education sciences

MDPI

Article

STEM Distance Teaching: Investigating STEM Teachers' Attitudes, Barriers, and Training Needs

Katerina Tzafilkou *, Maria Perifanou and Anastasios A. Economides

SMILE Lab, University of Macedonia, 546 36 Thessaloniki, Greece
* Correspondence: tzafilkou@uom.edu.gr

Abstract: The aim of this study was to investigate STEM teachers' attitude towards STEM Distance Teaching (DT), as well as their perceived barriers and training needs. A mixed survey was conducted on 158 STEM teachers in secondary education who taught their courses fully online due to COVID-19. The results revealed that STEM teachers perceive STEM DT quite positively, but their attitude can be affected by several factors, such as the efficiency of the schools' digital infrastructure, as well as their gender, age, and STEM teaching subject. The qualitative thematic analysis identified several barriers to efficiently applying STEM DT, including the (i) lack of students' interaction and engagement, (ii) inefficiency of digital infrastructure, (iii) lack of students' and teachers' digital skills, (iv) lack of space/equipment, and (v) increased teaching workload. The generated themes of training needs highlighted the need for targeted and adjusted training to every STEM discipline, as well as training on DT tools and pedagogies. Finally, the results indicated the STEM teachers' need for psychological support and consulting.

Keywords: distance education; STEM barriers; STEM distance teaching; STEM teachers' needs

Citation: Tzafilkou, K.; Perifanou, M.; Economides, A.A. STEM Distance Teaching: Investigating STEM Teachers' Attitudes, Barriers, and Training Needs. *Educ. Sci.* **2022**, *12*, 790. https://doi.org/10.3390/educsci12110790

Academic Editor: Billy Wong

Received: 26 September 2022
Accepted: 1 November 2022
Published: 5 November 2022

1. Introduction

Teachers' training and professional development on Science, Technology, Engineering and Mathematics (STEM) is an important priority for educational policymakers who argue that countries should develop programs and initiatives to improve the quality of STEM subjects (or disciplines), particularly in primary and secondary education [1]. Through STEM teaching, teachers assist their students in acquiring knowledge and skills through experience and hands-on activities by integrating science, technology, engineering, and mathematics. Through STEM, learners are expected to be able to solve real-life problems, produce creative ideas, and transfer what they learned to different areas. STEM education is mainly based on the experiential learning theory approach, since learners use their existing knowledge to solve problems from different disciplines using STEM activities. STEM is also thought to improve students' motivation and self-efficacy, enable their self-management skills, and help them design materials by following the engineering design process [1,2]. To this end, STEM education has several particularities compared to other disciplines and requires STEM teachers to use specific teaching methods and tools. STEM distance teaching (DT) has several particularities that should be seriously considered during the design of teachers' professional development and Information and Communication Technologies (ICT) training programs.

While there is considerable research on STEM teachers' professional development, only a few programs have been designed to effectively train STEM teachers on how to apply relevant instructional practices [2,3]. The evidence supports that many teachers believe that they are not well-prepared to implement STEM approaches in their courses; hence, there is increasing concern about the efficiency of STEM teaching at schools [4]. STEM teachers need further support and guidance in the efficient application of ICT and digital tools in the classroom [5]. The main difficulties in STEM teaching recognized in the literature include the lack of physical resources, the students' negative attitude, their lack of interest or engagement, and the lack of administrative support [4].

In a recent OECD publication, Vincent-Lancrin et al. [6] support the idea that motivating students to use digital tools in courses such as maths and science can potentially develop students' agency and leverage their level of engagement and active participation. Such components are considered essential in both STEM and DT practices. However, while research on DE has been increasing, studies on STEM DT are under-researched.

Teachers in primary and secondary education have recently expressed a mixed attitude towards DE, being negatively affected by several socio-emotional factors such as increased levels of fatigue, stress and low levels of collaboration and interaction. On the other hand, perceived joy and creativity tend to yield positive outcomes towards DE [7]. Researchers generally agree that factors such as attitude towards DE, individual characteristics and school infrastructure tend to affect teachers' adoption of DE and integration of ICT in their teaching practice [8].

However, most of these studies have been developed and evaluated on broad teacher populations, mainly distinguishing between level of education (K-12, higher education, etc.) and not the teaching discipline. The case of STEM DT is under-researched and studies in the field mainly focus on students' perspective [9,10]. Moreover, research on barriers regarding the integration of ICT into the teaching practice and the instructional design of STEM courses has revealed two major categories of barriers: (i) teacher-level or personal and (ii) school-level or institutional [4,8]. However, the barriers to adopting STEM DT might imply different or more thematic codes, for instance, difficulties with students' interaction and communication [11] or socio-psychological attributes [12]. The technical and dynamic nature of STEM teaching might yield even more challenges, grounded on the need for labs or physical equipment, as mentioned in [4]. In addition to all these, researchers agree that maintaining the sustainability and feasibility of STEM education is a problem that should be discussed.

Motivated by the challenge and the outlined research gap, this study seeks to explore STEM teachers' attitudes towards STEM Distance Teaching (DT), and their perceived barriers and training needs. In this study, STEM distance teaching refers to the process of teaching STEM-related courses using technological means when the teacher is in a different location to the students.

The research questions were used to examine a sample of STEM teachers in secondary education participating in a National Teachers ICT Training Program in Greece that aimed to integrate digital technologies in teaching. Due to the COVID-19 pandemic crisis, all STEM teachers delivered their school teaching modules via distance education. The study was guided by the following research questions:

Q1. *What is the STEM teachers' attitude towards distance teaching?*
Q2. *Are there any differences in the teachers' attitude towards STEM DT based on individual characteristics, like gender, age, teaching experience using ICT, STEM subject, and school infrastructure?*
Q3. *What are the barriers that STEM teachers meet during STEM distance teaching?*
Q4. *What are the STEM teachers' training needs (skills and knowledge) that should be considered by future teachers' training programs?*

The main aim of this study is to shed light on the STEM teachers' attitudes, barriers, and training needs in the context of STEM distance teaching. This study employs a mixed analysis approach, aiming to provide useful insights and real-case examples of STEM teachers' needs and difficulties in effectively conducting STEM distance teaching during the remote education conducted during the COVID-19 emergency. This study also aims to analyse potential differences in the examined constructs that might be yielded by STEM teachers' individual factors, teaching STEM subjects and school digital infrastructure. The results of this study can be used by researchers, ICT educators or institutions in the design of effective and personalized training programs for STEM distance teaching. This study might also be useful during or after COVID-19 towards the design of pedagogical practices to encourage and more deeply involve STEM teachers in the efficient application of STEM DT in secondary education.

