

Flipping a science education course for pre-service teachers: A case of Finnish-Palestinian collaboration

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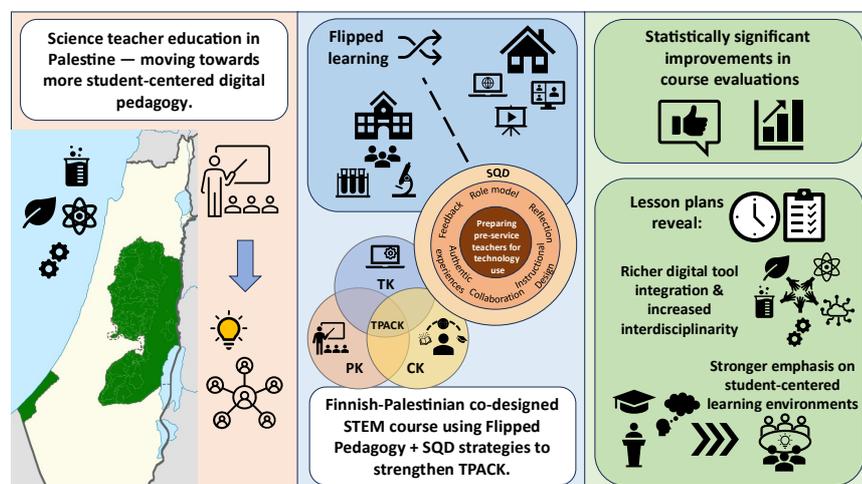
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Abstract: This case study aimed at exploring how pre-service science teachers perceived a jointly developed course based on flipped pedagogy and how it supported their learning. For this purpose, quantitative data of how pre-service science teachers perceived the course was collected through a standardized instrument, while qualitative data was collected from lesson plans that they developed before and after the course. Target group consisted of 14 students who are enrolled in their pre-service teacher education diploma program. Quantitative data was analyzed using Mann-Whitney U-Test comparing the target group to previous two years ($N = 29$). The qualitative data was analyzed through deductive content analysis based on Technological Pedagogical Content Knowledge framework. Quantitative results revealed that pre-service teachers assessed the newly designed course very positively and statistically significant differences were found. While qualitative results show a shift from the lecturing type teaching toward more student-centered learning activities in the lesson plans, such as collaborative and interactive group work. Also, results pointed out deeper student understanding of the STEM content knowledge with concrete examples of important scientific concepts and ideas and paying more attention to alternative conceptions. Moreover, final versions of the lesson plans included explicit and rich use of digital technology elements such as links to videos and use of specialized tools and applications for science education. The results strongly suggest that flipped pedagogy is a promising model and encourage its further use for science teacher training.

Keywords:

flipped pedagogy,
flipped classroom,
pre-service teachers,
science teachers,
teacher education,
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1 Introduction

Today's students are expected to gain readiness to cope with a highly digitalized and fast evolving society. Common for the descriptions is the emphasis on students' readiness to collaborative learning and working, critical and creative thinking, skills for learning and skills to use Information and Communication Technologies (ICT) as tool for their learning and working (Voogt & Roblin, 2012; Kennedy & Sundberg, 2020). According to Voogt & Roblin (2012), teachers need to be familiar with these areas to support the development of their students' 21st century skills i.e., how these skills are supported and especially as part of the pedagogies used. Pre-service teachers need to be trained using pedagogical approaches they are supposed to use in their future work as teachers (Häkkinen et al., 2017). In 21st century skills, this focuses on methods stressing the areas such as collaboration, self-regulation, critical and creative thinking, and the use of ICT (Teo, et al. 2021). The same can be seen from the perspective of ICT in education. According to Wang et al. (2018), Graham (2011), the most beneficial way for supporting pre-service teachers' readiness to use ICT in education is to integrate it into teacher training in pedagogically meaningful ways. Similarly, Tondeur et al. (2012) suggest that teacher trainers should serve as role models of using the ways of teaching and technologies aimed. Altogether the role of teacher training is vital for the development of today's and future pre-service teaching, especially the pedagogical and technological aspects of teacher training courses.

Education in Palestine continues to be a challenging and unstable context due to the ongoing colonial occupation, frequent closures, wars and mobility restrictions which requires a more need to apply more flexible and open learning environments such as e-learning, blended learning and flipped classroom pedagogies in education in general and science teachers' education in particular (Fragkaki, et. al. 2015; Itmazi & Khlaif, 2022; Smith & Scott 2023; Scott et al. 2024). There is a growing need to enhance science teachers' readiness to provide necessary 21st century skills for the students in schools by merging digital technologies within their pre- and in-service programs. This need for innovation and digital technology adoption has also been identified by Scott et al. (2024) to promote successful teaching at the school level.

Developing collaborative and student-centered teaching and learning practices is not a new topic. During the 90s Barr and Tagg (1995) emphasized the need to change the pedagogical practices used from the instruction paradigm toward the learning paradigm, posing demands for student-centered pedagogical practices. Again, Harasim (2006) suggested that more attention need to be focused on students' knowledge building, moving from the broadcasting of knowledge to the construction of knowledge. In order to adapt teaching methods to better align with the demands of 21st-century skills, there exists a wide array of different pedagogical models. These models are designed to provide more concrete guidelines to develop educational practices and cater to the evolving needs of today's students. In this study, we focus on the flipped learning model (see. Dweikat & Raba, 2019; Cheng et al., 2022; Sointu et al., 2019), which aims to facilitate students' active

and collaborative role as part of the learning and learning process and the pedagogically meaningful use of technologies.

