gunbatar et al., 2020, 2021; Ciftci et al., 2022; Dinh & Nguyen, 2020; Galadima et al., 2019; Wu et al., 2021) and others, based on the trans-versalization of contents (Alan et al., 2019; Aldahmash et al., 2019; Toma & Retana-Alvarado, 2021; Chaipidech et al., 2021; Costa et al., 2022; Huang et al., 2022; Kelley et al., 2020; Pewkam & Chamrat, 2022; Wu et al., 2019). **Table 3** shows how each training program, according to the methodological strategy used, carried out the processes of integration of STEM disciplines. It is identified that, for the authors, design-based learning is the most appropriate strategy to carry out the integration processes.

Table 3. Documents identified according to methodological strategies used in training programs & process they used for integration of STEM disciplines

Methodological strategy	Integration strategy	
	By competencies	By content
Design-based learning	- Galadima et al. (2019) - Dinh and Nguyen (2020) - Wu et al. (2021)	- Aldahmash et al. (2019) - Wu et al. (2019) - Kelley et al. (2020) - Chaipidech et al. (2021) - Pewkam and Chamrat (2022)
Problem-based learning	- Ciftci and Topcu (2022)	- Alan et al. (2019) - Toma and Retana-Alvarado (2021)
Project-based learning	- Aydin-Gunbatar et al. (2020, 2021)	
Collaborative learning		- Costa et al. (2022)
ODR approach		- Huang et al. (2022)

DISCUSSION

This systematic literature review examined three queries regarding the purposefulness, structure, and execution of STEM education training programs.

Based on the findings, the analyzed documents indicate a distinct inclination towards enhancing conceptual aspects, cultivating aptitudes relevant to the contemporary citizen's 21st century skills, and detailing the educators' role in this framework. This finding reinforces Song's (2020) idea on the three domains of teaching competencies: cognitive characteristics, instructional skills, and affective characteristics. Therefore, training programs could have specific objectives during their development, which would affect conceptions, attitudes, and pedagogical practices.

In relation to the intentionality of teacher training programs, from a conceptual standpoint, Breiner (2012) and Martín-Páez et al. (2019) point out that, although the number of studies on education with a STEM approach has increased in recent years, there is still a need to strengthen and seek consensus on concepts. This need is due in part to STEM's promotion as a pedagogical strategy with an integrative approach since its inception. However, some authors, including Toma and Retana-Alvarado (2021), have questioned the suitability of the approach due to ongoing challenges in developing coherent conceptualizations aligned with current perspectives. Nonetheless, this review of training programs reveals that most participating teachers advance from basic conceptualizations to more sophisticated theoretical models. It is necessary to consider that the various efforts should not only seek to unify concepts or measure progress in degrees of sophistication, but also establish their scale, that is, at what level is STEM education developed, current of thought, paradigm, model, approach or methodological strategy? As mentioned above, for the research purposes of this document, the concept of STEM is addressed as an approach and in this sense, it must respond in some way to a pedagogical model that, for the particular case, is considered constructivism. However, none of the training processes evaluated respond conclusively to the conceptual scale, so it is considered that it should be evaluated whether, from pedagogical practice, student learning is truly self-structuring.

Nevertheless, it could be argued that more structured conceptual models do not guarantee more and better integration processes of STEM disciplines. Yet, it is expected that more practical aspects will allow the development of skills and capacities for the realization of concrete actions. However, Costa et al. (2022) affirm that training programs not only improve knowledge, but also the skills of teachers to implement STEM in classroom practices. Aydin-Gunbatar et al. (2020, 2021) support the thesis and assert that the training processes develop skills such as communication, teamwork, creativity, and interdisciplinary integration. Leoste et al. (2022), also share this idea and suggest that the training programs provide the necessary knowledge for interdisciplinary integration. Therefore, these programs are aimed at imparting training in STEM teaching competencies.