Previous Studies

Several studies focused on analysing the factors affecting STEM teachers' efficiency in applying the knowledge gained from participating in STEM professional development programs. The results indicated that the professional programs' effectiveness is mainly affected by individual characteristics and attitudes toward STEM professional development activities [13–15]. Several research works have also underlined the role of external factors such as the training program design and the training material [16].

El-Deghaidy et al. [17] reported that insufficient access to resources and a lack of instructional support and development opportunities can negatively influence STEM teaching. In an extended literature review [18], the authors recognized a set of contextual barriers to STEM education, including the teachers' difficulties communicating in a cross-disciplinary context and the lack of teaching materials or access to advanced technologies.

In their study on STEM teachers, Shernoff et al. [4] identified the following needs and challenges for STEM teachers to effectively integrate STEM disciplines in their courses: (a) lack of physical resources and technology, (b) students' attitudes, (c) mixed skills and gaps in students' understandings, (d) lack of students' interest and engagement, (e) lack of collaboration, (f) completing paperwork, and (g) lack of district administrative support. In terms of their needs, STEM teachers expressed the following needs: (a) more resources and technology support, (b) support for collaboration, (c) more professional development, (d) greater interests in topics among students, and (e) new standards focusing on fewer topics more deeply. In [3], Rinke et al. identified technology and computational thinking as being among the greatest training needs of STEM teachers. In the same study, knowledge of STEM pedagogies did not reveal any significant differences between STEM and non-STEM teachers in elementary schools. However, the authors outline the need for a STEM teacher to plan and design STEM instructional material, requiring the use of problem solving, real-world applications, and content-driven dialogue.

In the context of DE, recent research on STEM mainly concerns the students' perception. For example, Mutambara and Bayaga [10] examined students' acceptance of mobile-based STEM learning, suggesting that the perceived attitudes of rural high school STEM learners, their parents, and teachers affect their intention to use mobile learning. Additionally, Arpaci et al. [9] extended the Technology Acceptance Model to show that knowledge practices have a positive impact on the acceptance of Massive Open Online Courses (MOOCs) for engineering students.

Despite the recent trends of DE and the COVID-19 crisis, which have pushed all disciplines to 'move online', research in STEM teaching is limited and mainly concerns MOOCs. For instance, Zielinski et al. [11] examined the factors that drive STEM instructors teaching a MOOC. Their thematic analysis identified a set of nine themes across two main categories of personal and situational factors. These are as follows: outreach, impact on learners and engagement, professional development, pedagogical development, personal enjoyment, support (technical and institutional), institutional pressures, material development, and time commitment.

2. Materials and Methods

2.1. Mixed Methods Design and Measurement Model

The data in the present study were gathered through a questionnaire with two sections. The first section included six closed-ended questions about the teachers' demographics (age, gender), STEM teaching subject, experience in teaching using ICT, experience in previous training programs and perceived efficiency of their school's digital infrastructure in terms of the hardware, software, and networking, regarding their teaching needs. The second section consisted of 13 closed-ended bipolar questionnaire items rated in a 5-point Likert style format, regarding the teachers' perceptions towards STEM DT and its characteristics.

The items were selected based on a review of previous studies [18–20] that measured various attitudinal items such as perceived easiness, satisfaction, engagement, attention, etc., and supported the idea that attitudinal characteristics towards DE can be quantified in merged and/or adjusted measurement models. In the context of DE characteristics, researchers also attempted to measure the teachers' and students' perceived communication, interaction, and collaboration [21–23]. To this end, this study focused on measuring the teachers' perceived (a) easiness, (b) engagement, (c) interaction/collaboration and (d) openness/flexibility of STEM DT.

The structure of the questionnaire is depicted in Table 1. As depicted, the measured items are scaled from negatives to positives (from isolation to social, from difficult to easy, etc.). The statement for every component was phrased as "*Online distance teaching (synchronous & asynchronous) is [item 1] . . . [item 2]*".

Table 1. Survey items to measure attitude towards STEM distance teaching.

Description: Online distance teaching (synchronous & asynchronous) is:		
	Item 1	**Item 2**
Easiness		
ES1	Difficult (1)	Easy (5)
ES2	Tiring (1)	Effortless (5)
ES3	Time demanding (1)	Time saving (5)
Engagement		
EN1	Unsatisfying (1)	Satisfying (5)
EN2	Unpleasant (1)	Pleasant (5)
EN3	Uninteresting (1)	Interesting (5)
Interaction/Collaboration		
IC1	Individual (1)	Collaborative (5)
IC2	Teacher centric (1)	Student centric (5)
IC3	Static (1)	Interactive (5)
IC4	Isolating (1)	Social (5)
Openness/Flexibility		
OF1	Discriminating (1)	Inclusive (5)
OF2	of restricted access and use (1)	of open access and use (5)
OF3	Inflexible and Fixed (1)	Flexible (5)
OF1	Discriminating (1)	Inclusive (5)

Data regarding barriers and training needs were collected through a set of open-ended questions (OQ) as follows:

OQ1. What was the biggest difficulty (problem, barrier) you faced during the distance teaching?

OQ2. What subjects would you like to be included in a future training program?

The wording and the structure of the questionnaire was reviewed by two experts in the field of Teacher Training and Technology Enhanced Learning (TEL) to eliminate any typos and difficulty in perceived words or expressions.