The expectations described also apply to STEM (Science, Technology, Engineering and Mathematics) education. Due to the ongoing ambiguity of terms, it is somewhat important here to make a distinction between science education and STEM education. While science education can be seen as any of the following discipline-based education in physical, life or earth and space sciences or engineering, technology, and applications of science (NGSS, 2013; NRC, 2012), STEM education still has some ambiguity in its meaning as it hasn't been around as long as the other discipline-based terms. Still, there are generally common goals of STEM education based on the structure and execution. Moore and Smith (2014) give a characterization, where integral to STEM education is that teachers combine engineering with one or more of the other STEM disciplines based on the relationship between real-world issues and the subjects. Again, Martín-Paéz et al. (2019) created a list of qualifiers based on previous research that need to be matched for classroom teaching to be considered STEM teaching. According to Martín-Paéz et al. (2019) there must be integration of STEM disciplines, promotion of the understanding of the interdisciplinary connections, it must include real-world problem solving, and that STEM education should additionally involve promotion and improvement of learning in the four disciplines it refers to.

In order to study the roles of pedagogy and technology within the STEM education context, the Technological Pedagogical Content Knowledge (TPACK) provides a sound and actively used tool for the purpose (Mishra & Koehler 2006; Petko, 2020). TPACK framework provides three core areas of teachers' knowledge, Technological knowledge (TK), Pedagogical knowledge (PK) and Content Knowledge (CK). Again, these areas are combined as Technological pedagogical knowledge (TPK), Technological content Knowledge (TCK) and Pedagogical content knowledge (PCK) (Koehler et al. 2013). TPACK framework has been used widely for studying and understanding the nature and development of pre-service teachers' readiness to use educational technology in pedagogically meaningful ways. This research continues this research approach within the context of Palestinian teacher education targeting STEM education. Within the context of the Middle East the integration of pedagogical methods aligning with 21st century skills are well needed (Dweikat & Raba, 2019; Farrah & Qawasmeh, 2018). Although there have been continuous efforts to explore use of digital technologies in teacher education programs in Palestine (Abdelmoneim et al., 2024; Dweikat & Raba, 2019; Itmazi & Khlaif, 2022; Elhawa, 2023; Younis, 2024) the studies exploring adoption those technologies in practice are very limited. A previous study by Younis (2024) has explored the effectiveness of an AI-literacy professional development program within the TPACK framework and found it useful in improving attitudes and intentions towards AI use in teaching, indicating a need for targeted interventions to foster the use of digital technologies in the classroom. The aim of this paper is to study how an updated flipped science education course incorporating STEM activities and online learning materials was: first, perceived by pre-service science teachers and second, developed their readiness to use pedagogical

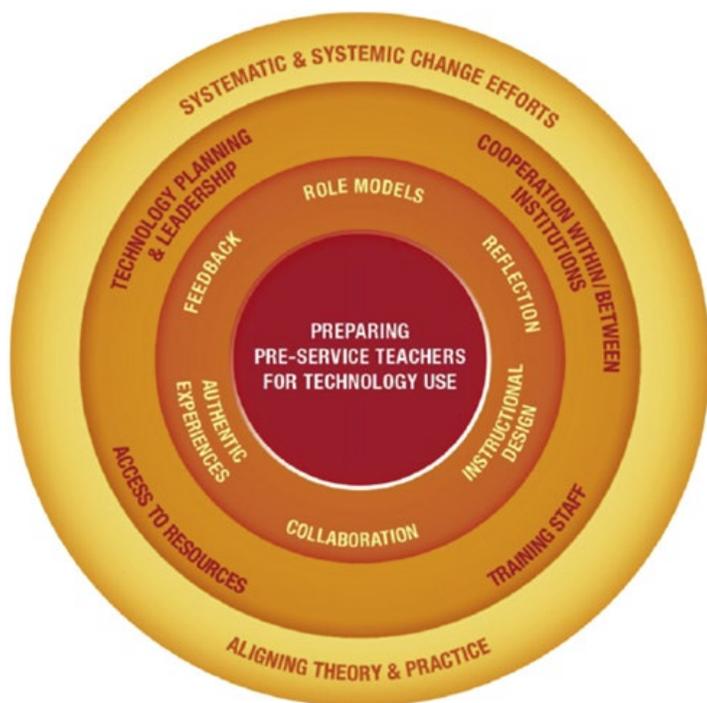
practices and technologies aligning with the expectations related to 21st century skills and today's curricula. In this study we will refer to the course as science education course instead of STEM course, since not all of the qualifiers of Martín-Paéz et al. (2019) are present throughout the course.

2 Theoretical framework and literature review

The development of pre-service teachers' readiness to use education technology during teacher training is a complex issue. Tondeur et al. (2012) developed a three-level model to outline strategies that have proven to be effective for this purpose. This Synthesis of Qualitative Data (SQD) framework (Figure 1) has been actively used in studies targeting teacher training development. The outer circle targets the department level containing the four areas: 1) technology planning and leadership, 2) cooperation within and between institutions, 3) staff development and 4) access to resources. Within this article we focus on the inner level, that contains six more concrete strategies for developing teacher training: 1) teacher educators as role models 2) reflection on attitudes about the role of technology in education, 3) learning technology by design, 4) collaborating with peers, 5) scaffolding authentic technology experiences, and 6) continuous feedback. These six strategies should be considered within teacher training to provide pre-service teachers with good facilities for developing their skills to use educational technology in pedagogically meaningful ways. These themes can be seen as a starting point for developing the STEM rich science education course studied within this article.