In this field, two noteworthy perspectives exist regarding competency development training. One perspective, illustrated in the works of Ciftci and Topcu (2022) and Dinh and Nguyen (2020), argues that computational thinking makes the use of the integrative approach more effective and, therefore, it is considered a key competence because it improves self-efficacy in teaching. This notion was previously articulated by Alan et al. (2019) and later by Padrón et al. (2021), who state that the use of digital tools and computational thinking in the process of teacher training in STEM improves problem-solving skills. In the same vein, Pewkam and Chamrat (2022) contend that training programs enhance participants' digital knowledge and confidence, thereby fostering development in their classroom practices. At this point it is observed that the development of one competence is necessary for the functionality of another. Computational thinking affects other practical competencies such as problem solving, teamwork and the execution of instructional strategies, and in turn, the development of affective competencies such as self-efficacy. In this sense, it is considered that for education with a STEM approach, computational thinking is a transversal competence. However, this position overlooks a crucial consideration: the context in which teachers work or receive training. Depending on the initial characterization of the teachers, the program could focus on improving the effectiveness of integration if the group to be trained already possesses strengths in digital knowledge. Alternatively, the program should take on the challenge of strengthening the digital knowledge of the teachers to be trained if there are no existing strengths in this area. In this regard, a comprehensive review is required to determine whether the computational thinking competency ought to be adopted as a cross-cutting and interdisciplinary proficiency in the STEM curriculums of educational establishments.

Another perspective is design thinking development as an important transversal competency and interdisciplinary. It is evident that self-efficacy and teamwork are impacted by computational thinking, as seen in the previous one. According to Wu et al. (2019, 2021), design thinking contributes to improved technical and pedagogical development of content as well as collaborative work. This is supported by Boice et al. (2021) and Leinonen and Durall (2014) who conclude that, in addition to the above, design thinking helps teachers to articulate their plans for interdisciplinary education. In other words, the deliberate conceptual development of STEM teachers has the potential to create opportunities for acquiring and enhancing 21st century skills and competencies. However, when the focus is on developing key competencies, it permits a more applicable theoretical advancement towards the integration of STEM disciplines, thereby making the analysis of selected training programs quite intricate.

Although according to the logic of the results, the identified competencies conform to what is described by Song (2020), many competencies required by teachers for their work are not mentioned. For example, among the cognitive type competencies, the ability to plan lessons and adjust course components is not described. Likewise, specific key competencies such as the development of instructional and assessment strategies are left out of practical competencies. In this way, it is necessary to affirm that, in addition to the gap to be filled in the conceptual aspect, it is also essential to make agreements regarding the competencies that a STEM teacher must develop.

In response to the question what the methodological strategies are used, the type of training and the target population, it is observed that, this complexity is also transferred to the field of training program design, since the intentionality of the program affects, to a certain extent, the selection of the methodological strategy to be used. The methodological strategy that stands out in this review is that of design-based learning. This type of strategy, according to Aldahmash et al. (2019), improves perceptions regarding difficulty, because it promotes responsibility for self-regulation of learning and develops skills to solve complex tasks through reflection and teamwork (Duckworth & Yeager, 2015). Thus, Wu et al. (2021) affirms that the strategy improves participants' acceptance of STEM education, as well as their conceptions and the development of design thinking competence. Aydin-Gunbatar et al. (2021), on the other hand, considers that training programs with this type of strategy, where engineering design was used as a context, improved the participants' STEM conceptions and the complexity of their explanations in relation to communication, teamwork and creativity.

The study found that training programs utilizing the project-based learning methodology had a significant positive impact on participants' pedagogical strategies when teaching STEM (Galadima et al., 2019). Similarly, Boice et al. (2021) reported high levels of integration among teachers who underwent the training program. As a result, these teachers were successful in planning and implementing integrated lessons, ultimately bridging the pedagogical and content gap. However, the authors emphasize that the program's success relied on ongoing pedagogical and financial support following the implementation of the training program.

Thus, the strategy chosen in the design aims to reinforce the intended outcomes of the training program on conceptions and competencies, reflecting the influence of intentionality in two distinct ways. For this case, it is noted that the design-based learning strategy has the highest number of positive points for designing and implementing teacher training programs with a STEM approach for integrating curricula.

Regardless of the methodological strategy, a marked tendency to carry out integration through content development is evident. This may be due to the need to carry out, as a first step, the design of curricula to be applied in the classrooms. What was observed can be considered as an indicator that shows that academic processes related to education with a STEM approach are still incipient. However, this trend is worrying, since it is expected, to a certain extent, that this approach will be developed from a constructivist model. In this sense, the construction of curricula based on content would not be coherent.