The measurement model was validated in terms of consistency and reliability. As depicted in Table 2, all constructs proved to have internal consistency and reliability since their Cronbach alpha values were above the threshold of 0.60, and their composite reliability values were above 0.70. The convergent validity was also confirmed since the average variance extracted (AVE) was above the value of 0.50 [21,24]. The discriminant validity was consistent with the criteria set by Fornell and Larcker, as presented in Table 3.

Table 2. Consistency and reliability results of the measurement model.

	Cronbach's Alpha	Rho_A	Composite Reliability	Average Variance Extracted (AVE)
Easiness	0.769	0.797	0.862	0.676
Engagement	0.909	0.923	0.943	0.846
Interaction/Collaboration	0.789	0.791	0.864	0.613
Openness/Flexibility	0.748	0.756	0.856	0.666

Table 3. Discriminant validity of the measurement model.

	Easiness	Engagement	Interaction/ Collaboration	Openness/ Flexibility
Easiness	0.822			
Engagement	0.492	0.920		
Interaction/Collaboration	0.501	0.717	0.783	
Openness/Flexibility	0.466	0.654	0.647	0.816

2.2. Context, Participants, and Procedure

The study was applied to a set of STEM teachers in secondary and primary education in Greece, who participated in the National Project of "Advanced Training for the Utilization and Application of ICT in the teaching practice". The project was part of the B2-Level ICT teacher training program named "In-service Training of Teachers in the Utilisation and Application of Digital Technologies in the Teaching Practice" (https://e-pimorfosi.cti.gr/en/the-project/about-b-level-ict-teacher-training) (accessed on 31 October 2022), implemented by "Diophantus", the Computer Technology Institute and Press (CTI), in collaboration with the Institute of Educational Policy (IEP).

The project is also known as the B-Level ICT Teacher Training, which followed the previous A-Level ICT Training and was mainly addressed in the following teaching disciplines: Philology–Language, Mathematics, Physical Sciences, Informatics, Primary Education and Kindergarten Teachers.

The main aim of the project was to train and enable in-service teachers to efficiently apply digital technologies in teaching. The 60-h module included 42 teaching hours and additional 18 h for preparing in-class practice, and a total of 5800 teachers were enrolled in the project that was scheduled to run within 2020. The questionnaire for this survey was distributed to the 5800 teachers participating in the program. Out of 849 responses, 158 were only received by STEM teachers (81 males, 77 females). Their STEM disciplines were Mathematics (23.4%), Informatics (27.2%), Natural Science (19%), and Engineering (30.4%). All 158 STEM teachers replied to the required and quantitative part (measured variables) of the questionnaire, while 44 did not reply to the perceived-barriers open-ended question and 47 did not reply to the training needs open-ended question. That is, 114 replied to the open-ended question regarding perceived barriers and 111 replied to the open-ended question regarding their training needs regarding the skills and knowledge that should be included in future training programs.

The questionnaire was sent online via email and all participants were asked to consent for their volunteer and anonymous participation. All data were collected according to the ethical standards of the institutional research committee.

Table 4 presents the socio-demographic characteristics of the participants, including their perceived satisfaction with their school's digital infrastructure (hardware, software, Network), their previous participation in training programs, and their experience with teaching using digital technologies. Perceived satisfaction with school infrastructure received a mean value of 3.00 out of 5.00 (St. dev = 1.12). As depicted, most of the participants attended previous training programs that lasted more than 20 weeks.

Table 4. Socio-demographic characteristics of participants, and perceived efficiency of their school digital infrastructure (n = 158).

Age	n%	Teaching Experience Using Digital Technologies (Duration in Years)	n%	Previous Participation in Training Programs (Duration in Weeks)	n%	Efficiency of School Digital Infrastructure (1 = "Not at all"—5 = "A lot")	n%
<30	-	<5	18.4%	0	3.8%	1	7.0%
31–40	14.6%	5–10	27.8%	1–4	6.4%	2	31.6%
41–50	54.4%	11–15	25.3%	5–10	5.1%	3	24.7%
51–60	29.1%	15–20	19.0%	11–20	25.5%	4	26.6%
>60	1.9%	>20	19.5%	>20	59.2%	5	10.1%

Note. The data presented correspond to the STEM teachers that answered the quantitative part of the questionnaire.

2.3. Data Analysis

The data were analysed for the sample of 158 STEM teachers participating in the survey. Research questions RQ1 and RQ2 were examined through quantitative analysis, while RO3 and RQ4 were examined through qualitative analysis based on the collected textual feedback.

The quantitative data analysis was based on the following methodological steps:

(i) Evaluation of the validity of the measurement model by assessing Cronbach alpha, convergent validity, and composite reliability.

(ii) Descriptive statistics to measure mean values and standard deviations of the examined variables cross the STEM teachers' population.

(iii) Non-parametric statistical methods (Mann–Whitney, Kruskal Wallis, Spearman Rho) to examine significant differences between the STEM teachers' groups regarding their gender, age, school infrastructure, experience in previous training programs, teaching experience using ICT and STEM subjects.

(iv) The phase of qualitative analysis included a thematic analysis of the text data collected through the open-ended survey questions regarding perceived barriers to distance teaching and emerging teacher training needs that should be included in future training programs. Both qualitative constructs were investigated through thematic analysis. The analysis was carried out by applying thematic analysis, in which keywords were identified and matched with extracts from the qualitative data. The aim was to identify the important or most frequent opinions and code them into distinct thematic areas. The thematic analysis was based on the procedural steps described in [25–27]:

  (i) Familiarization with the data;
  (ii) Coding;
  (iii) Generating themes;
  (iv) Reviewing themes;
  (v) Defining and naming themes.

During data familiarization, all text written responses from the questionnaires were compiled into an excel file. This first step was to get to know the data we collected and gain a detailed overview of these data before individual analysis.

Next, data coding was carried out. Sentences or whole sentences of the text were carefully read and labelled with differently coloured code tags (codes) to describe their content. Each code described the participants' idea or perception, as expressed in the corresponding part of the text. The generated codes focused on the research objectives of this study, referring to barriers and training needs, and neglecting non-relevant concepts. Some coding examples include hardware, software, engagement, communication, equipment, pedagogy, etc.

