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In-service teachers' TPACK development through an adaptive e-learning environment (ALE)

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Abstract
Due to the effects of the COVID-19 crisis on educational institutions, schools had to close and switch to online education. Training in-service teachers to incorporate and utilize technology as part of Internet-based instructions was a challenge and pressing necessity. TPACK is an essential framework for comprehending how teachers employ technology in teaching. Despite the significance of adaptive learning environments in recent years, research has not addressed how to use these environments to improve the TPACK of in-service teachers, particularly during crises. Consequently, our objective was to design an adaptive learning environment that provides in-service math, science, and English teachers with substantial and continuing support for each TPACK component. A total of 173 in-service teachers were divided into two groups: an experimental group of 83 who used adaptive learning and a control group of 90 who used Zoom techniques. TPACK questionnaires were administered before and after the experiment. The experimental group improved TPACK more than the control group. All teachers believed that adaptive learning training helped them to build technology-integrated lesson plans. This study provides ideas and practices for developing an adaptive learning environment for the in-service teachers' TPACK development. The challenges to adaptive learning environments have been highlighted, identifying the potential for future investigations.

Keywords Distance education and online learning · Improving classroom teaching · Teacher professional development · Teaching/learning strategies · 21st-century abilities

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1 Introduction

Throughout history, human disasters and epidemics have prompted people to reassess their established techniques and embrace new ones (Cahapay, 2020). The World Health Organization declared the COVID-19 outbreak to be a public health emergency on January 30, 2020 (World Health Organization, 2020). According to a recent UNESCO report, nearly 143 countries were forced to close their schools worldwide, resulting in the disruption of learning and education for an estimated 1.2 billion pupils (UNESCO, 2020). The search for an alternative to conventional classes is a huge task since face-to-face education has also become nearly impossible (Bryson & Andres, 2020).

After some time away from conventional teaching, educational institutions all over the globe are working to better manage their students' curricula and develop tactics that are more sensitive to their needs as a consequence of their reliance on technology and the Internet. Included in this is teaching the use of technology (Adipat, 2021). In light of the complex and multifaceted challenge of moving to online learning in Saudi Arabia's public schools (Arasaratnam-Smith & Northcote, 2017), there is a pressing need for innovative solutions to improve the educational endeavors, expand participation, and further access to distance education in public schools in the Kingdom of Saudi Arabia.

Information and Communications Technology (ICT) consists of a biological infrastructure for governments that want to maintain regular education activities during the pandemic (Almarzooq et al., 2020). One of the primary motivations for moving the provision of instruction to the Internet was to ensure that the students could continue their education at their own pace (Badiozaman et al., 2020). This has led to the creation of creative learning and communication platforms that have changed the teaching and learning scene of specialties and institutions that were once thought to be solely a physical environment (Turnbull et al., 2021).

Through the methods of communication between students and teachers, this integration enhances learning and deepens the relationship between students and teachers (Ponce Gea et al., 2021). The teacher's digital efficiency is thus essential for mastering and integrating information and communication technology in learning and education (Hatlevik et al., 2018). One of their objectives is to ensure that curricula, their applicability, and their reaction to catastrophes, epidemics, and crises remain relevant in the future (Adipat, 2021). The bottom line is that improving the teachers' knowledge and skills in relation to educational materials, technology, and pedagogy are essential if the students are to get an effective education (Basilaia & Kvavadze, 2020).

Several studies have shown that: (1) good training leads to individual learning (Knight et al., 2007; Steinert et al., 2016) and (2) individuals who study online require extensive and constant assistance (Riedinger & Rosenberg, 2006; Shelton, 2011). Although it is commonly thought that training programs will have long-term impacts, rigorous assessment studies are required to establish whether this is accurate (Brinkley-Etzkorn, 2018).

The Technological Pedagogical Content Knowledge (TPACK) framework is gaining popularity among both researchers and scholars (Mishra & Koehler, 2006). It has been shown that there are strategies to improve and build TPACK for teachers through research (Karchmer-Klein & Konishi, 2021). The first step is to have a better understanding of how the model components and teachers' self-efficacy are intertwined (Joo et al., 2018). It is also important to appreciate the value and usefulness of technology in increasing student learning. According to research, TPACK development is possible when teachers are trained and prepared in a comprehensive program that enhances technology-integrated lesson planning (Shinas et al., 2015).

There are many ways to help teachers do their jobs better but Pea and Wojnowski (2014) state that the success of these methods depends on how well they meet the specific training needs and preferences of teachers in different educational settings. A novel software-based computer-adaptive personalization method was used for the creation of TPACK (Harris, 2016).