Based on recent studies, the six strategies within the SQD framework have proven to be beneficial for developing teacher training practices (Baran et al. 2019; Hsu and Lin 2020). Developing teacher training aligning with the six strategies has had positive effects on pre-service teachers' readiness to use educational technology. The strongest effect has gained from the reflection and instructional design strategies (Hsu & Lin, 2020), emphasizing pre-service teachers' active role in creating technology enhanced educational artefacts and reflective activities. Still, according to Baran et al. (2019) and Valtonen, Hoang et al. (2019), the most actively used strategy has been the teacher educators as role models strategy i.e., teacher trainers have designed the courses with pedagogically sound methods of using technology allowing pre-service teachers to gain experiences about the benefits of educational technology.

Figure 1. The SQD Framework (Tondeur et al. 2012).



In order to better understand the nature of readiness needed to use educational technology, this research is grounded on the TPACK framework (Mishra & Koehler, 2006). TPACK framework contains three core teacher knowledge areas, technological knowledge, pedagogical knowledge and content knowledge (more detailed descriptions in table 1). Within this case the content knowledge area refers to STEM i.e., knowing the large discipline combining science, technology, engineering, and math, within the school science teaching. Pedagogical knowledge focuses on collaborative learning practices. As mentioned above, the collaborative learning approach serves as an umbrella term, targeting students’ active role as opposed to mere lecturing. Within this case the flipped classroom approach provides a more concrete model of these aims. Technological knowledge relies on technologies targeted for special features of STEM such as tools for measuring and visualizing STEM contents and for general level technologies, such as online learning environments and cloud services. Within the FC approach, especially the use of videos is in central role (Sointu et al. 2019).

Table 1. TPACK core constructs aligning with Koehler et al. (2013) and Chai et al. (2013)

Content Knowledge	... knowledge of the subject matter, including theories, concepts, and practices pertinent to the field. CK is characterized by a profound grasp of the discipline’s fundamentals, irrespective of pedagogical considerations.
Pedagogical Knowledge	... knowledge of teaching methodologies, classroom management strategies, assessment techniques, and insights into students’ learning. PK emphasizes general learning theories without being tied to specific content areas.
Technological Knowledge	...knowledge targeting comprehension of the development and potential of technology. TK denotes the expertise required to keep pace with rapid technological advancements, independent of its application to teaching and learning processes.

Along with the three core elements TPACK also contains the combining areas (more detailed descriptions in table 2). These areas focus on knowledge beyond the three areas of knowledge described above. These are the core areas of teacher knowledge that merge the knowledge in larger entities: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). Finally, the TPACK combines all areas producing “an understanding that emerges from interactions among content, pedagogy, and technology knowledge. Underlying truly meaningful and deeply skilled teaching with technology” (Koehler et al. 2013).

Table 2. TPACK combining constructs aligning with Koehler et al. (2013) and Chai et al. (2013).

Pedagogical Content Knowledge	... knowledge for tailoring subject matter with pedagogical practices, facilitating the building of understanding of specific content areas. PCK also includes an understanding of common misconceptions associated with particular topics.
Technological Content Knowledge	... knowledge of the interplay between technology and content, acknowledging the use of technology within various subject domains. TCK involves recognizing how subject matter evolves alongside technological progress, without the need to consider pedagogical aspects.
Technological Pedagogical Knowledge	...knowledge leveraging appropriate technology to support specific pedagogical methods, understanding the pedagogical advantages and limitations of various technologies. In alignment with TK, TPK advocates for proactive technology utilization to optimize learning outcomes, without being content-specific.

TPACK has been actively used for studying pre-service teachers, especially their readiness to use educational technology (Redmond & Lock, 2019). Research has been conducted using both quantitative and qualitative methods (Willermark, 2018). Especially studies using different self-assessment instruments have been popular (Valtonen, Sointu et al, 2019), but again more and more different qualitative methods have been used. Different kinds of courses and learning modules have been designed and conducted in order to show support for the development of pre-service teachers' TPACK (Hsu & Lin, 2020; Lachner et al., 2021; Mouza et al. 2014; Valtonen et al. 2023). Common for these experiments have been providing pre-service teachers with meaningful experiences of learning with technology in pedagogically meaningful ways. The results have shown rather positive results focusing on different TPACK areas. The experiment by Lachner et al. (2021) indicated positive effects for content specific TPACK, similarly the results by Mouza et al. (2014) indicated big change in TCK and the highest assessments for TPK. Again, Hsu and Lin (2020) showed positive results from all measured TPACK areas. Within the study by Valtonen et al. (2023) where technologies were used to support students' collaborative inquiry learning, the results showed positive effects especially for their pedagogical thinking, the role of technology remained in minor role, almost absent. Altogether, these results provide a rather positive picture about the potential to use well-designed instructional interventions and activities as means to support the development of pre-service teachers' TPACK.

Within this article the aim was to support the development of pre-service teachers' TPACK, especially their pedagogical knowledge along with technology. For this purpose, we used the Flipped classroom approach (Bergmann & Sams, 2012). The theoretical foundation of FC model is grounded on principles of collaborative learning, emphasizing student's active role (Bond, 2020). Within the FC model the lecturing elements of the courses are replaced with different pre-materials, typically short video (Sointu et al., 2019). The aim of the short videos is to provide students with possibilities to prepare themselves for the face-to-face meetings, providing a shared starting level for classes, better abilities for students to work with the pre-studied contents and also possibilities to ask help and support with areas that were perceived challenging within pre-materials (Akçayır, & Akçayır, 2018). According to Cheng, et al. (2022) the actively used methods during face-to-face meetings have been different problem solving and discussion activities, designed to promote higher order thinking. Along with pedagogy, the FC model is seen as an approach where technology is also in central position (Sointu et al., 2023). A key reason for this is the pre-material phase, that is usually conducted with videos and possible tasks, demanding the use of online environments. Along with the pre-material phase, technologies provide various applications and environments for supporting students' collaboration and working with the topic (Sointu et al., 2019). Altogether, the FC model with different phases provides a well working approach for providing pre-service teachers with pedagogically sound ways of learning with technology i.e., to support the development of their TPACK.