In the third step of the thematic analysis, we examined the codes that were created to identify patterns and begin to identify themes. At this point, we unravelled the codes we created, as some may be unclear or not relevant enough because they do not appear very often in the data; therefore, they can be discarded. Thus, we aggregated similar conceptual codes into themes of barriers and needs. For instance, codes related to issues of interaction, communication, engagement, and attendance were grouped under the theme 'Students' interaction & engagement'.

In the theme review, two experts in the field reviewed the original dataset with the themes that were created to test whether they are accurate and useful representations of data. Finally, the name of each theme was finalized. In this last step, the title of the themes for which this was deemed necessary was reworded in a concise manner that helps one to better understand their data.

3. Results

3.1. Quantitative Analysis

The phase of quantitative analysis included the processes used to calculate and present the descriptive statistical results and examine the potential group-based differences in the observed constructs.

Descriptive Statistics and Differentiation Factors

Descriptive statistics for the items that measured STEM teachers' attitude towards distance teaching are presented in Table 5. Table 6 presents the significant differences among the STEM teachers' groups according to their gender, age, and STEM field. Finally, Table 7 shows the correlations between teachers' attitude towards distance teaching and perceived efficiency of school digital infrastructure.

Table 5. Descriptive statistics results (n = 158).

	Minimum	**Maximum**	**Mean [1,5]**	**Std. Deviation**
Easiness	1.00	5.00	2.8586	1.03259
Engagement	1.00	5.00	3.2785	1.05266
Interaction/Collaboration	1.00	5.00	3.1630	0.89981
Openness/Flexibility	1.00	5.00	3.2700	0.99905

Table 6. Mann–Whitney and Kruskal–Wallis among STEM teachers' groups (n = 158).

	Easiness	**Engagement**	**Interaction/ Collaboration**	**Openness/ Flexibility**
Grouping variable: gender				
Mann–Whitney U	2839.500	2463.000	2786.500	2598.000
Wilcoxon W	5842.500	5466.000	5789.500	5601.000
Z	−0.975	−2.293	−1.160	−1.821
Asymp. Sig. (2-tailed)	0.329	0.022 *	0.246	0.069
Grouping variable: age				
Chi-Square	9.634	6.361	2.414	6.408
df	3	3	3	3
Asymp. Sig.	0.022 *	0.095	0.491	0.093
Grouping variable: STEM Field				
Chi-Square	11.438	1.321	5.449	5.449
df	3	3	3	3
Asymp. Sig.	0.010 *	0.724	0.142	0.142

* Statistical significance at level $p = 0.05$.

Table 7. Spearman Correlations between STEM teachers' attitude towards distance teaching and perceived efficiency of school digital infrastructure (hardware, software, network) (n = 158).

Attitude Items		School Digital Infrastructure
Easiness	Correlation Coefficient	0.194 *
	Sig. (2-tailed)	0.015
Engagement	Correlation Coefficient	0.240 **
	Sig. (2-tailed)	0.002
Interaction/Collaboration	Correlation Coefficient	0.305 **
	Sig. (2-tailed)	0.000
Openness/Flexibility	Correlation Coefficient	0.183 *
	Sig. (2-tailed)	0.022

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

3.2. Qualitative Analysis

3.2.1. Perceived Barriers in STEM Distance Teaching

In previous studies, the barriers to adopting ICT are described as "obstacles, which prevent or inhibit teachers from adopting and integrating ICT into teaching and learning activities" [8]. Similarly, barriers to adopting STEM distance teaching can be perceived as the difficulties or problems that prevent or inhibit STEM teachers from adopting distance teaching methodologies into their STEM teaching practices.

Participants (n = 114) detailed the perceived barriers to teaching STEM disciplines through distance teaching during the beginning of the COVID-19 pandemic. Since their feedback was collected during the COVID-19 crisis, they were asked to reply according to their recent experience in emergency remote education. The thematic text analysis revealed some of the most common barriers to STEM teachers' distance teaching of their STEM disciplines. The identification of the themes was mainly based on previous findings on teachers' perceived ICT barriers [4,8]. Table 8 presents the coding categories that make up the five major themes. The number of responses exceeds the sample size because many participants provided more than just one comment. The five themes of barriers included: (a) students' interaction and engagement, (b) digital infrastructure, (c) students' digital skills, (d) space and equipment, and (e) teachers' work overload and stress. Table 8 also presents one or more example phrases, along with some basic information regarding the participants (STEM teaching subject, gender, age group).

Table 8. The perceived barriers to STEM distance teaching: results from a qualitative thematic analysis (n = 114).

Content Area (Theme/Code)	Frequency in Responses	Example(s) 'Statement' (Teacher Discipline, Gender, Age)
Theme 1 Students' interaction & engagement		
Lack of students' interaction and engagement in course	28	*'The students did not respond and did not send the assignments/exercises'* (Informatics, female, 41–50)
Lack of students' attendance	19	*'Students participated minimally (attendance was not mandatory)'* (Informatics, male, 31–40)
Difficulty to communicate with students	9	*'My initial communication with my students. I contacted them personally after I searched and found phones and emails'* (Informatics, female, 41–50)
Theme 2 Digital Infrastructure		
Technical issues	26	*'Connection problems/Loaded lines!'* (Informatics, male, 51–60)
Poor school digital infrastructure	12	*'School computers are old, and I cannot access HTTPs'* (Mathematics, female, 41–50); *Lack of organization on the part of the ministry and the school'* (Mathematics, male, 51–60)