When it comes to educational technology, adaptive learning has taken center stage in the last several years (Yang et al., 2013). This is even though just a few teachers are making use of adaptive learning environments to raise their level of TPACK proficiency. Only a small amount of research has examined its efficacy (Murray & Pérez, 2015). Adaptive learning is more successful since the course material is tailored to each learner's specific needs and learning style (Chen, 2014). To increase the quality of online learning, the Adaptive e-Learning Environment (ALE) is a customizable environment that may adjust to the learner's requirements, preferences, and learning style (Kolekar et al., 2017; Oxman et al., 2014). Before or during course delivery, such as an online exam, the interactive e-learning environment has to be evaluated, such as by monitoring the learner responses (DeCapua & Marshall, 2015).

Despite the relatively recent use of adaptive learning environments (ALE) in the professional development of teachers, this study sheds a light on it in comparison to the traditional methods of teacher professional development. This frequently fails in regard to the educational thinking and practice of enhanced ICTs (Timotheou et al., 2017). To summarize, we see an enormous value in putting this technology to use, and the data from the existing studies suggest that teachers may benefit from ongoing professional development to help make this technology a part of everyday classroom life (Kopcha, 2012) (see Fig. 1).

The development of TPACK among in-service teachers is the focus of this study which tries to determine the effect of an adaptive learning system. The research discusses the implementation of an adaptive e-course using the Classera system which gives in-service teachers control over their training on how to use technology in their teaching themes. This research aims to add to the literature on adaptive learning and the teachers' professional development. The following question will be addressed in this research project: 'Is there a significant difference between the mean scores in the TPACK questionnaire of in-service teachers who used the adaptive learning system and the mean scores of in-service teachers who used the conventional technique (ZOOM)'?

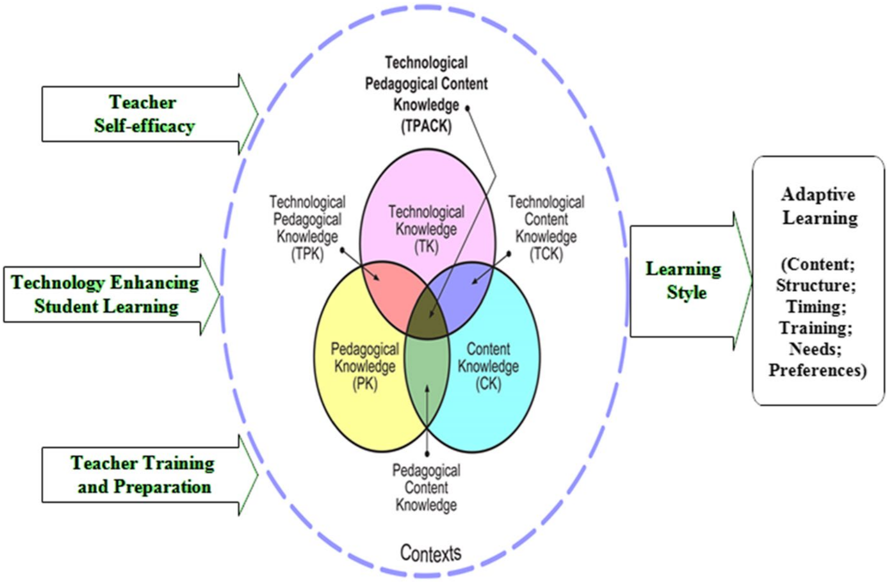

Fig. 1 TPACK framework in an adaptive learning environment (ALE)

2 Literature review

2.1 In-service teachers' TPACK development

The ICT curriculum in teacher education programs is based on Shulman's (1986) work and the notion specialized of Pedagogical Content Knowledge (PCK). TPACK has been used as a theoretical foundation for organizing the ICT curriculum in teacher education programs (Chai et al., 2011). There is an acronym, TPACK, which stands for teaching and learning through the integration of technology in the classroom. This was first proposed by Mishra and Koehler (2006). It is a Venn diagram with three overlapping circles that depicts how teachers can use ICT tools in the classroom. TPACK is a framework for understanding how technology may be used to teach the material to individual learners in specific circumstances to enhance the student learning outcomes (Angeli et al., 2015).