From the perspective of STEM education, the flipped learning model seems a well-suited teaching method. A meta-analysis of 225 studies conducted by Freeman et al. (2014) arrived at the conclusion that incorporating active learning elements in STEM sciences increased students' examination performance on the topics covered in active learning sections. This would suggest that a flipped classroom model incorporating active learning sequences such as practical work, group work and discussions should increase student performance during course and improve learning outcomes (Yan et al. 2024). In a second meta-analysis of 53 studies conducted about flipped classroom or flipped learning model in STEM education setting Gong, Cai & Cheng (2024) found out that overall flipped classroom model yielded better student performance than traditional teaching in the higher education setting. Out of the 53 studies analyzed by Gong et al. (2024) only 17 studies had statistically significant effect sizes in favor of the flipped classroom model, while another 27 studies showed some modest gains. So, while the result of flipped classroom model might not yield great results in all the contexts, generally it should be beneficial for student learning in STEM context.

From the perspective of technology, the flipped learning model is a well-suited method for technology integration (Sointu et al. 2023). A meta-analysis conducted by Chai (2019) found out that typically professional development programs in the STEM context have three essential roles for computer-based technology: using technology as subject matter-specific tool, technology as a learning tool and technology as general information and communication tool to sustain communities of practice. According to Chai (2019) the

TPACK framework is especially well suited for STEM education as it requires teachers to combine aspects of content knowledge, technology and pedagogy while designing tasks that enable design thinking for the students.

3. Methodology and context

This research was conducted at Birzeit University in Palestine. The research emerged from within a Palestinian-Finnish collaboration project titled OLIVE: TEACHER EDUCATION WITHOUT WALLS, focused on creating new online learning environments and developing pedagogical approaches. The aim of this research is to explore how a jointly developed flipped science education course incorporating STEM activities and online learning materials was: first, perceived by pre-service science teachers and second, supported their readiness to use pedagogical practices and technologies aligning with the expectations related to 21st century skills. The core assumption aligns with the SQD strategies introduced by Tondeur et al. (2012), emphasizing especially the authentic experiences with technology, teacher trainers' position as a role model of technology use, instructional design and reflection. To understand pre-service teachers' perceptions and the effects of the course for the development of pre-service teachers' readiness to integrate digital technology the research questions are:

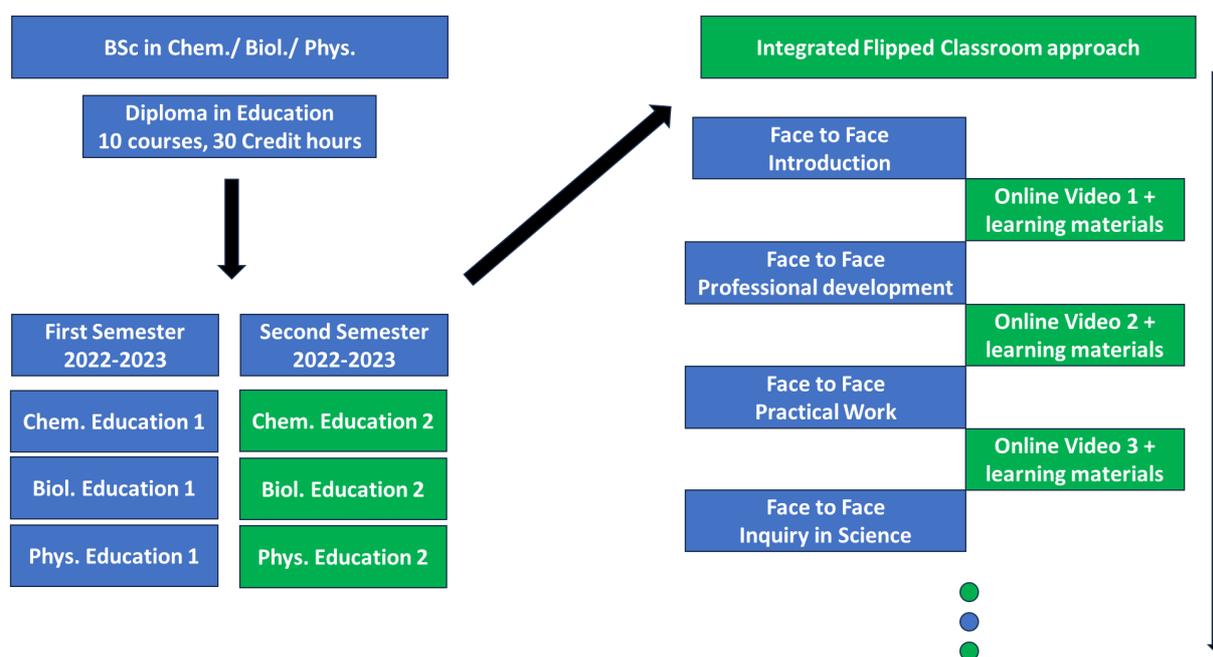
RQ1: How pre-service teachers perceived the newly flipped science education course?

RQ2: How did pre-service teachers' lesson plans change after the course in respect to pedagogy, technology use and content knowledge?

