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Enhancing Digital Skills of Early Childhood Teachers Through Online Science, Technology, Engineering, Art, Math Training Programs in Estonia

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Teacher professional development programs, including mid- and long-term Science, Technology, Engineering, Art, Math (STEAM) courses, have recently moved from in person learning at university premises to an online environment. Whether it is a temporary change in learning methods caused by the COVID-19 restrictions or whether it will become a new normal is currently under discussion in many teacher training institutions around the world. The aim of this study was to design and implement time- and money-saving synchronous online teacher training format for conducting co-design courses for early childhood teachers in the theme of STEAM integrated learning activities. Based on Tallinn University's curriculum of in-person training courses on the same topic, with the volume of 40 contact hours, we delivered the content in two different formats: in 11-months (as it used to be in pre-COVID period) and in 4-months, adapted to participants' needs. We used a self-assessment survey, based on DigCompEdu framework, to assess the increase of digital competences in the two formats. The long-format course had 31 participants and the short-format course had 50 participants. The assessment was based on pre- and post-test and we used structured live video presentations to let participants retrospectively describe their learning experiences. Results indicate that the participants of both courses had improved their digital competences and achieved the learning outcomes set by course content. There was no significant difference in increase of digital competences or the way the course was perceived between participants of both courses. This brings us to the cautious consideration that it is possible

to achieve desired outcomes of STEAM courses even in a shorter period when conducting them online compared to the in-person courses. There is a need for further research where results from participants of in-person and online teaching courses are compared.

Keywords: digital competence, teacher training, STEAM, DigCompEdu, online education

INTRODUCTION

In the near future at least 90% of professional roles in Europe will require basic digital skills, similarly to the skills of basic literacy or numeracy (European Commission, 2017a). However, the improvements in this area have been slow. According to the DESI 2021 report (European Commission, 2021a), by 2020 about 42% of the adult population still lacked basic digital skills, a 1% improvement compared to 2015. The situation is further aggravated by the fact that 88% of workplaces have done nothing to increase their employees' digital skills, often citing high costs as the main barrier to actions to deal with digital skills caps (European Commission, 2017b). Combined with the ambitious goal of the EU to ensure that at least 80% of adults would have basic digital skills by 2030 (European Commission, 2021b), it becomes clear that, together with other actors, the educational systems of EU countries are expected to contribute to achieving this goal.

According to the United Nations Development Programme's Global Knowledge Index (GKI), Estonia is a leading performer in knowledge infrastructure. It ranks 15th out of 154 countries in the GKI 2021 and 15th out of the 61 countries with very high human development. Estonia's areas of strength include E-participation, and the country's areas of improvement show an increase in teaching staff compensation (% tertiary expenditure). Estonia's recent global success in the PISA assessment has been widely discussed. The country's "Learning-adjusted years of schooling index" is also ranking Estonia in 5th place according to GKI (based on World Bank's Human Capital Index). It is worth mentioning that in GKI's global comparison, Estonia ranks 1st both in "Schools with access to computers in primary education (%)" and "Schools with access to computers in secondary education (%)" (based on UNESCO Institute for Statistics' Database). According to GKI, "ICT Employment" and "Internet activities by individuals (%)" are also very high in Estonia; in both categories, the country is ranking 5th. However, at the same time, the "Gross enrolment ratio in early childhood education" is not necessarily high: Estonia ranks in 49th place in this category according to GKI (UNDP & Mohammed Bin Rashid Al Maktoum Knowledge Foundation, 2021).

The task of educational systems to prepare the youth for the requirements of the modern labor market, including providing them with adequate digital skills, has been discussed frequently for several decades already. Integrating Science, Technology, Engineering, Art, Math (STEAM) principles into regular curricula has been offered as a viable solution for making students become interested in jobs that require good digital skills (i.e., the majority of jobs in the coming decades). However, integrating STEAM to curricula requires teachers to en masse accept the principles of technology-enhanced learning (TEL) – a task that according to various studies has not been entirely successful (Niederhauser et al., 2018; Leoste, 2021) for various reasons. One of these reasons being the low level of existing digital competences (Sánchez-Cruzado et al., 2021). As teachers are expected to use technology for both making their work more efficient and for providing students with relevant subject-related technological skills, it has become crucial to provide teachers with training programs with teachers' digital competences as one of the key aims (Usart Rodríguez et al., 2021).