Technology, pedagogy, and content interact in the TPACK framework (Mishra & Koehler, 2006). The interaction of these three knowledge types is an intuitive understanding of the teaching subject using suitable pedagogical tools and methodologies (Adipat, 2021). Pedagogical knowledge (PK), content knowledge (CK), and technology knowledge (TK) are the three main areas of knowledge in the TPACK diagram. Seven components (see Fig. 1) are included in the TPACK framework. They are defined as:

1. **Technology knowledge (TK):** knowledge of numerous technologies, from pencil and paper to the Internet, digital video, interactive whiteboards, and software applications.
2. **Content knowledge (CK):** is the "knowledge about actual subject matter that is to be learned or taught" (Mishra & Koehler, 2006, p. 1026). Teachers must understand their curriculum and how the knowledge differs by subject.
3. **Pedagogical knowledge (PK):** covers the understanding of the teaching methods, assessment, lesson plan construction, and student learning.
4. **Pedagogical content knowledge (PCK):** subject knowledge related to teaching (Shulman, 1986). For each curriculum area, pedagogical content knowledge integrates content and pedagogy to improve the teaching practices.
5. **Technological content knowledge (TCK):** understanding how technology can develop new representations or specific content. It implies that teachers realize that adopting a specific technology can have an impact on how students practice and grasp concepts in a specific content area.
6. **Technological pedagogical knowledge (TPK):** understanding how various technologies can be used in education and how technology may influence how teachers teach.
7. **Technological pedagogical content knowledge (TPACK):** helps teachers integrate technology into any subject. By teaching content using appropriate pedagogical methods and technologies, teachers intuitively understand the intricate interactions between the three basic components of knowledge (CK, PK, TK).

The main goal of TPACK is to educate pre-service teachers on how to effectively use technology in a variety of educational settings such as face-to-face instruction, blended learning, online learning, and homeschooling, as well as other types of education (McGarr & McDonagh, 2019). The professional development of teachers is most successful when it is active, sustained, job-related, and focused on the curriculum of their students, according to Harris (2016). This model gives teachers an excellent foundation for their professional development (Niess, 2011). It does this by using the TPACK framework to get teachers involved in meaningfully integrating technology into a wide range of learning areas.

Given the growing body of evidence showing the importance of contextualizing and personalizing teacher training programs to meet the specific needs of their participants (Kopcha, 2012), an adaptive and interactive e-learning system called e-TPACK is an absolute necessity for improving teachers' proficiency in TPACK (Angeli et al., 2015). Professional development in the field might benefit greatly from the e-instructional TPACK's design methodology (Timotheou et al., 2017). On the Internet, the process of adapting to different learning contexts is based on a series of well-planned activities. It is the goal of the adaptive learning environment framework to bring together the educational framework developed inside these settings and the demands of the students (El-Sabagh, 2021) (see Fig. 2).

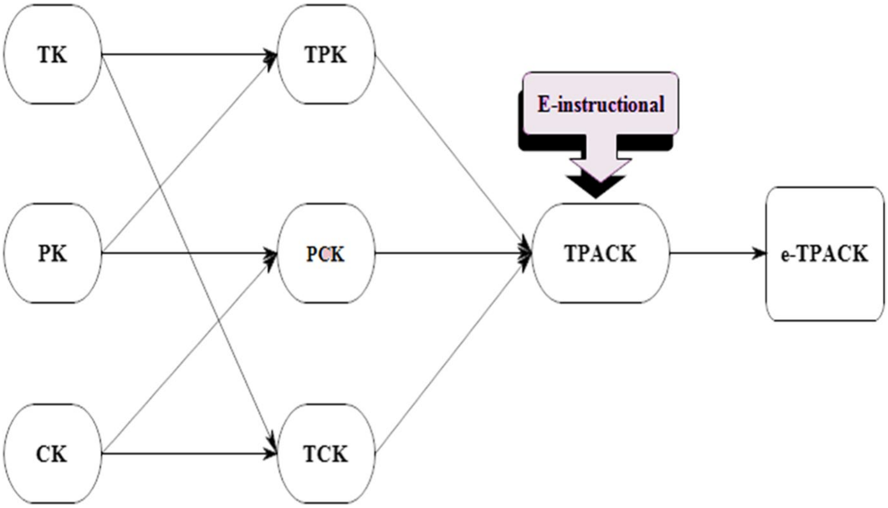

Fig. 2 Complex unity of all TPACK components in an E-instructional environment

2.2 Adaptive learning environments (ALE) and TPACK development

Many studies have looked at the impact of variations between individuals on learning outcomes to tailor education to meet the needs of each person. As a result, new methods have evolved that call for the creation of personalized or adaptive learning environments and systems tailored to the specific needs of these individuals (Chou et al., 2015; Dolenc & Aberšek, 2015). Adaptive education is often defined as "the use of various instructional methodologies and school resources to deliver learning experiences that match the diverse requirements of individual students" (Wang & Walberg, 1983, p. 603).

When compared to traditional classroom instruction, traditional web-based educational systems still have some drawbacks such as a lack of contextual and adaptable assistance (Chrysafiadi & Virvou, 2013). Because adaptive learning technologies allow for the customization of learning opportunities for students, online learning environments provide more options and chances for learning than conventional classroom settings (Albatayneh et al., 2018; Truong, 2016).