Pre-service teacher education is offered by the faculty of education at the different universities in Palestine. This includes two options for those who are aiming to teach science in elementary level schools, the first option is to join a bachelor's program in science education, while the second is to earn a bachelor's degree in chemistry, Biology, or Physics and in parallel (usually the last 3rd or 4th year) get a diploma in the subject education according to their specialization. The context of this study was a science education course at Birzeit University during spring 2023. The topics of the course combine physics, chemistry, and biology education. Those topics were dealt with from the perspectives of pedagogy and digital technologies, trying to build the pre-service teachers' STEM related TPACK. The course consisted of 15 sessions, three hours each. The design of the course was conducted in collaboration between experts from Palestine and Finland. Within this case the flipped learning model consisted of pre-materials presented to students (pre-service science teachers) in a video format. The videos were typically short clips from 10 to 20 minutes each. The aim of the videos was to provide all participants with more or less the same level of background knowledge about the topics to be studied during the face-to-face classes, so that students can collaborate and further elaborate their understanding. Also, the face-to-face classes provide an opportunity to ask questions and

inquire in practical activities on the most challenging topics (Sointu et al., 2023). In order to highlight pre-service teachers' thinking, their STEM TPACK, the participants wrote a lesson plan at the beginning of the course and at the end of the course. These tasks were part of the course, aimed at supporting participants' reflection, about how they see the roles of pedagogy and digital technologies within the STEM context.

Figure 2. Structure of the flipped STEM course.



The target group of this study consists of 14 pre-service teachers who participated in the course. Participants were well informed about this research. The aims and ways of analyzing the data were explained to the students, the participation was voluntary. The data collection methods were designed to support the learning goals of the course and posed no extra workload to the students.

In order to answer the research questions, we adopted a case study design incorporating mixed-methods approach (Ivankova, & Creswell, 2009), integrating qualitative and quantitative data collection techniques. The aim of using both qualitative and quantitative data sets was to gain a more comprehensive understanding about how participating pre-service teachers perceived the flipped science education course. The first data set contain quantitative measures targeting participants' evaluation of the course (RQ1). For this purpose, before the final course exam, the students evaluated the course they had been taking through using a 15-item standardized evaluation instrument that used a 5-point Likert-scale. This instrument has been used for evaluating courses within Birzeit University. In order to indicate possible changes between the newly designed flipped classroom course with previous courses, the pre-service teachers' course evaluations were compared to the previous ones regarding the same course. Yearly data sets were available from 2020 to 2023, but the year 2020 had different items than the others due to COVID-19 arrangements, so it had to be omitted. The instructor did not

change between the years 2020-2023. It was deemed sufficient that the previous years 2021 and 2022 were merged and used as a control group, since they showed no statistically significant differences between each other for any of the items. For the year 2023 the number of evaluations $N=11$, year 2022 $N=10$ and year 2021 $N=19$. The items in the course evaluation form are presented in table 3.

Since the number of yearly student evaluations of the course are both low and skewed towards one end of the scale, the normality of the distribution was assessed for each item through Shapiro-Wilk test. The test indicated a violation of normality for the grades ($p < 0.05$) for each item. Due to this the non-parametric Mann-Whitney U test was used to compare the items between the two groups to see if a significant difference could be seen in any of the items (Metsämuuronen, 2005). The significance level was set at $p \leq 0.05$ and assessed through exact p-value due to the limited sample size (Metsämuuronen, 2005). Rank bivariate correlations were calculated through Wendt's formula (Wendt, 1972) to assess the effect sizes for each item.

Table 3. List of items presented to the students in the course evaluation form.

Order	Item
1	Based on what I learned, this course was:
2	The organization (structure and content) of the course is:
3	I consider the assessments and exams were diverse and comprehensive and covered the course contents:
4	The availability of the resources (files, presentations, videos, ...) on course e-platform was:
5	The materials used covered the objectives of the course as described in the course syllabus:
6	The lecturers' pedagogical methods were:
7	The lecturers' knowledge of the subject was:
8	The quality of lecturers' preparation for his lectures and activities was:
9	The ability of the lecturer to sustain and develop my interest in the subject was:
10	I found the relations between the lecturer and the students to be:
11	I found the lecturer to be fair in evaluating and grading the students:
12	The lecturer provided timely feedback on students' tasks:
13	Overall, this course was:
14	I feel that I benefited from the lecturer's instruction in this course:
15	If I was given the opportunity, I would study another course with this lecturer:

The second data set consist of the pre- and after the course lesson plans written by the pre-service teachers. Lesson plans written by teachers or pre-service teachers has been actively used within the TPACK research, in order to gain insight into the target groups understanding is related to the use of digital technologies (Canbazoglu Bilici et al., 2016; Valtonen et al., 2020). These lesson plans targeted the second research question. The pre-

and post-course lesson plans were analyzed using qualitative content analysis, especially deductive approach (Elo & Kyngäs, 2008). The aim of the deductive approach is that the categorization of the data is based on some existing theoretical framework, in this case TPACK framework. The TPACK framework with seven different areas of knowledge is a challenging framework for the analysis i.e., the boundaries of different areas can be little fuzzy (Cox, & Graham, 2009). Within quantitative data the separation of separate statements aligning with seven areas using factor analysis, becomes difficult (Valtonen et al. 2015). Similarly, with coding different qualitative data sets, making the difference between for example pedagogical knowledge and pedagogical content knowledge, the challenge is considerable. For this reason, we reduced the number of TPACK categories used for categorization and only focused on the core TPACK areas i.e., Pedagogical knowledge, Technological knowledge and Content knowledge within the context of STEM education. This analysis ended with three main themes related to the changes within pre- and post-lesson plans.