Two significant aspects to analyze in program implementation are modality and training duration. Although the majority of analyzed programs were conducted in-person, Ciftci and Topcu (2022), Leoste et al. (2022), and Pewkam and Chamrat (2022) argue that virtual or blended environments provide a more flexible and adaptive training approach that caters to the individual needs of participants. However, according to Wu et al. (2019, 2021) these training environments create a significant workload for both work and learning, as many virtual tools are overwhelming and at times impractical, leading to usability and integration inadequacies.

In contrast, Alan et al. (2019) and Wu et al. (2019, 2021) argue that the duration of STEM teacher training programs is a crucial factor in their success. This position is supported by Aldahmash et al. (2019), who suggest that short training processes do not contribute to enhancing teachers' attitudes toward teaching the STEM curriculum. Ciftci and Topcu (2022) and Kelley et al. (2020) assert that teachers' perceptions were enhanced through their participation in the professional development program regardless of the duration. This contradicts the aforementioned position. In the same vein, Aydin-Gunbatar et al. (2020, 2021) contend that training time was both a key factor in success and a limiting factor. While their training programs spanned thirteen weeks and resulted in noteworthy enhancements in conception and skill acquisition, longer training periods would yield even better outcomes in terms of curriculum integration activities. Therefore, and coinciding with the statements of Aldahmash et al. (2019), Aydin-Gunbatar et al. (2020, 2021), and Song (2020), it is advisable to design lengthier and more consistent training programs, whenever feasible, with a mix of modalities. Assuming this thesis, in theory, preservice teachers, who can take long courses in relation to the fact that they would have more time for training, would be more competent on paper. However, it cannot be a generalized statement because, in practice, it could be considered better impacts on in-service teachers, since they have the possibility of applying their knowledge in real scenarios, so that, with less training time, they would be more competent. The latter could, in fact, be an interesting niche for research.

The training programs were implemented in accordance with the designs and goals put forth by each trainer, outlining the methodological strategies and disciplinary integration processes. However, the identification of specific cases in the future is necessary in order to provide more in-depth knowledge regarding the curricular integration processes related to the training programs.

CONCLUSIONS

Efforts to advance STEM teacher training research have been recurrent, although a gap persists not only in the amount of published research, but also in the impact of such training on teaching practices. In relation to the first research question, this study shows that teacher training programs are crucial for acquiring, developing, and strengthening STEM concepts and competencies, while also promoting design thinking and computational thinking. Similarly, these training strategies not only transform teachers' attitudes, particularly in self-efficacy and self-regulation of learning, but also facilitate the modification of perceptions regarding the difficulty of the STEM approach.

In response to the second and third research question, the analysis of the systematic review shows that five methodological strategies have been disseminated for structuring teacher training programs: project-based learning; design-based learning; problem-based learning; collaborative learning and ODR approach, where the design-based learning strategy was the most recurrent in the programs analyzed and the one that generates the best conditions for the integration of concepts and competencies of STEM disciplines, since it allows the content and practical activities to be related to the theoretical and practical aspects of the integration and implementation of STEM lessons in the classroom, which facilitates the successful and efficient design of STEM curricula. Likewise, it allows the development of design thinking competence and favors the application of acquired knowledge on experimental skills.

Finally, an aspect that deserves special attention is the one that considers that, for an adequate development of the computational thinking competence, training programs of a mixed nature, permanent and of continuous accompaniment, are necessary, which could guarantee greater success in the integration processes.

Future Developments

It is necessary to deepen research that will allow further strengthening of knowledge in STEM education, as well as the characterization of teaching competencies for teaching STEM with an integrative approach. To this end, it is proposed for future research to identify the impact of the development of computational thinking and the development of design thinking as possible transversal competencies of teacher training programs in education with a STEM approach.

Likewise, as research opportunities, it could be possible to open paths towards the identification of the impact of training modalities and times on the acquisition, development and strengthening of concepts and competencies in STEM. Likewise, the realization of case studies would allow the identification, in more detail, of how curricular integration processes are carried out in certain training programs.

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