The amount of research examining adaptive e-learning has risen steadily in the last few years. All levels of education are seeing a rapid rise in the prevalence of this practice (Oxman et al., 2014). Adaptive learning environments have been established by Angeli et al. (2015), specifically a set of courses and curricula suited for both the instructor and the student. Angeli et al. (2015) found that being able to guide the learner based on their answers helps them learn to control their learning.

According to Caliskan and Bicen (2016), the Moodle learning management system provides options for autonomous learning in a more flexible location and time with a clearer, more thorough and systematic approach to the exciting learning resources on the market. According to the findings of Ifinedo et al.'s (2018) research, the TPACK-based learning management system has helped students meet their learning goals and improved their level of concept mastery in comparison to the control group.

An online adaptive learning environment for teaching both students and teachers that utilizes geospatial technologies, GeoThentic includes a three-part teacher interface that analyses teacher-reported, program-assessed, and user-path data to produce TPACK professional learning profiles and recommended emphases for further development (Doering et al., 2009).

Nurdiani et al. (2019) compared two classes, one of which used a learning management system (LMS) to upload video explanations of embryology concepts and the other that did not. They found no difference between the two classes. With these findings in mind, it may be inferred that the role of the instructor in learning achievements can be reduced by using Moodle, an online learning management system (LMS). This also shows how well the interactive multimedia (IM) made for this research represents the educational content in the field of embryology.

Because adaptive learning environments aim to provide and deliver learning elements tailored to the needs and behaviors of learners (Pliakos et al., 2019) as well as enhancing learning and progression by providing more personalized learning units, the goal is to provide and deliver learning elements tailored to the needs and behaviors of the learners (Zhang & Chang, 2016). As part of the adaptive learning environment, each student has a virtual teacher. This is because Woolf (2010) found that "one teacher to one student" is the best way to learn.

Learning deficits may emerge in adaptive learning settings because students have diverse demands and learning characteristics (Lo et al., 2012). Adaptive systems, according to Boticario et al. (2005), must be capable of managing personalized learning paths for each user, monitoring and interpreting the user activities using specific models, and inferring the needs and preferences of the users to dynamically facilitate learning. Furthermore, an adaptive educational system must be able to accommodate individual learning preferences.

Adaptive systems may help students avoid cognitive overload and stress by recommending suitable learning resources and guiding them through the learning process, considering unique the student preferences. The system has to understand the student's personality traits to be effective (Vogel-Walcutt et al., 2011).

3 Methods

3.1 Participants

Five schools in Riyadh, Saudi Arabia's capital, were chosen for the experiment to ensure that the protocols were followed and that the findings were accurate. After receiving the required permits from the schools to conduct the experiment, the emails of every teacher in the schools was retrieved, and the English, math, and science teachers were singled out for further scrutiny. They were all checked. All teachers in the disciplines mentioned agreed to participate in the experiment which included a simplified description, its aim, and a check box for the chosen manner of engaging in the training, whether by picking the Zoom

Table 1 Demographic distribution of the participating teachers, specializations, and the training method used

Specialization	Training Method	Male	Female	Total
Science	Adaptive	13	12	25
	Traditional	19	11	30
Mathematics	Adaptive	15	10	25
	Traditional	12	12	24
English	Adaptive	18	15	33
	Traditional	22	14	36

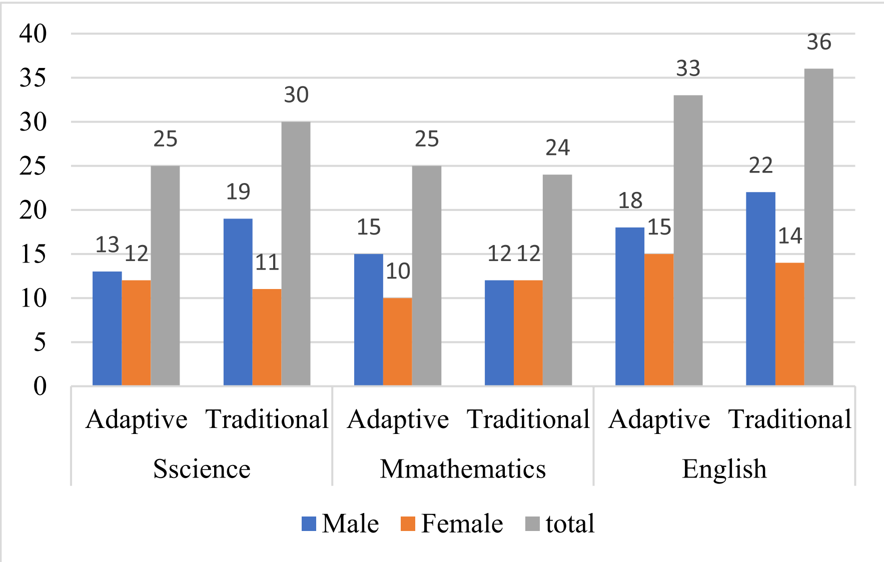

Fig. 3 Demographic distribution of the participating teachers, specializations, and the training method used

program or via the adaptive learning environment. For teachers to be able to take part in this program, they had to fill out a questionnaire before they could start training.