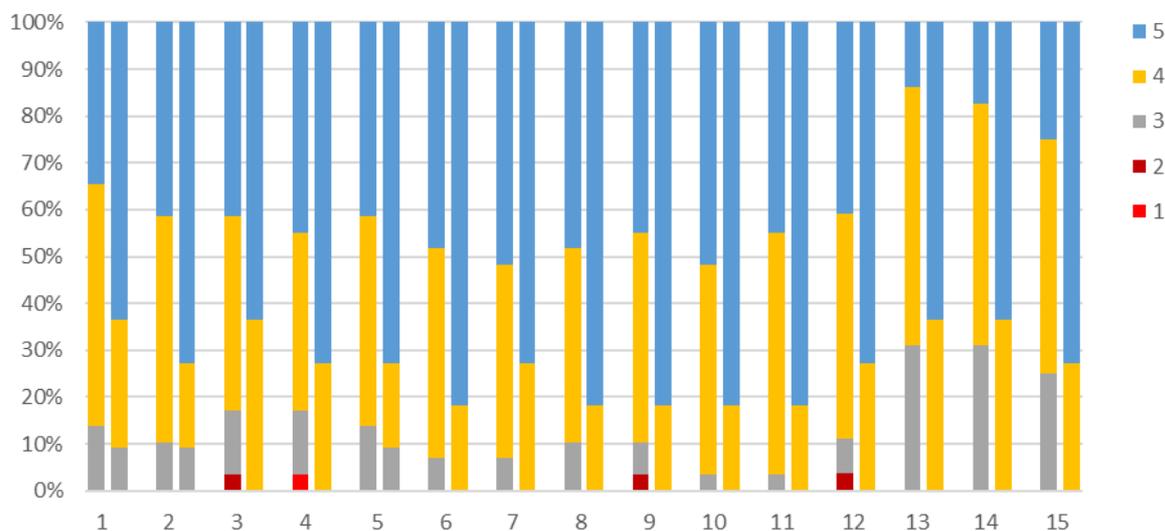
4 Results

Within the results section we outline the main findings answering the research questions. The aim is that first the quantitative findings will provide us with a general level understanding of how pre-service science teachers experienced the newly designed course. After this the results from the qualitative data will be outlined, aiming to provide insights into changes within developed lesson plans from the perspective of TPACK.

4.1 Experiences from the course - quantitative data

Looking at figure 3, results revealed more positive evaluations from students' perspectives to all aspects covered by the items in the evaluation instrument compared to the previous two years. Those aspects included course organization, structure, content, assessment, availability of resources and lecturer knowledge, fairness and pedagogical methods.

Figure 3. Evaluation distributions for the control and test groups to items 1-15 in the evaluation form. For each cluster the left bar represents the control group, and the right bar represents the test group. In the chart 1 represents the most negative evaluation and 5 represents the most positive one.



From table 4 we can see that there is a statistically significant difference in the responses to items 13–15 between the control group of previous two years and the test group. Since the means for those items are also higher than in the control group, this indicates that generally students responded more positively to the items. Regarding item 13, where response options ranged from very unsatisfactory to very satisfactory, the students felt more satisfied overall with the course.

Finding that there was a statistically significant difference in item 14 indicates that the students felt they benefitted more from the same lecturer in the flipped classroom model, where same topics were provided with revised learning materials and pedagogical approaches. Finally, the responses to item 15 show that the students would be more interested in taking other courses with the lecturer.

The rank-bivariate correlation effect sizes suggest that items 13–15 all have strong effects and indicate meaningful correlation within the data. While items 4, 6 and 8–12 didn't show statistically significant differences between the groups, a moderate rank bivariate correlation effect was present in these items.

Table 4. Control group and the test group as evaluated in the course evaluation form by the students. Statistical difference was evaluated with Mann-Whitney U-test and effect size by Wendt's formula for rank-biserial correlation.

Item	Control 2021 & 2022 (N=29)			Test 2023 (N=11)	
	Group	Mean	Std	Exact p-value	Effect size
1	Control	4.207	0.663	0.175	0.282
	Test	4.545	0.656		
2	Control	4.310	0.660	0.166	0.288
	Test	4.636	0.643		
3	Control	4.207	0.819	0.175	0.285
	Test	4.636	0.481		
4	Control	4.207	0.940	0.116	0.326
	Test	4.727	0.445		
5	Control	4.276	0.702	0.157	0.298
	Test	4.636	0.643		
6	Control	4.414	0.628	0.096	0.348
	Test	4.818	0.386		
7	Control	4.448	0.632	0.280	0.229
	Test	4.727	0.445		
8	Control	4.379	0.677	0.090	0.354
	Test	4.818	0.386		
9	Control	4.310	0.761	0.060	0.389
	Test	4.818	0.386		
10	Control	4.483	0.574	0.139	0.307
	Test	4.818	0.386		
11	Control	4.414	0.568	0.069	0.376
	Test	4.818	0.386		
12	Control	4.259	0.764	0.095	0.350
	Test	4.727	0.445		
13	Control	3.828	0.658	0.002*	0.611
	Test	4.636	0.481		
14	Control	3.862	0.693	0.004*	0.577
	Test	4.636	0.481		
15	Control	4.000	0.720	0.008*	0.545
	Test	4.727	0.445		

* Significant difference

4.2 Experiences from the course - qualitative data

In order to indicate the changes within students' readiness to use digital technology in pedagogically meaningful ways, we outlined the results from the qualitative data i.e., the pre and post course lesson plans. The results targeted the lesson plans from the perspectives of Pedagogical knowledge, Technological knowledge and Content knowledge. The focus is on the changes, how the post-course lesson plan differs from the pre-course lesson plan and on general considerations about pre-service teachers TPACK after the course.