Table 8. *Cont.*

Content Area (Theme/Code)	Frequency in Responses	Example(s) 'Statement' (Teacher Discipline, Gender, Age)
Theme 3 Digital skills		
Students' digital skills	12	'*...nor could I contact the students by email because they did not have the technology and knowledge to use some of the applications I sent*' (Mathematics, female, 41–50)
Teachers' digital skills	7	'*I was more bothered by the behaviours of my colleagues who were negative about distance learning and completely opposed to its development to the point that some of them never participated*' (informatics, male, 41–40); '*Many difficulties in learning the platforms for modern and asynchronous education without any previous experience*' (Engineering, male, 51–60)
Theme 4 Space and equipment		
Students' lack of equipment (computer, mobile, network, etc.) or space at home	25	'*The students did not have a computer or internet connection. It was not treated.*' (Informatics, female, 31–40); '*There were students who could not participate because their brother had to study at the same time (the necessary internet speed was not available, there is no fiber optics in the province)*' (Informatics, male, 31–40)
Need for physical lab or class equipment (e.g., boards)	4	'*The fact that the course I teach (High School Technology) is in a laboratory and cannot be implemented as such in remote conditions except with tools such as virtual labs (e.g., tinker cad-designs / circuits), which are not so easy to be managed by students.*' (Engineering, female, 51–60)
Theme 5 Work overload/stress		
Work overload and stress	11	'*Many working hours for the smooth running of the course*' (natural science, female, 41–50); '*It was an extremely stressful time with daily ten hours of work, not excluding Saturdays and Sundays*' (Informatics, female, 41–50)

As depicted, the most frequently perceived barriers, in descending order, are as follows: (i) lack of students' engagement, (ii) technical issues, (iii) lack of space and equipment, (iv) lack of digital skills, and (v) teachers' increased workload and stress. As derived from the combined results of this study, digital infrastructure is a major factor in the STEM teachers' positive attitude towards DE. However, the results also confirm that DE depends on a set of behavioral and attitudinal issues, not only on technology-related issues [12].

3.2.2. Perceived Training Needs towards STEM Distance Teaching

As part of the qualitative analysis, four main themes were identified based on the feedback of the STEM teachers (n = 111) when asked to express their needs from a future ICT Training Program: (a) tools and platforms, (b) personalized/targeted training, (c) course design methodologies, and (d) pedagogical and psychological approaches.

In Table 9 we provide the themes subsets and one or more representative examples of each one, along with the basic characteristics of the respondents (STEM subject, gender, age group). As depicted, most of the participants reported the need to be trained in specialized issues in their STEM discipline, tools and platforms for distance teaching, teaching design methodologies, as well as pedagogical and psychological practices for distance education.

Table 9. The subjects that STEM teachers need to be included in future training programs: results from a qualitative thematic analysis (n = 111).

Content Area (Theme/Code)	Frequency in Responses	Example(s) 'Statement' (Teacher Discipline, Gender, Age)
Theme 1: Tools and platforms		
Learning management systems and video conferencing platforms for distance teaching	10	*'Learning Management Systems'* (Engineering, female, 41–50)
Tools for online student assessment and collaborative activities	11	*'Training for online assessment of students'* (natural science, female, 41–50); *'Collaborative learning tools'* (Engineering, male, 41–50)
Programming languages	7	*'Seminars on new programming languages'* (Informatics, male, 41–50)
Theme 2 Personalized/targeted training		
Software for STEM-related courses	9	*'Software for natural science'* (Natural Science, male, 41–50)
Targeted and adjusted training to every (STEM) discipline	10	*'Distance education on our discipline and not all together'* (Engineering, male, 41–50)
Theme 3: Course design methodologies		
Distance teaching course scenarios and examples	9	*'Case studies and exemplary teachings with ICT'* (Natural Science, male, 51–60)
Design methodologies for distance courses	11	*'The material I will teach how to teach remotely the whole curriculum in mathematics and what'* (Mathematics, female, 51–60)
Theme 4: Pedagogical and psychological approaches		
Pedagogical approaches and tools for students' engagement	10	*'Ways of better communication. Tools that will improve the interaction between teacher—student.'* (Mathematics, male, 51–60)
Psychological impacts and consulting	10	*'Counselling Positive Psychology and Adolescent Psychology for School Life -Exams -Reading Methodology Stress Management'* (Informatics, male, 41–50)

4. Discussion

4.1. Discussion on Attitude towards STEM DT (Quantitative Results)

Overall, STEM teachers expressed an average of around 3.00/5.00 positive attitude towards STEM distance teaching throughout the examined attitudinal variables.

As depicted in the quantitative results (see Table 6), the analysis revealed significant gender differences in the construct of engagement, where male teachers expressed lower values than female teachers in the measured items of engagement: 'interesting, satisfying and pleasant'. Although previous research findings [28,29] have not detected any gender-related differences in the field of DE, the component of engagement needs to be examined further in future research.

The results also indicated some age-related differences in the component of easiness, where teachers in the age groups of 41–50 and 51–60 expressed the highest values. Previous studies suggest that age is a determinant factor on the teachers' efficiency in implementing technologies in their teaching [30–32]. Easiness of STEM DT was also affected by the teachers' STEM subject, where the field of engineering revealed the highest scores while informatics revealed the lowest.

Finally, as depicted in Table 7, the perceived efficiency of teachers' school's digital infrastructure is significantly and positively correlated to their attitude towards DT across all the examined components, implying that efficient digital infrastructure in schools is linked to a positive attitude towards STEM DT.

Previous experience in training programs and teaching using ICT did not reveal any significant differences in the examined population.

4.2. Discussion on Perceived Barriers in STEM Distance Teaching (Qualitative Results)

Our findings are in accordance with previous studies identifying difficulties in STEM teaching, such as the need for physical resources, the lack of student engagement and the lack of skills and competencies [4,11]. As expected, the transition to DE has further highlighted the barriers to efficiently conduct STEM courses due to the distinct needs of STEM teaching practices like interactivity, collaboration, and practical activities.

The results of this study also extend the previous findings by revealing several more codes that were not mentioned before, such as the teachers' increased workload and the need for digital equipment to teach STEM disciplines online. This extension possibly derived from the distinct needs and particularities of the emergency remote education in the context of COVID-19 pandemic crisis.

In the following paragraphs, we discuss the results for the three major identified themes of student interaction/engagement, digital infrastructure and space and equipment, comparing them with the relative literature to consider some practical implications.

4.2.1. Students' Interaction and Engagement

Previous research has identified interaction, collaboration, and communication between students and professors as important components in distance teaching and learning compared to 'traditional' face-to-face education [22,28]. Isolation and a lack of interaction are of the major challenges in DE, reflecting both synchronous and asynchronous modes [8]. There are also reports on the role of STEM teachers' anxiety regarding their students; progress and the various instructional challenges that they face [33].