Note that during the COVID-19 pandemic, teachers were also using Classera as a distant learning management system. This is an important fact to keep in mind when designing an adaptive learning environment.

There were 215 emails sent to all primary school teachers who majored in science, math, or English. Of those, 173 asked to take part in the training, 90 asked for traditional training through the Zoom program, and 83 asked to take part in the adaptive learning environment (ALE).

Table 1 and Fig. 3 show the demographic distribution of the participating teachers, their specializations, and the training method used.

3.2 Study instrument

Considering the nature of our study, it was imperative that we selected and developed a study instrument that was both effective and appropriate. A variety of research and studies were examined, and the theoretical framework was analyzed. The TPACK framework's fundamental model was appropriately depended upon and studied (Mishra & Koehler, 2006). Following the review of a number of questionnaires, Hsu and Chen's (2019) questionnaire was followed to serve as the foundation upon which the questionnaire would be built. The reason for this is that the questionnaire is the one that corresponds most closely to the purpose of the study that is currently being conducted. Additionally, it presented us with terms and ideas that we may use to gauge the level of TPACK use by in-service teachers. The researchers worked to increase the number of sections in the questionnaire from five to seven and the number of statements contained within each section in order to assess all aspects of the TPACK model. For instance, more emphasis was placed on technological knowledge than in the original questionnaire. As a result, more related responses were included in the final questionnaire. Our goal is to strengthen this area by making it more comprehensive and detailed in light of the recent COVID-19 pandemic and the importance placed on online education and other forms of technology and communication support.

In-depth conversations with subject-matter experts and classroom teachers using the video conferencing platform Zoom allowed us to refine the list of questions and ensure that they accurately reflect the domain of the study. The validity of the questionnaire content was verified by presenting it in its initial form to a number of specialists in the fields of educational technology, curricula, and teaching methods to ensure the clarity of the questionnaire instructions, the clarity of the wording of the phrases, the link of the phrase to the axis to which it belongs, the validity of the quinquennial assessment, the extent to which the item relates to the study's area of focus, and the addition, modification, or deletion of certain phrases. Based on the comments from the experts, some changes were made. Specifically, some phrases were omitted and others were added to ensure the validity and measurability of the questionnaire.

Using pilot research, 10 teachers completed the questionnaire on two separate occasions, four weeks apart, to test the questionnaire's dependability. The results were TK = 0.92; CK = 0.89; PK = 0.89; PCK = 0.91; TCK = 0.92; TPK = 0.88; and TPACK = 0.90. In addition, the item-total correlations and Cronbach's alpha internal consistency were computed where 0.70 is considered to be an appropriate Cronbach's alpha coefficient level for research questionnaires (Anastasi, 1982). The internal consistency of the scale is indicated by the Cronbach's alpha coefficients of the subscales, while the item-total correlations between the scale items are relatively strong. The survey meets both the discriminant and test–retest validity criteria.

All items in the exploratory factor analysis EFA had factor loadings of more than 0.48 which is higher than the cut-off value of 0.35, as suggested by Hair et al. (1998). The findings of the EFA indicate that the question items for each subscale accurately assess each variable. To summarize, the questionnaire's statistics show that it is ready and suited for implementation (see Table 2).

Table 2 TPACK questionnaire constructs, indicators, factor loadings, and Cronbach's alpha