The post-course plans revealed mainly deeper contemplation of the study module. In several plans, a more diverse spectrum of pedagogical approaches has been considered in greater detail, and the objectives of the methods have been examined more clearly. Similar reflection is evident in some of the plans also from the perspective of technologies. From the technological standpoint, this partly targeted the added value that different technologies may bring in relation to specific pedagogical methods or particular content themes. This phenomenon, the deeper consideration of pedagogical and technological themes, can be seen as a central aspect from the TPACK perspective. The model emphasizes the importance of the cut points, the evaluation of intersecting themes across different areas, and how different areas can support each other in ways that best enhance learning.

Pre-course:

“... students listen to their colleagues' heartbeat and explain the sounds they heard, use a short video to explain the mechanism of heartbeat, teacher explain and discuss using heart model, one student is asked to identify parts of the heart on a model ...”

After-course:

“...using short explanatory videos to explain mechanism of heartbeats and various electrocardiograms readings, starting the lesson with brainstorming, asking questions during watching videos, asking students to write notes, students listen to a colleagues' heartbeat, interpret the sounds, and distinguish between long and short heart sounds, demonstrate placing the stethoscope on the left side of the chest area, then students will practice ...”

From the perspective of pedagogical knowledge, the post-course plans revealed typically stronger emphasis on describing pedagogy, especially compared to describing the content knowledge areas. The plans more effectively outlined the pedagogical objectives from the perspective of students' role, from their learning activities. From the standpoint of pedagogical knowledge, key changes include stronger emphasis on more collaborative and self-directed learning methods. After the course, plans highlighted collaborative work at a general level and also in a more detailed manner, using learning activities like discussions, brainstorming, and real-life assignments. Also, it was typical to build courses

and lessons on experiments in laboratory conditions emphasizing the hands-on activities. Moreover, the use of many different types of pedagogical methods was evident in most of the after the course plans, ranging from lecture-based teaching to units built upon students' own active work. Also, gamification was mentioned as one of the many pedagogical methods used. Still, what is interesting, is that actual flipped learning approaches were not mentioned. The data samples following are from the after-course plans.

"Students discuss the concept of chemical reaction based on their understanding by pre-provided video link and engage then in group discussions to confirm answers"

"The teacher distributes materials and equipment to students divided into groups to conduct an activity related to substitution and decomposition reactions"

"Upon completion of the experiment, each group presents the results of the reaction and analyzes them."

From the perspective of technologies used there was more variation within the after the course lesson plans, before and after the course. Within some lesson plans technologies were not mentioned at all. Again, at the other end, the technologies and purposes for their use were mentioned in detail. Altogether, in the after the course lesson plans, where technologies were mentioned, the use of them was better opened and justified. Most often mentioned forms of technology was video. Aligning with the flipped learning approach videos in different formats were provided for students to familiarize themselves with different contents and for demonstrations. For this purpose, YouTube was often mentioned. Along with videos the everyday software, such as Google Drive, PowerPoint and Excell were typically mentioned. Similarly, the Kahoot application was mentioned as a way to launch conversation during classes. The role of more special technologies for content specific purposes remained in minor role. Only the Vite program for writing chemical equations was mentioned. Even though the technologies were better highlighted within the after the course plans, still the use of technology remained in rather modest role. The more innovative approaches for using technology were missing. The data samples following are from the after-course plans.

"... the teacher explains the thermochemical equation game. She gives a simple introduction on the thermochemical equation before starting to play. Then asked them to enter the flashcards section and do training on how to use the game. Students use their personal devices to play the game and solve the challenge individually. Through this, the teacher examines the students' understanding of the concepts"

..."teacher divides students into groups to conduct an experiment, use excel to graph the relationship between force and acceleration, then, through dialogue and discussion, students analyze the experiment results and graphical representation, leading to a practical deduction of Newton's second law."

"Utilizes Excel software and video presentations for data analysis and visualization, Writing Newton's second law and solving textbook examples, along with providing enrichment examples. Presenting videos that include real-life examples to illustrate applications of Newton's second law."

The areas from the content knowledge varied from ionic and covalent bonds and forms of energy to the structure of heart, indicating a vast variety of STEM contents. The content remained the same within the pre- and after the course lesson plans. Compared to the pedagogical knowledge and technological knowledge the changes were minor with the content knowledge area. The changes were mainly in how deeply the contents taught were outlined. Also, within some post-course lesson plans the topic was covered in larger number of details providing more rich content. The content knowledge area showed also within learning materials. within these cases the nature and role of learning materials for certain contents were better outlined. Still, this area combines the areas of pedagogy and technology, indicating the challenging nature of the TPACK framework.

"...classes go beyond the basics by including asking students to watch specific videos on sounds and electrical activity of the heart and allow them to discuss, practice tasks and answer questions related to it."

"...distributing students in groups, allowing them to observe videos on chemical bonding and draw atomic structures to form different kinds of compounds."

"...using PowerPoint presentations including photos of different forms of energy, allow students to perform different exothermic reactions and assess their learning using Kahoot application."

5 Discussion

This article focused on science education course conducted aligning with flipped learning approach within Palestinian teacher education context. The aim was to show the possibilities of supporting the development of pre-service teachers' abilities to integrate technology in pedagogically meaningful ways. The course design followed the strategies of the SQD framework (Tondeur et al. 2012), emphasizing the authentic experiences of learning with technology integrated in pedagogically meaningful ways, the role model of the teacher collaboration between students and also the designing of artefacts, in this case lesson plans. The results indicate that this approach was beneficial, the results were positive based on both the quantitative and qualitative findings.