Students' interaction and collaboration was also recognised in the quantitative part of this research as a distinct attitudinal variable towards DT, with most of the STEM teachers expressing a relatively positive level of perception (mean = 3.27/5.00). Similarly, engagement was examined in the quantitative analysis as a distinct construct, reflecting an average score of 3.10/5.00.

Answering the open-ended questions, several STEM teachers recognized the importance of students' interaction and engagement for STEM DE. In particular, the lack of student interaction and engagement during online courses was perceived as the most frequent difficulty that STEM teachers faced, with many of them admitting that they never managed to solve this issue. Additionally, the non-mandatory attendance in DE meant that many students could not participate in the online courses. STEM teachers also complained about the negligence of students' participation in DE from the parents; several times, teachers needed to contact parents and explain to them the benefits of DE for their kids. One participant marvelled:

> "[A barrier I met was:] the negligence of students and parents. With frequent communication via email, I managed to get 5 children from each department."

However, some respondents shared that parents were supportive and willing to help their kids with technical or other issues that emerged during the online courses.

According to the collected perceived experience, we can conclude that both students and parents should be further informed of the benefits of DE, and institutions should design policies and strategies to motivate and engage students in DE, especially when attendance is not mandatory. Fortunately, STEM distance learning might be a strong motivator for students to use their computers and digital media to conduct STEM-related activities and significantly enhance their engagement and participation in STEM-related courses [6].

4.2.2. Technical and Institutional Support

Technological characteristics have been recognized to influence the adoption of a particular innovation, especially when it refers to technology, and previous studies suggest that technological attributes, as perceived by teachers, influence the rate of adoption and integration [8]. In [34] Lee et al. found that teachers' capacity, technological, pedagogical, and subject knowledge are amongst the most important factors when transferring the knowledge gained in training to the teaching practice.

This research showed that STEM teachers perceived technological support, network speed and school's digital infrastructure as an important factor in their ability to efficiently adopt DT. As one participant stated:

> "In the first days the system was not functional, and we had technical problems."

It also appears that many STEM teachers complained about the support they received from their institutions. This finding is consistent with previous studies identifying issues with institutional management and support. Previous research highlights the important role that the efficient management of institutions plays in facilitating the access to infrastructure and supporting the adoption and integration of digital or other resources [4,8], as well as in STEM teachers' intention to adopt DT [28]. Governments and institutions play the most important role in digital and innovative educational transformation, since, as recently stated by OECD (2019) "They can also play a key role as platform and broker, as stimulator and enabler; they can focus resources, set a facilitative policy climate, and use accountability to allow innovation rather than compliance".

4.2.3. Space and Equipment

According to the STEM teachers' feedback, many students lacked the appropriate equipment for distance teaching. One teacher mentioned that only 2 out of 10 students in the class had computers or Internet in their houses. In addition, there was shortage of equipment, mainly because several family members needed to use the equipment at the same time:

> "In my family there were three pupils, one student and myself all enrolled in distance education activities. It was many times during the week that there were simultaneous needs and neither the computers nor the speed of the line nor the rooms of the house were enough."

This situation had a significantly negative impact on the process of DT and there was one teacher who expressed, as a future training theme, the knowledge of ways and means to solve the shortage of equipment for their students and family members. Although previous studies state that the adoption of DE is influenced by financial factors [11], the theme of space and equipment has not been underlined. However, this study separates this as a distinct barrier in STEM distance teaching considering the COVID-19 situation, where several family members are enrolled in daily DE activities and a home digital infrastructure is essential not only for students' attendance but also for their psychological state, which is highly impacted in DE, especially fully remote education [12].

4.3. Discussion on Perceived Training Needs towards STEM Distance Teaching (Qualitative Results)

The generated results indicate the urgent need for STEM teachers to acquire and develop digital skills targeted towards distance teaching. The STEM teachers participating in teachers' ICT training programs need to further develop their practical skills and knowledge of how to use the tools for DT and effectively organize their courses. Interestingly, many of them expressed the need to be taught strategies and methods to achieve higher student engagement and interaction in their courses, as well as to implement collaborative learning activities. Only few of them reported the need to gain knowledge on data protection issues, although the quantitative results on attitude revealed low levels of perceived security in DE.

Overall, most of the recognized codes are in accordance with previous studies [11] declaring that the professional development and improvement of technical skills reinforces teachers' motivation and acceptance of STEM distance teaching. Similarly, our results are in accordance with recent findings [5] supporting the idea that STEM teachers need considerably more guidance on how to incorporate ICT and digital tools in their teaching practices. Support and guidance from institutions is another critical factor. This research also highlights the importance of the pedagogical and psychological aspects of DE, leveraging their role in STEM teaching disciplines.

4.4. Contribution and Implications

The findings of this study seem to align well with previous findings in the field, confirming the difficulties that STEM teachers faced in their emergency DT tasks during the pandemic. Apart from the recognised barriers of the lack of student and parental engagement or digital skills and infrastructure, this study extends the previous findings and highlights the important role of psychological and pedagogical support. Such factors are not only considered important in STEM, but also in DE in general, since recent research demonstrated increased levels of mental fatigue and stress among primary and secondary education teachers [7]. As explained, teachers felt unprepared for the DE transition and had difficulties organizing their courses online. To this end, the findings of the current study revealed STEM teachers' need for emotional support and consultation, as well as their need to learn new pedagogical approaches and tools to further engage their students in STEM courses.

This study also implies that most of the perceived needs might yield solutions to the difficulties that STEM teachers face in DT, as expressed in the barriers list in 8. For example, learning how to apply online pedagogical approaches to engage students can enable teachers to achieve higher online interaction and possibly increased attendance in their courses. Moreover, by learning how to digitally organize their courses, use LMS tools and conduct online assessments, STEM teachers will possibly save time and reduce their workload. This will also have positive psychological impacts (e.g., by relieving teachers from stress and/or anxiety symptoms). As a fact, recent studies in different areas revealed that several STEM teachers managed to enhance their digital skills during the pandemic because they needed tools and approaches for DT [33].