Digital technologies are recognized not only as working and learning tools but also tools of participation in society. Because of the deep embeddedness of digital technology in our society and to prevent the further growth of the digital gap, early childhood educators need to develop their own and their students' digital competencies (Galindo-Domínguez and Bezanilla, 2021). At the same time, early childhood education's vulnerability in these aspects has been recognized in connection with the worrying situation of the lower technological competence at lower educational levels (Portillo et al., 2020). The complex needs and existing shortcomings in this field have become clearly visible in the COVID-19 era.

The COVID-19 pandemic affected all levels and areas of education, including teacher training and professional development of teachers. To cope with the first shocks of the forced transition to "emergency remote teaching" (Bozkurt and Sharma, 2020), both educators and learners needed to solve complex technical, pedagogical, social, cognitive, and practical challenges. Teacher training institutes, including the Tallinn University were required to develop new infrastructure and learning environments and adapt to new teaching methods, learning scenarios, and study materials. Moreover, both the instructors and the participants of the teacher education and professional development programs had to develop their digital competencies to respond to all the new kinds of challenges.

In Europe the demand for a workforce with meaningful basic digital skills is growing rapidly while the educational systems have difficulties in keeping pace with the demand, partly due to low digital competence of teachers. In order to increase the educational systems' capacity of improving teachers' digital competence, relevant teacher training courses need to become shorter while at least retaining the existing efficiency – or even improving it. In this article, we summarize the main outcomes of a case study, which provided the scientific background to Tallinn University's synchronous online teacher training format for conducting co-design courses for early childhood teachers in the theme of STEAM integrated learning activities. We start by opening the theoretical background on teacher digital competence, its impact on student digital skills development,

ways of training it, and stating the research aim and research questions. Next, we describe the background of the case study that examines the results of two different teacher training courses, followed by the description of the data collection and analysis methods and of the sample. We then answer our two research questions, and discuss the findings.

Theoretical Background

Building Digital Literacy in Education

Digital skills make it possible for people to participate in modern learning, working and social activities by allowing them to manipulate digital content, use digital communication and collaboration tools for solving various problems in their lives (UNESCO, 2018; European Commission, 2020). Of these, basic digital skills are required for basic use of digital and online technologies and, together with reading, writing and numeracy, are considered an important component of the modern literacy skill set (UNESCO, 2018). Teaching digital literacy at schools requires schools to accept several TEL innovations and to appropriate relevant novel classroom practices (Heidmets and Eisenschmidt, 2020), integrating these technologies and related practices to various subject disciplines. Students need their teachers to act as guides and facilitators (Pérez-Jorge et al., 2020) when constructing their digital skills, as their learning outcomes are significantly related to the teachers' mastery of teaching subject discipline (Bakar, 2018; Fauth et al., 2019). The success of integrating digital technologies in classroom practices depends largely on teachers' digital competences (Pérez-Jorge et al., 2020; Sabalete Suárez and Roblizo Colmenero, 2021) and attitudes (Papadakis et al., 2021a). However, the reality of technology integration can be different from theoretical approaches, as teachers are often unable to integrate technology and relevant methodologies with their subject content (Franzoni Velázquez et al., 2020). This deficiency suggests that teachers would need proper training and support when adopting technology in their classrooms (Franzoni Velázquez et al., 2020). Besides providing teachers with technology-related knowledge, these training courses should help them to develop their digital competence, needed to teach their students (Pérez-Jorge et al., 2020). Providing effective and attractive learning environments requires a complex approach on every level, considering a wide range of design principles to support the implementation of multiple pedagogies and developing both subject-based and cross-curricular knowledge, skills, attitudes, values, and ethics (Mäkelä et al., 2020).

Early Childhood Educators' Digital Competences

Findings in teacher training, and professional development for early childhood education (Ananiadou and Rizza, 2010; Tondeur et al., 2017; Casillas et al., 2020) show future teachers' perception of medium digital competence. While the COVID-19 crisis increased the emphasis on training and professional development in ICT and digital competences for early childhood education. In some cases, however, training programs were limited to using some online platforms, and there were no pedagogical practices and digital competences built for effectively engaging in online or distance education with young children (Atiles et al., 2021). A recent study (Galindo-Domínguez and Bezanilla, 2021) points out that pre-service teachers of early childhood education scored significantly lower regarding content creation compared to other digital competence dimensions. In line with Galindo-Domínguez and Bezanilla's (2021) discussion, the reinforcement of digital content creation is crucial. Both teachers and children already from an earlier age are expected to be not only end-users of technology but to become content creators (Drotner, 2020). More digital creativity in the learning environment also leads to more effective implementation of active and innovative methodologies (López Belmente et al., 2019).