TK (Technology Knowledge)		**Factor Loading**	**Cronbach's**
1–1	I can solve technical problems myself	0.56	0.92
1–2	I can learn new technology easily	0.74	
1–3	I follow modern technology	0.69	
1–4	I have the basic skills to deal with technology	0.82	
1–5	I can integrate technology into the teaching process	0.66	
1–6	I am able to merge technology with lesson planning	0.72	
1–7	The technology I use makes my students feel comfortable	0.81	
1–8	When I integrate technology into teaching, I feel that the students feel safe using technology	0.88	
1–9	I can make the students feel that using technology is beneficial not only for education	0.65	
1–10	I can make the students love using technology in teaching and learning	0.91	
1–11	I can motivate the students to use technology in different aspects of life	0.92	
1–12	I know the basic computer applications (e.g. Windows and Media Player) and their functions	0.91	
1–13	I can use the Office programs that I need in my work efficiently (such as Word, Excel, etc.)	0.88	
1–14	I can easily create presentations (e.g. PowerPoint and Prezi)	0.89	
1–15	I can create video clips using special software	0.68	
1–16	I can deal with the Internet and use search engines easily (such as Google and Firefox)	0.88	
1–17	I can share files with students online	0.92	
1–18	I can download or upload files from the Internet	0.93	
1–19	I can deal with YouTube and share video links with the students through it	0.85	
CK (Content Knowledge)		**Factor Loading**	**Cronbach's**
2–1	I have full knowledge of the content that I teach	0.88	0.91
2–2	I have many ways and strategies for presenting the material that I teach	0.85	
2–3	I can develop activities and projects in class	0.77	
2–4	I follow the continuous developments that are happening in my content area	0.75	
2–5	I regularly attend conferences and activities related to my content area	0.85	
PK (Pedagogical Knowledge)		**Factor Loading**	**Cronbach's**

Table 2 (continued)

3–1	I know how to determine the level of knowledge of the students in a class	0.85	0.88
3–2	I can modify my explanation based on the student's understanding or lack of understanding of the content presented to them	0.68	
3–3	I can adapt the teaching strategy based on the individual differences of the students	0.75	
3–4	I can vary the teaching methods that I use	0.65	
3–5	I have learnt how to organize and manage the class	0.78	
3–6	I can use the size and speed of the right methods to explain the form effectively	0.91	
3–7	I know when I can change my teaching method based on different situations and needs	0.85	
PCK (Pedagogical Content Knowledge)		**Factor Loading**	**Cronbach's**
4–1	I can ask the students the right questions at the right time	0.58	0.87
4–2	I know the concepts and theories behind the content that I will be teaching	0.88	
4–3	I know the theory of the basics regarding the content that I will be teaching	0.68	
4–4	I know the most appropriate teaching strategy for the lessons I will be explaining	0.78	
4–5	I know how to use older theme knowledge in a way that is understandable	0.92	
4–6	I can imagine knowledge by topic and convert it into content appropriate for education according to the aim of the course	0.88	
4–7	I can plan and design the course	0.78	
4–8	I can link the learning topic in my course to the rest of the other courses	0.69	
4–9	I can link what the students learn in the classroom with what they learn outside the classroom	0.87	
4–10	I can develop tests, evaluations, and polls for my area of content	0.87	
	TCK (Technological Content Knowledge)	**Factor Loading**	**Cronbach's**

Table 2 (continued)

5–1	I can choose the appropriate technological applications for the subjects I teach	0.87	0.89
5–2	I can combine more than one technology while presenting the scientific material to achieve the desired goals	0.68	
5–3	I can positively use technology to achieve the ability to understand and assimilate students	0.87	
5–4	I prepare the scientific material using computer applications (such as Word and PowerPoint)	0.92	
5–5	I use the Internet and social media to promote the content I show (such as YouTube and SlideShare)	0.78	
	TPK (Technological Pedagogical Knowledge)	**Factor Loading**	**Cronbach's**
6–1	I can use appropriate technology that helps me implement my teaching method or strategy	0.87	0.84
6–2	Use different computer applications to support the competition between students (e.g. KAHOOT)	0.74	
6–3	Use technology applications that enhance student participation during and after class	0.76	
	TPACK (Technological Pedagogical Content Knowledge)	**Factor Loading**	**Cronbach's**
7–1	Use techniques that improve the content, how it is conveyed, and what the students learn	0.85	0.86
7–2	Combine specialist content, techniques, and teaching strategies to create assessment activities	0.74	
7–3	I can help many other teachers combine appropriate content, teaching methods, and technology	0.90	

On the final form, the TPACK of the in-service teachers was assessed using a structured questionnaire consisting of 52 questions on a Likert scale (with 5 being highly agreed, 4 being agreeable, 3 being indifferent, 2 being disagreeable, and 1 being very disagreeable). There were seven areas in the questionnaire: (TK) Technology Knowledge (19), (CK) Content Knowledge (5), (PK) Pedagogical Knowledge (7), (PCK) Pedagogical Content Knowledge (10), (TCK) Technological Content Knowledge (5), (TPK) Technological Pedagogical Knowledge (3), and (TPACK) Technological Pedagogical Content Knowledge (3 items).

The online questionnaire's first page included a clear description of the study's goal, and all participants agreed to participate after reading and agreeing to this explanation. Once the participants gave their permission, the questionnaire was started. Our goal is to help teachers who are already teaching improve their TPACK by using an adaptive learning environment instead of the usual method.