As Harasim (2006) already suggested that more attention needs to be focused on collaborative knowledge building over the mere lecturing and broadcasting approach, these results go in this direction. The results based on quantitative data showed that the students (pre-service science teachers) find the pedagogical approaches used well working. These results are apparent from items especially covering the lecturer, pedagogical methods used, and the approaches used to support collaboration between peers. These results align with earlier studies on flipped learning approaches, as a way to emphasize collaborative and more hand on activities to meet the needs of the STEM education challenges (Freeman et al., 2014; Yan et al. 2024).

There can be seen improvements in the median scores to the item between the control and test groups, but due to ceiling effect, only the items, where the starting median was 4 or below, have yielded statistically significant differences between the two groups. Nevertheless, responses to item 13 show that the participating students felt overall more satisfied with the course implementation in the test group as opposed to the control group of the previous years. This highlights that the use of flipped classroom model responded effectively for the students' needs in the especially difficult teaching-learning environment of the West Bank, where the teachers and learners have had to shift between remote and blended learning.

As the responses to items 14 and 15 show that the students felt they benefitted and would be more willing to take further courses from the same lecturer. Since the same lecturer held all the versions of the course between 2021 and 2023, it can be inferred that the flipped classroom method is benefitting the learners by getting more out of the course. It should be noted that although the course also featured revised learning materials and videos prepared by the international team of experts, items 2 and 4 didn't yield statistically significant differences between control and test groups. This can be attributed to the fact that many of the materials were developed and presented to students in English which required more lecturer input and Arabic clarifications during the face-to-face meetings. Given the strong effect size and the fact that the sample size in the test group ($N=11$) is a quite large portion of the population ($N=14$), it would seem like these results could be applicable in a broader sample in a follow-up study.

The results highlighted that the lecturer has a better pedagogical method (item #6), content knowledge (item #7), preparation and learning activities (item #8), and managed to raise students' motivation (item #9). Those individual results were evaluated higher, but not statistically significant, although the overall impact was significant. This may be explained by the overlapping nature of the TPACK model, which reflects the collective effect of the different components combined together, rather than studying their effect separately.

The results based on qualitative data reflect pre-service teachers' abilities to more deeply elaborate the pedagogical and technological aspects within STEM context. From the perspective of the TPACK framework, the separate knowledge areas technology, pedagogy and content, gained more profound considerations. Still, the combining areas especially, the technological pedagogical knowledge, combining pedagogy and technology

showed more in more advanced manners. These positive results are rather similar with studies with different TPACK intervention during the teacher training (Lachner et al. 2021; Mouza et al. 2014). Previous studies, especially with self-assessments measures have indicated similar positive results within pre-service teachers' increased confidence towards technology integration. Within this study we were able to show these results as pre-service teachers' own words, how they express their ideas for technology integration in pedagogically meaningful ways. The study by Valtonen et al. (2023) suggested that pre-service teachers typically grasp on the pedagogical aspects of the courses i.e., how the course was conducted and experiences from pedagogical perspective. We assume that within the context of STEM education and especially the flipped learning model with pre-materials the benefits came from the use of pre-materials. Students came to the face-to-face sessions better prepared and thus had more time for practical work.

Conclusions

Education in Palestine continues as a challenging task. During recent years' efforts for developing teaching and learning practices towards more collaborative direction have been made in general and in science teachers' education in particular (Fragkaki, et. al. 2015; Itmazi & Khlaif, 2022). The results from this study continue this challenging developing work with rather positive results. We assume that the highly positive results from the quantitative data reflect participating pre-service teachers' overall experiences of the course, especially their active role participating in hands-on collaborative activities. These positive experiences can be seen as a key event for triggering also the changes and development shown in the qualitative results. Altogether, the change from following the broadcast to constructing new understanding (see. Harasim, 2006), can be seen as a big step, providing authentic and inspiring experiences for developing pre-service teachers TPACK within STEM context.

This article continued a long tradition of research aimed at developing teacher education practices from a pedagogical and technological perspective (see. Tondeur et al. 2012). The theoretical models used, the TPACK, SQD and Flipped learning approach, which form the background to the research, served well as a starting point in this challenging development work within the STEM context. The small size of the target group was a challenge for this work. However, this must be accepted as the status quo and the results have to be considered in this context. However, when reflecting the success of the development work, the comparison of quantitative results with previous years (Cam et al., 2022) provides credibility in terms of the decisions made during the development work. For the future, it is essential to continue with similar pilots and to give a strong voice to the pre-service teachers involved. Especially in the context of the Middle East, implementing change requires attention to existing practices, as updated practices can be substantial development in comparison to existing practices. To overcome these

challenges, qualitative methods for consulting different actors will provide valuable insights to support the development of teacher education in STEM context.

Research ethics

Author contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements following the [CrediT taxonomy](#) must be used. For example:

“A.A.: conceptualization, investigation, methodology, project administration, data collection, validation, visualization, writing—original draft preparation, writing—review and editing, funding acquisition.

J.Ki.: conceptualization, investigation, methodology, project administration, validation, visualization, writing—original draft preparation, writing—review and editing.

J.Ko.: conceptualization, investigation, methodology.

M.A.: conceptualization, methodology, project administration, review and editing, funding acquisition.

E.A.: data collection and analysis, writing qualitative results summaries, review.

T.V.: conceptualization, investigation, methodology, project administration, validation, visualization, writing—original draft preparation, writing—review and editing, funding acquisition.

All authors have read and agreed to the published version of the manuscript.”

Artificial intelligence

GPT was used for language editing purposes.

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Informed consent statement

We have received informed consent from all participants before starting the research.

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Conflicts of Interest

The authors declare no conflicts of interest.

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