Teachers' Professional Development in Digital Competences Through Science, Technology, Engineering, Art, Math Approaches

Teachers' digital competences are often developed through the means of teacher professional development (TPD) programs that utilize co-creation related social processes (Prieto-Alvarez et al., 2018) while providing teachers with knowledge and skills about certain STEAM approaches or technologies (Herranen et al., 2021). In such training programs, experts of various domains (e.g., technology, pedagogy, and learning content) combine their knowledge in order to provide participants with in-depth knowledge about using the selected technologies in the context of teachers' everyday teaching routines (Leoste, 2021). The co-creation approach relies on the ideas about user innovation, where end-users are involved in co-creation of innovation-related artifacts (in the context of education: teaching methods and relevant materials, related to various educational digital technologies), leading to higher user motivation and better innovation adoption rates (Von Hippel, 2017; Bradonjic et al., 2019).

Previous research indicates that participant learning can be better supported via iteratively arranged longitudinal training courses, which consist of cycles of contact days followed by participant activities of co-creation and implementation (Botha and Herselman, 2018; Leoste et al., 2020). Similarly, Henriques et al. (2021) argue for longer duration training courses, as these would help participants to better associate the learned content with their real-life practices. Such a daily teaching practice-oriented, continuous training model is argued positively by further studies as well (Papadakis et al., 2021b).

However, the question of duration is not an easy one as different authors define it differently. Burgess and McGregor (2018), in their literature review about formal teacher training programs, describe brief programs with the duration of several hours to some weeks, whereas in their classification there are also longitudinal programs that stretch over multiple years, while delivering tens of contact hours combined with a few online modules. In general, it seems that a course that lasts less than a semester is considered a short-term program, while a program with longer duration is considered a long-term program. While the short-term training courses might not see the same maturation of participant knowledge compared to long-term courses, they still have some important benefits. For example, short-term courses could lead to savings in financial

resources, and are also less demanding on teachers' already intensive schedules (Leoste et al., 2019).

Research Aims

Our goal in this paper is to examine two teacher-training courses with different durations that aim at increasing teachers' digital competences, using the STEAM technology of educational robotics as the learning focus of the courses. In particular, we are examining how the course duration influences the teachers' post-course digital competences. The underlying rationale for the study is based on teachers' overbooked schedules. The lack of time makes it more difficult for teachers to participate in long-term courses, forcing them often to choose for shorter-term courses.

We are using the European Commission's DigCompEdu framework (European Commission, 2022) to evaluate participants' digital competences before and after the courses, and, by using participant self-reflection, we will gather their more general feedback about the courses. To keep our study in focus, we have formulated the following research questions (RQs):

1. How did teachers assess their digital competences before and after the STEAM course?
2. Are there any differences in development of digital competences between long and mid-term course participants?
3. How did teachers describe their learning experience they got in the STEAM course?

MATERIALS AND METHODS

Case Descriptions

During the year 2021, two online in-service teacher-training courses were conducted at Tallinn University. The participants of both courses were the teachers of early childhood and primary school education levels. The goal of the courses was to provide teachers with necessary skills and knowledge for integrating digital STEAM tools to their teaching practices. Both of the courses included online contact lessons (32 academic hours) and independent work (20 academic hours). One academic hour in Estonia is 45 min. The major difference between the courses was their longitudinal structure: one of them (Case 1) took place from January to November 2021, having in total 13 online gatherings (8 of those had a duration of 1.5 academic hours and 5 had a duration of 4 academic hours). The other course (Case 2) took place from August to December 2021, having in total 8 online gatherings with the duration of 4 academic hours each. Considering that most of the learners were kindergarten teachers and took part from their workplaces, the courses started at 1 PM when in the Estonian kindergartens there is a sleeping hour for children.