Overall, the findings significantly outline the need for STEM-specific teaching and learning strategies. STEM teachers expressed the need for STEM-oriented pedagogies to engage students and help them succeed in STEM disciplines. For instance, pedagogies for the development of self-regulated learning are crucial in STEM courses. In this context, STEM teachers should have the knowledge and ability to cultivate observation, formulation, analysis reformulation, and evaluation skills, as suggested in [30]. Other STEM-specific skills of students, such as motivation [6], problem-solving and creativity [1,2], should also be a high pedagogical priority of STEM teachers. However, to efficiently apply such pedagogies online, STEM teachers need to be trained on the DE technological facilities that might be differentiated or utilized in a different manner from online courses of non-STEM disciplines. The knowledge needed to apply STEM-useful learning theories such as experiential learning [30] in online teaching environments will possibly be a strong component of STEM DT achievement. Finally, as expressed by the examined teachers, STEM-related online software should be available and easily accessible to assist teachers in conducting practical online STEM tasks. The challenges of STEM-oriented physical labs should also be considered [4] to provide hybrid and/or tailored solutions. Although this study does not discuss how teachers/participants handled experiential learning activities and student support in DT, suggestions and successful practices should be included in future studies.

Overall, the results of this study recommend and highlight the need to apply effective STEM-oriented professional development initiatives, and support STEM teaching in their DT task technologically, pedagogically, and psychologically.

4.5. Limitations

The limitations of this study include the self-reported nature of the data collection, which can cause some bias in the quantitative results. The research shows that self-reported responses are at risk of not fully representing the truth because of the human need for social desirability or approval [32]. Another source of potential self-reporting bias in the current study is recall error, which reflects the participants' erroneous responses, which depend on their ability to recall previous events [32].

Some other possible limitations are related to the design characteristics of the utilized platforms and tools, or the national and school policies that might have affected teachers' perceived outcomes.

Future research should be conducted on different populations and consider identifying new STEM- and DE-oriented barriers or training needs (e.g., by interviewing or posing open-ended questions adjusted to STEM disciplines and teaching approaches).

5. Conclusions

The objective of this study was the investigation of STEM teachers' attitudes, perceived barriers, and training needs in the context of STEM distance teaching. The findings emphasize the urgent need for ICT- and DE-oriented training, tailored to STEM teaching and learning strategies. On a positive note, the study reported that STEM teachers participating in teachers' ICT training programs perceive DE quite positively. However, they identified several barriers preventing them from efficiently applying STEM DT. Their suggested training needs include STEM-specific and generic DE educational aspects.

The study included both a quantitative and qualitative analysis. The quantitative analysis examined the STEM teachers' attitude towards STEM DT, considering four constructs: (1) easiness, (2) engagement, (3) interaction/collaboration, and (4) openness/flexibility. The individual factors of gender and age revealed some differentiations across the measured attitudinal components, while the factor of school digital infrastructure significantly affected all the examined constructs. Previous experience in teaching using digital tools and participation in training programs did not yield any significant effects.

The qualitative analysis examined the STEM teachers' perceived barriers and training needs. Five thematic areas of barriers and four themes of teacher training needs were identified. Lack of students' interaction, technical issues, and lack of space or equipment were the barriers most frequently perceived by STEM teachers. The teachers' needs for future training programmes concern STEM-oriented ICT training, STEM-related software, and DE pedagogies to leverage students' engagement. Such needs can be practically considered by teacher training institutions in the design of future training programs.

The recent trends in DE and hybrid education mean that the results of this research contribute to the identification of the distinct needs and challenges faced by STEM teachers. Educational policymakers should consider not only the particularities of STEM teaching, but also STEM teachers' attitudes, needs, and difficulties using distance teaching to effectively design future teacher training programs.

Author Contributions: Conceptualization, M.P. and A.A.E.; Data curation, K.T.; Investigation, M.P. and A.A.E.; Methodology, K.T.; Project administration, A.A.E.; Resources, A.A.E.; Validation, M.P.; Writing—original draft, K.T.; Writing—review & editing, M.P. and A.A.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Michalow, R.J.; Road, F.P. Pre-service teachers using their VOISES to verify STEM and inquiry training. *Int. J. Educ. Soc. Sci.* **2015**, *2*, 1–5.
2. Aslam, F.; Adefila, A.; Bagiya, Y. STEM outreach activities: An approach to teachers' professional development. *J. Educ. Teach.* **2018**, *44*, 58–70. [CrossRef]
3. Rinke, C.R.; Gladstone-Brown, W.; Kinlaw, C.R.; Cappiello, J. Characterizing STEM teacher education: Affordances and constraints of explicit STEM preparation for elementary teachers. *Sch. Sci. Math.* **2016**, *116*, 300–309. [CrossRef]
4. Shernoff, D.J.; Sinha, S.; Bressler, D.M.; Ginsburg, L. Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *Int. J. STEM Educ.* **2017**, *4*, 13. [CrossRef] [PubMed]
5. Bati, K.; Yetişir, M. Examination of Turkish Middle School STEM Teachers' Knowledge about Computational Thinking and Views Regarding Information and Communications Technology. *Comput. Sch.* **2021**, *38*, 57–73. [CrossRef]
6. Vincent-Lancrin, S.; Urgel, J.; Kar, S.; Jacotin, G. Measuring innovation in education 2019: What has changed in the classroom? In *Educational Research and Innovation*; OECD Publishing: Paris, France, 2019.
7. Tzafilkou, K.; Perifanou, M.; Economides, A.A. Socio-Emotional Characteristics of Emergency Distance Teaching: A Mixed-Method Investigation in Greece. *J. Inf. Technol. Educ. Res.* **2022**, *21*, 53–73. [CrossRef]