A pre-and-post-TPACK questionnaire application was employed in a quasi-experimental manner. The results were compared. The TPACK of the teachers was assessed before and after the experiment. Pre- and post-measurements were used in this research to evaluate two training approaches: an adaptive learning environment and Zoom instructions, the latter of which is more often used in schools.

According to the pre-test findings, there were no statistically significant variations in the average scores of the two groups. The first semester of 2021 was used for the study experience, and all processes for training or contacting participants were done online since in person attendance was prohibited at this time due to the COVID-19 pandemic. We did the experiment, which took about a month and a half, near the end of the first semester.

Post-measurement was administered to all participants, both in the experimental and control groups, and all of the data acquired was analyzed. SPSS 22 was used to compare the means and standard deviations of the two groups as part of the descriptive quantitative analysis (Pallant, 2020).

3.3 Designing the course

The teaching methods and curricula for science, mathematics, and the English language will be developed by professors with extensive experience in these fields, all of whom hold academic positions at public universities. These professors also have extensive knowledge of the TPACK model and how it can be used to enhance student learning in the classroom. Six specialists in curriculum, teaching techniques, and educational technology reviewed the training courses and scientific material to verify that the information was accurate before it was made available online. After a few changes and additions, the learning materials were ready to be put into the adaptive learning environment.

The exploratory group was able to verify that the material and linkages were working properly using the Classera system. In this way, the course is ready for testing with the experimental group. The Classera system was chosen because it is the same method through which the teachers in the chosen schools taught students from afar when COVID-19 broke out and the schools were closed.

Design-based research was used to create ALE which attempts to improve and expand the teachers' TPACK by providing technology-enhanced scenario material. A diagram of the adaptive learning environment (ALE) is shown in Fig. 4. For teachers, each of these situations offers a roadmap for making instructional design choices about how to teach a certain subject using specific numerical resources (Angeli et al., 2015). The system is meant to let teachers set their goals, plan their participation, and choose which activities to start or finish. This helps

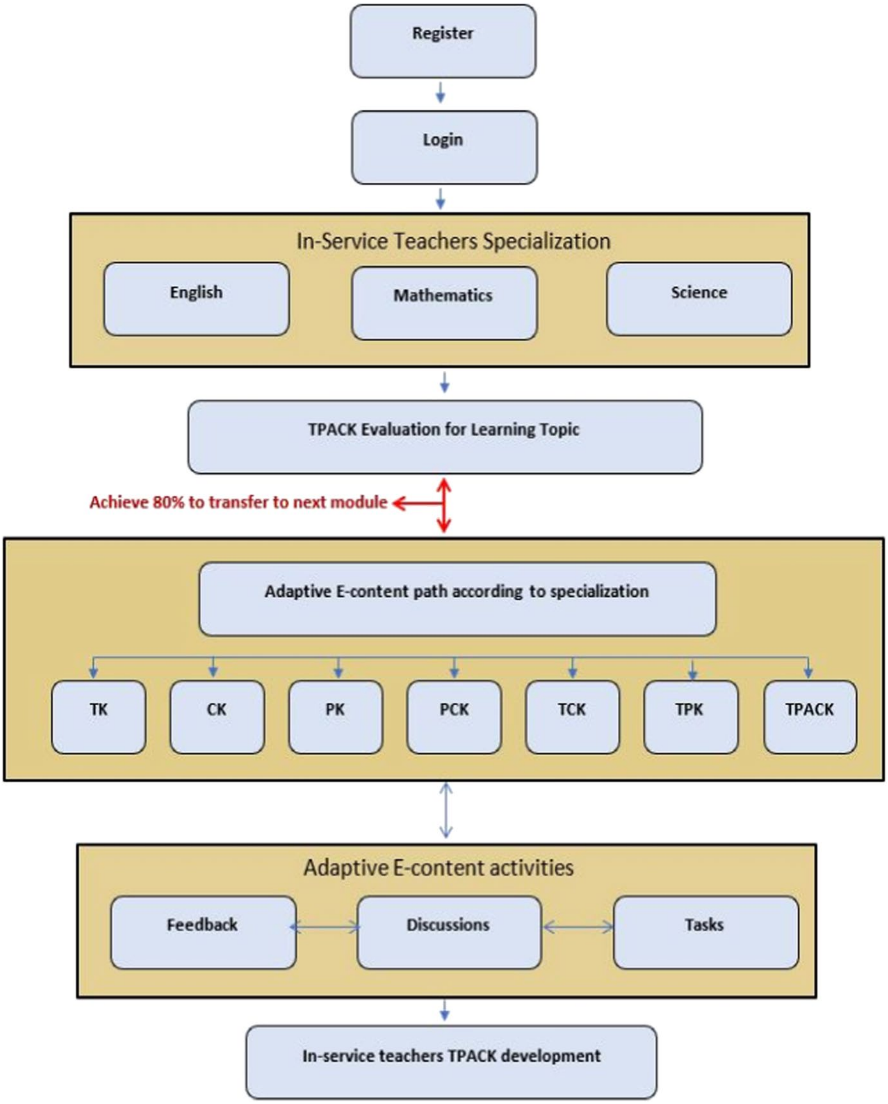

Fig. 4 Adaptive learning environment (ALE) based on TPACK

them reduce their cognitive load and self-regulate, and it also provides us with a way of tracking their learning and seeing how they react.