The gatherings of both courses included the following content:

(a) lectures about digital competences of teachers and students, the influence of digital devices on the different aspects of child development, appropriate teaching practices for digital devices, and special teaching cases such as with students with special educational needs;
(b) introduction of STEAM teaching approaches and devices, such as digital educational games, simple educational robots, digital educational toys, various novel educational technologies (VR, AR, interactive flat panels, etc.), and digital environments for creating simple educational games and apps;
(c) additional activities, such as co-creation of teaching activities, individual and group reflections, presentations of final assessments.

The actual content of courses was similar and the lecturers were the same, to ensure that besides the difference in overall duration the training course experience would be the same for the participants of both courses.

The participants were pre-informed about the type of STEAM kits introduced and used in the dedicated sessions, so they could equip themselves with the needed kits or similar substitutions. In case the participants did not have any kits available at their workplace, they were able to lend them from the university's lab. The participants had to create teaching activities and test them with their students during the periods between the online gatherings, and reflect on their experience of conducting activities.

Data Collection and Analysis

RQ 1 and 2: Our interest is to understand the differences in growth of participant digital competences between an online training course with its duration stretched on a longer period (e.g., 11 months) and a greater number of online gatherings (e.g., 13 gatherings), and a course with a shorter duration (e.g., 4 months) and less gatherings (e.g., 8 gatherings).

To this end, we measured the digital competences of course participants before and after the course, using a shortened online query tool that is based on the Estonian translation (HARNO, 2022) of the European Commission's DigCompEdu framework (European Commission, 2022). We left out the areas "personal learning and development" and "student assessment" as the content of the courses did not especially target these areas. The final questionnaire in Estonian consisted of 32 indicators, which are divided into four areas of competence:

- Area 2, "Digital Resources": sourcing, creating and sharing digital resources.
- Area 3, "Teaching and Learning": managing and orchestrating the use of digital technologies in teaching and learning.
- Area 5, "Empowering Learners": using digital technologies to enhance inclusion, personalization and learners' active engagement;
- Area 6, "Facilitating Learners' Digital Competence": enabling learners to use digital technologies creatively and responsibly for managing information, communication, content creation, wellbeing and problem solving.

The questionnaire used Likert-type scales with six levels as follows:

- 0: No previous experience. I have not yet developed this competence.
- 1: Beginner. I can explain what it is, and I have tried it in my work.
- 2. I'm halfway to becoming an expert.
- 3: Expert. I am routinely using it.
- 4: I'm halfway to being a leader.
- 5: Leader. I am an advisor and expert in this field both inside and outside my organization.

The levels 0 and 1 indicate little to no previous contact with digital technologies. The levels 2 and 3 refer to educators' ability to appropriate and adapt basic digital practices, levels 4 and 5 refer to educators' ability to effectively manage their digital practices, with the level 5 indicating the educators' ability to critically assess existing practices, develop new ones and share their knowledge with peers. The questionnaire in its adapted form was previously used and validated in a study by Heinmäe et al. (2022) where university experts confirmed that the meaning of the questionnaire items, when compared to its original form, was retained as in the sources. We used Google Forms as the media to deliver the questionnaire to the participants. The questionnaire was asked to be filled in before and after the training course that the participant took part in. Answering the questionnaire was personalized to eliminate entries that were missing either the pre or post-test answers. However, personal information was removed before data analysis.

For analyzing the Likert-type scale data (see also Pimentel, 2019) we first summed the responses by each scale level, and by merging the scale levels within every DigCompEdu area by its subcategories. Next, we reduced the number of Likert items' response levels by merging the scale level responses 0 and 1 (into the level "Beginner"), the scale level responses 2 and 3 (into the level "Expert") and the scale level responses 4 and 5 (into the level "Leader"). Subsequently we counted the number of responses in each of the new levels in every DigCompEdu area and calculated the share of each level (in percentages) per DigCompEdu area. That way we found the share of beginners, experts and leaders among the participants of each course before and after the course (**Tables 1** and **2**).

RQ 3: We also wanted to understand how the participants appropriated the innovative method, introduced them during the training course, and how they planned to start using it in their organizations. To this end, we asked the participants to prepare a short presentation as part of their final assessment, based on the following two questions: "How did the participant assess their digital competences before and after the training course?" and "How did the participant describe the learning experience they got in the training course?" The presentations were video recorded during an online session and transcribed by two researchers. We used open coding when looking for emergence of meaning of clusters (Williams and Moser, 2019). The differences in coding results were removed through consensus-seeking discussions. The occurrence of codes was not quantified due to the different sample sizes.