8. Lawrence, J.E.; Tar, U.A. Factors that influence teachers' adoption and integration of ICT in teaching/learning process. *Educ. Media Int.* **2018**, *55*, 79–105. [CrossRef]
9. Arpaci, I.; Al-Emran, M.; Al-Sharafi, M.A. The impact of knowledge management practices on the acceptance of Massive Open Online Courses (MOOCs) by engineering students: A cross-cultural comparison. *Telemat. Inform.* **2020**, *54*, 101468. [CrossRef]
10. Mutambara, D.; Bayaga, A. Determinants of mobile learning acceptance for STEM education in rural areas. *Comput. Educ.* **2020**, *160*, 104010. [CrossRef]
11. Zielinski, M.; Hicks, N.M.; Wang, S.; Douglas, K.A.; Bermel, P.; Diefes-Dux, H.A.; Madhavan, K. Instructor outcomes of teaching a STEM MOOC. In Proceedings of the Frontiers in Education Conference, FIE, Indianapolis, IN, USA, 1–7 October 2017.
12. Bozkurt, A.; Jung, I.; Xiao, J.; Vladimirschi, V.; Schuwer, R.; Egorov, G.; Rodes, V. A global outlook to the interruption of education due to COVID-19 Pandemic: Navigating in a time of uncertainty and crisis. *Asian J. Distance Educ.* **2020**, *15*, 1–126.
13. Affouneh, S.; Salha, S.; Burgos, D.; Khlaif, Z.N.; Saifi, A.G.; Mater, N.; Odeh, A. Factors that foster and deter STEM professional development among teachers. *Sci. Educ.* **2020**, *104*, 857–872. [CrossRef]
14. Lunenberg, M.; Dengerink, J.; Korthagen, F. *The Professional Teacher Educator: Roles, Behaviour, and Professional Development of Teacher Educators*; Sense Publishers: Rotterdam, The Netherlands, 2014.
15. Sprott, R.A. Factors that foster and deter advanced teachers' professional development. *Teach. Teach. Educ.* **2019**, *77*, 321–331. [CrossRef]
16. Polgampala, A.S.V.; Shen, H.; Huang, F. STEM Teacher Education and Professional Development and Training: Challenges and Trends. *Am. J. Appl. Psychol.* **2017**, *6*, 93. [CrossRef]
17. El-Deghaidy, H.; Mansour, N.; Alzaghibi, M.; Alhammad, K. Context of STEM Integration in Schools: Views from In-service Science Teachers. *Eurasia J. Math. Sci. Technol. Educ.* **2017**, *13*, 2459–2484. [CrossRef]
18. Chai, C.S. Teacher Professional Development for Science, Technology, Engineering and Mathematics (STEM) Education: A Review from the Perspectives of Technological Pedagogical Content (TPACK). *Asia-Pac. Educ. Res.* **2019**, *28*, 5–13. [CrossRef]
19. Joo, Y.J.; Lim, K.Y.; Kim, N.H. The effects of secondary teachers' technostress on the intention to use technology in South Korea. *Comput. Educ.* **2016**, *95*, 114–122. [CrossRef]
20. Martínez, S.J.R.; Ordoñez, X.G.; Guillen-Gamez, F.D.; Agapito, J.B. Attitudes towards technology among distance education students: Validation of an explanatory model. *Online Learn.* **2020**, *24*, 59–75. [CrossRef]
21. Chung, E.; Subramaniam, G.; Dass, L.C. Online Learning Readiness Among University Students in Malaysia Amidst COVID-19. *Asian J. Univ. Educ.* **2020**, *16*, 45–58. [CrossRef]
22. Tanis, C.J. The seven principles of online learning: Feedback from faculty and alumni on its importance for teaching and learning. *Res. Learn. Technol.* **2020**, *28*. [CrossRef]
23. Tsai, C.-L.; Ku, H.-Y.; Campbell, A. Impacts of course activities on student perceptions of engagement and learning online. *Distance Educ.* **2021**, *42*, 106–125. [CrossRef]
24. Hair, J.; Black, W.; Babin, B.; Anderson, R. *Multivariate Data Analysis: A Global Perspective*, 7th ed.; Hall, P.P., Ed.; Pearson: London, UK, 2010.
25. Hsieh, H.-F.; Shannon, S.E. Three Approaches to Qualitative Content Analysis. *Qual. Health Res.* **2005**, *15*, 1277–1288. [CrossRef] [PubMed]
26. Caulfield, J. How to Do Thematic Analysis | A Step-by-Step Guide & Examples. Scribbr. 2019. Available online: https://www.scribbr.com/methodology/thematic-analysis/ (accessed on 31 October 2022).
27. Kiger, M.E.; Varpio, L. Thematic analysis of qualitative data: AMEE Guide No. 131. *Med. Teach.* **2020**, *42*, 846–854. [CrossRef] [PubMed]
28. Zheng, S.; Wisniewski, P.; Rosson, M.B.; Carroll, J.M. Ask the instructors: Motivations and challenges of teaching massive open online courses. In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing, San Francisco, CA, USA, 27 February–2 March 2016; pp. 206–221.
29. Griffiths, B. A Faculty's Approach to Distance Learning Standardization. *Teach. Learn. Nurs.* **2016**, *11*, 157–162. [CrossRef]
30. Nuangchalerm, P. STEM education and Kolb's learning styles. *J. Community Dev. Res. (Humanit. Soc. Sci.)* **2018**, *11*, 11–17.
31. Althubaiti, A. Information bias in health research: Definition, pitfalls, and adjustment methods. *J. Multidiscip. Healthc.* **2016**, *9*, 211–217. [CrossRef]
32. DeCoito, I.; Estaiteyeh, M. Transitioning to Online Teaching During the COVID-19 Pandemic: An Exploration of STEM Teachers' Views, Successes, and Challenges. *J. Sci. Educ. Technol.* **2022**, *31*, 340–356. [CrossRef]
33. Margot, K.C.; Kettler, T. Teachers' perception of STEM integration and education: A systematic literature review. *Int. J. STEM Educ.* **2019**, *6*, 2. [CrossRef]
34. Lee, M.H.; Hsu, C.Y.; Chang, C.Y. Identifying Taiwanese teachers' perceived self-efficacy for science, technology, engineering, and mathematics (STEM) knowledge. *Asia-Pac. Educ. Res.* **2019**, *28*, 15–23. [CrossRef]