Sampling

With both cases, participation in the study was voluntary for the training course participants. They were informed that their individual personal data would be removed from their input and that their decision to participate would not affect their chances to pass the course. Case 1 had in total 56 participants ($N1 = 56$), while Case 2 had in total 78 participants ($N2 = 78$). They all submitted their final assessment presentations (that we used to answer RQ3). All participants were female, their age was not recorded.

Of Case 1 participants, 31 ($n1 = 31$) filled in both the pre and posttest questionnaires (data for answering Research Questions 1 and 2). All of Case 1 survey respondents were female, with the average age of 42.7 years (at the moment of filling in the post test survey). Of Case 2 participants 50 ($n2 = 50$) filled in both the pre and posttest surveys. All of Case 2 survey respondents were female, with the average age of 43.1 years (at the moment of filling in the post test survey).

RESULTS

Teachers' Assessment of Their Digital Competences Before and After the Science, Technology, Engineering, Art, Math Course, and Differences in Digital Competence Development Between the Long and Mid-Term Course Participants

Before the long-term training course of Case 1, at least a third of Case 1 participants considered themselves possessing beginner-level digital competences, while slightly below 2/3rds viewed themselves as experts (**Table 1** and **Figure 1**). However, their competences when teaching their own students were assessed more critically – roughly half of the participants (48.4%) admitted that they had only limited knowledge about developing the digital competences of their own students, while less than half of the participants (47.3%) considered themselves experts in this area. In all DigCompEdu areas, only 4.9% of the participants considered to possess the leader-level digital competences. After the training course, the share of the participants who considered themselves to possess leader-level digital competences rose significantly in all DigCompEdu areas. The participants considered themselves especially competent in managing and using Digital Resources (57.3% on the expert level and 24.2 on the leader level), while the increase was the smallest in Facilitating Learner's Digital Competences (the majority of participants considered themselves as experts (54.3%) or beginners (31.7%) in this area).

According to the assessments of Case 2 participants, their digital competences before Case 2 training course were lower, compared to Case 1 participants (**Table 2** vs **Table 1**, **Figure 2** vs **Figure 1**). At least half of the participants considered themselves beginners, and about 40% considered themselves experts in most of the DigCompEdu areas, with the exception of the "Facilitating Learners' Digital Competence" area. In this latter area, about two thirds of the participants believed themselves to be at the

TABLE 1 | The level of Case 1 participants' digital competences, by percentage.

Competence level DigCompEdu Area	Beginner (levels 0 and 1)	Expert (levels 2 and 4)	Leader (levels 4 and 5)
Digital resources			
Pre-test	31.5	59.7	8.9
Post-test	9.7	57.3	33.1
Δ	*−21.8*	*−2.4*	*24.2*
Teaching and learning			
Pre-test	33.1	59.7	7.3
Post-test	6.5	71.8	21.8
Δ	*−26.6*	*12.1*	*14.5*
Empowering learners			
Pre-test	34.4	61.3	4.3
Post-test	11.8	67.7	20.4
Δ	*−22.6*	*6.5*	*16.1*
Facilitating learners' digital competence			
Pre-test	48.4	47.3	4.3
Post-test	31.7	54.3	14.0
Δ	*−16.7*	*7.0*	*9.7*

TABLE 2 | The level of Case 2 participants' digital competences, by percentage.

Competence level DigCompEdu Area	Beginner (levels 0 and 1)	Expert (levels 2 and 4)	Leader (levels 4 and 5)
Digital resources			
Pre-test	50.0	39.0	11.0
Post-test	14.0	65.0	21.0
Δ	*−36.0*	*26.0*	*10.0*
Teaching and learning			
Pre-test	50.0	45.0	5.0
Post-test	19.0	68.0	13.0
Δ	*−31.0*	*23.0*	*8.0*
Empowering learners			
Pre-test	53.3	39.3	7.3
Post-test	19.3	64.7	16.0
Δ	*−34.0*	*25.3*	*8.7*
Facilitating learners' digital competence			
Pre-test	64.3	32.3	3.3
Post-test	28.7	57.0	14.3
Δ	*−35.7*	*24.7*	*11.0*

beginner level and about a third considered themselves experts. This exception was similarly present also with Case 1 participants. However, after the training course the self-assessed competence levels improved significantly.

In most DigCompEdu areas, the share of expert level Case 2 participants became similar or even exceeded that of Case 1 participants, although the share of beginners remained higher and the share of leaders lower, compared to Case 1. Remarkably though, in the area of "Facilitating Learners' Digital Competence" the Case 2 participants' post-test confidence about their competences exceeded that of the Case 1 participants in all areas: there were less beginners (28.7 vs 31.7%), more experts (57 vs 54.3%) and slightly more leaders (14.3 vs 14.0%).

When comparing the dynamics of the digital competences of the participants of the both cases (**Figures 1** and **2**), the following suggestions can be made. First, with the short-term course (Case 2) the share of beginner-level participants reduced significantly more in all DigCompEdu areas, compared to that of the long-term course (Case 1). Second, the share of expert level participants increased remarkably more in Case 2, compared to Case 1. Third, the share of leader-level participants did increase more in the long-term course (with the exception of "Facilitating Learners' Digital Competences," but this can be explained by the higher initial digital competence levels of its participants. These observations lead to the fourth suggestion that specifically concerns the "Facilitating Learners' Digital Competences" area. This area is about one of the key competences of the teachers – their ability to enable their students to use digital technologies creatively and responsibly. With Case 2, the initial digital competence levels in this area were remarkably higher compared to Case 1. However, after the course, this was the area where Case 2 participants' digital competence levels exceeded those of Case 1

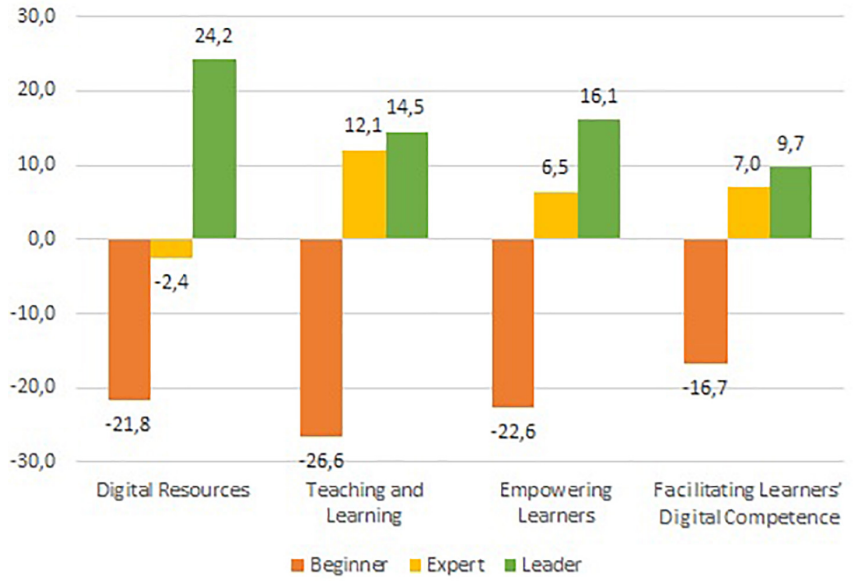

FIGURE 1 | Dynamics of Case 1 participants' digital competences (increase in competence-level group sizes, by DigCompEdu area, in percentage points).

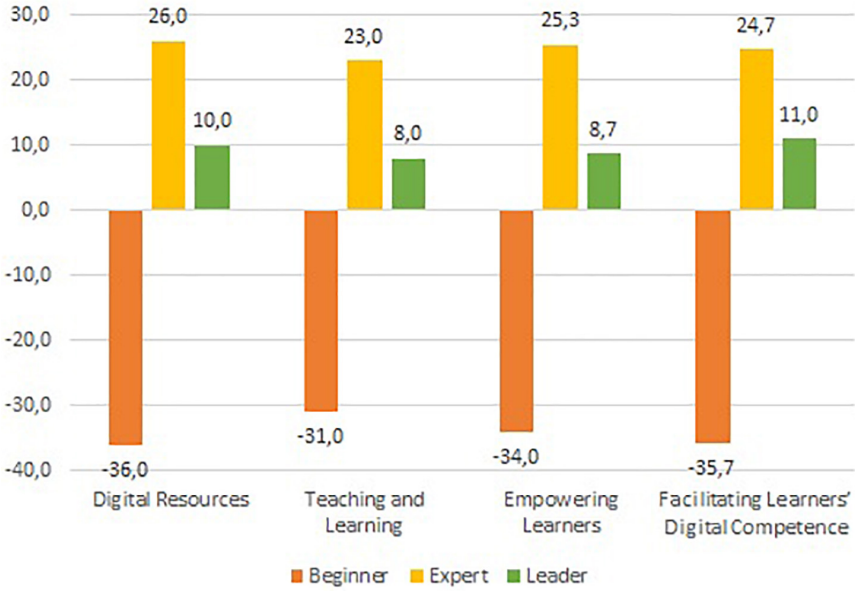

FIGURE 2 | Dynamics of Case 2 participants' digital competences (increase in competence-level group sizes, by DigCompEdu area, in percentage points).

participants. In other areas, the growth of competences was not so conclusively expressed.

Teachers' Description of Their Learning Experience They Got in the Science, Technology, Engineering, Art, Math Course

When reflecting on their learning experiences, all of the participating teachers of both training courses described how the training contributed to the growth of their knowledge and courage of using digital tools. The participants were able to become familiar with new tools and environments and learned to use them in their teaching practices. The participants found it important that the training courses used a variety of educational tools and good guiding materials, its instructors were supportive and that it was possible to learn from the experiences of their peers and feel their support. Many participants highlighted the possibility, considered as one of the biggest values of the courses, to learn from the activities, to use shared teaching materials

and practical experiences of their fellow teachers. For example, a kindergarten teacher said: "*Thanks to the course I became encouraged to start using (educational) robotics tools; regularity, consistency, courage to use developed in my activities. Whereas earlier I only used the tools I was familiar with, now I also have the courage to start using new (unfamiliar) tools.*" On the topic of substantive planning of learning activities, many participants pointed out the importance of understanding the meaning of the integration of subject areas. In their opinion, the training courses helped them to recognize better how to integrate subject disciplines while using digital tools to fulfill learning objectives.

Teachers who participated in the long-term training course repeatedly mentioned the increase in motivation, the development of self-analysis skills, and the systematic and consistent use of digital tools in their everyday teaching activities as an effect of the training on their professional development. In most cases, the reflection of teachers who had completed the shorter training was limited to mentioning the development of new knowledge, ideas and practical skills. In the case of supporting children's development, teachers of the shorter training highlighted their new experience in working with children with special needs, where digital tools have helped the child to learn actively and supported co-operation between teacher and child. For example, a comment from a schoolteacher with long-term teaching experience states: "*Using a digital tool makes it easier to get in touch with a student with SEN, makes it easier for the teacher to communicate with the child and the child is more in contact with the activity.*" Participants were asked to describe how they see the further development of the field of learning robotics in their educational institution.

A large number of participants mentioned that their educational institutions had purchased new digital educational tools. Teachers of the shorter training course saw further development mainly in the context of their own classroom: they mentioned how often and what different tools and activities they plan to use in their teaching practices in the future. Some teachers also mentioned training a teaching partner or conducting an in-house training course. In many cases, teachers who had completed the longer training course, mentioned training colleagues, organizing regular workshops and mentoring co-teachers as a part of integrating digital tools into teaching.

DISCUSSION

We aimed at clarifying how a long-term STEAM training course for teachers would influence their digital competences, compared to a shorter-term STEAM training course. To this end we conducted two similar training courses, both focused on providing teachers with the skills and knowledge needed for integrating the STEAM technology of educational robotics to their teaching practices. The main difference between these two courses was their duration: the length of Case 1 was 11 months whereas the duration of Case 2 was 4 months. There were no other meaningful differences between the two cases. The increase in digital competences was relatively similar with both the long-term and short-term cases. However, it seems that with the short-term training course the share of beginners decreased more vigorously and the increase of experts was more vigorous than with the longer training course.

The DigCompEdu area of "Facilitating Learners' Digital Competences" remains a question with particular importance as it reflects the ability of teachers to prepare their students for the digital future. With the short-term training course, the competence growth was uniform in all DigCompEdu areas (**Figure 2**), while with the long-term training course the growth was significantly higher in all other areas (both when compared to the "Facilitating Learners' Digital Competences" area or to the results of the short-term training course). Our experiment did not give full clarity about the reasons for this peculiarity, suggesting that further studies are needed to understand this question. It would be important to determine if a long-term training course would help teachers to become more realistic about the difficulties in enabling their students to creatively and responsibly use digital technologies, or if, considering that the final digital competence levels in this area were similar in both cases (e.g., 14.0% leaders in Case 1 vs 14.3% leaders in Case 2), it is possible for a teacher to understand relatively quickly these difficulties and therefore the problem is not solvable by allocating more training time but instead more effective teaching practices are required. However, it is also possible that the underlying reasons for this phenomenon are tied to the reasons teachers use digital technology in their lessons. In most countries, the curriculum goals have remained unchanged despite the pressure from stakeholders toward integrating TEL and STEAM (UNESCO, 2016). Thus, the primary focus of using technology in their lessons is on delivering daily teaching (Perifanou et al., 2021). In this case, facilitating the digital learning of their students would require national level curriculum change.

The qualitative results imply that both courses were beneficial for growing participants' digital knowledge and related confidence. With both approaches, long-term and short-term, it is important to cover a wide range of usable technologies, to have good guiding materials, supportive instructors, and to allow peer experience and support to be used as a part of the course. However, based purely on participant feedback, it would seem that the long-term courses could have better results in increasing participant motivation, in developing their self-analysis skills and changing their teaching practices – similarly to what is implied by Henriques et al. (2021). Then again, it is possible to argue that at least some of these developments can be achieved outside the training format naturally, as this maturation of knowledge happens as a result of teachers applying their newly-found knowledge and skills in their classrooms. In this case, it could save resources if instead of long-term training courses shorter ones were conducted with reasonable follow-up support, as competence decay (see Gawad et al., 2019) has to be addressed with both scenarios. For better understanding about this matter, in the similar future studies additional measurements need to be conducted after short-time training courses to get similar longitudinal data to the long-term courses.

The results of our study seem to suggest that a short-term training course would be useful for guiding teachers with beginner-level digital competences to the expert level, whereas a

long-term training course could result in higher share of teachers with top-level digital competences. While this suggestion seems to be confirmed by the data in **Figures 1** and **2**, there can also be other factors in play, for example, the different initial levels of the participants' digital competences of the compared cases. There are studies (e.g., Henriques et al., 2021) that support the idea that a long-term training course could lead to more beneficial outcomes, as the participants could better understand the impact of what they have learned on their classroom practices, and that changing teachers' teaching practices is a slow process. However, to fully understand the dynamics of both long-term and short-term training courses, it is important to provide clear definitions of what counts as short-term or what counts as long-term.

In this paper we examined if shortening the duration of STEAM training courses would have meaningful negative impact on various teachers' digital competences, measured by a survey that was based on the European DigCompEdu framework. We found out that while both of the observed STEAM courses had overall positive impact on the growth of teachers' digital competences (RQ1), the short-term course seemed to have better results in providing teachers with intermediate digital competences, and the long-term course seemed to provide more teachers with high-level digital competences.

Our study has some limitations that could have had an influence on its results. For example, the initial level of the participants' digital competences is not the same with the two cases compared. For better comparability, populations with similar characteristics are recommended. We only measured the participants' self-evaluations before and after the training courses. While self-evaluation of digital competence tends to correlate with evaluator's actual competence, some studies indicate that evaluators tend to overestimate their abilities (Tomczyk, 2021). The objectivity of results could be improved by using alternative methods that would measure participants' actual digital competences (instead of using their self-assessment). In addition, a third measurement, after some months or a year after the training, should be conducted in order to get an understanding about the long-term influence of the training-course.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The name of the repository and accession number can be found below: Google Drive, https://drive.google.com/drive/folders/15RBbRoaxFMuY7v0oEe27EyxusiBLfUY-?usp=sharing.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JL, KF, and ZL: conceptualization and supervision. JL and KF: methodology. ZL and MT: validation. JL, MT, and TÕ: formal analysis and writing – original draft preparation. JL: investigation and project administration. JL and MT: resources, data curation, and visualization. JL, MT, TÕ, KF, and ZL: writing. TÕ: funding acquisition. All authors have read and agreed to the published version of the manuscript.

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