When the teachers' realities, training needs, and characteristics concerning their level of TPACK were analyzed, it was important to consider whether the teachers' design decisions are influenced by their personal beliefs and classroom experiences (Dick et al., 2005), as well as the fact that their content knowledge interacts with their knowledge of the curriculum, learner demographics, and teaching methods. Angeli et al. (2015) said that the identity model that the teachers use is based on technical mapping which is a link between an instructional design and the development of TPACK.

Modules in the adaptive learning environment are meant to incorporate the following phases in each module: 1. studying a particular topic or area of knowledge; 2. providing a succinct summary of the subject's substance; 3. graduated learning objectives which include lower, intermediate, and higher goals, as well as goals related to the integration of communications and information technology; 4. this is by far the most important technical tool for displaying educational materials and concepts; 5. the chosen learning model or curriculum to be employed; 6. the students are motivated and encouraged to engage and learn new ideas via the learning activities linked to the subject matter; and 7. the assignments connect to the subjects that the students are studying.

In any case, either the users or the system may decide how adaptive a feature is. In our system, the instructor and system share an indicative adaptability (Angeli et al., 2015). Upon entering the system with his login and password, the instructor is sent to the area of his expertise (Science, English, Mathematics). When the teacher wishes to access any topic, he or she selects it from the subject attachments and may read or download the information inside. The content can also be viewed more than once and in the order that the instructor prefers. The teacher can start wherever he or she wants, and an icon will show whether the content has been seen before or not, as well as what percentage of all topics have been seen. This gives us three types of adaptive system scenarios: completed, partially completed, and new.

Each module includes a variety of instructional aids such as video clips, photos, web page connections, interactive tasks, and more. Adaptive systems provide an area for students in the same specialty to discuss and debate relevant subjects. There are also assessment questions for each training unit so then the trainer can know his or her genuine level of knowledge. This demands a score of at least 80%. It is mandatory for trainers who score less than 75% to view the module and answer the questions for that unit again. If the trainer has any issues with the tasks or the exhibited information, he or she will get feedback in this manner as well.

4 Results

4.1 TPACK questionnaire results

It is clear from Tables 2 and 3 that the adaptive learning participants outperformed their conventional counterparts in terms of test results ($p<0.05$, f 5.426, $p=0.01$)

Table 3 Between-group T-test results: TPACK's levels

Method	N	Mean	Std. Deviation	Std. Error Mean
Adaptive	83	230.67	7.919	0.869
Traditional	90	191.97	10.216	1.077

with means of 230.67 and 191.97 respectively. These findings indicate that the adaptive learning technique improved the TPACK level of the in-service teachers.

Regarding the seven components of the TPACK questionnaire, the mean and standard deviation values are shown in Table 4. The adaptive learning group had the most favorable feedback and their mean score was the highest of all the groups. When it comes to adaptive learning and conventional groups, the TK (Technology Knowledge) segment had the biggest mean difference (about 10.0) with means of 85.80 and 75.65, respectively. This is a sign that the teachers in adaptive learning groups have made significant strides in their understanding of how technology may be utilized and incorporated into their classes. Other parts, such as PK (Pedagogical Knowledge), had similar mean scores across the two groups (30.44 and 26.84, respectively) (see Table 4 and Fig. 5).

A significant difference is seen in the independent *t-test* between the two groups' means (adaptive learning and conventional instruction) in each part of the questionnaire (see Table 5 and Fig. 6 for details). Every part of the TPACK questionnaire had a significant influence on the adaptive learning group. However, $f =$ (16.168, 0.798, 0.004, 2.073, 0.465, 1.55, and 1.753) and $p < 0.05$ were found in all sections (TK, CK, PK, PCK, TCK, TPK, and TPACK, respectively) (Table 6).

5 Discussion

The goal of the present study was to increase the professional development of in-service teachers by creating an adaptive learning environment for science, math, and English teachers. An increase in TPACK was seen as a consequence of the adaptive learning environment training for in-service teachers which is consistent with the findings (Doering et al., 2009; Ifinedo et al., 2018; Knight et al., 2007; Steinert et al., 2016). The TPACK model was used to create an adaptive learning environment that provides teachers with extensive and continuous assistance regarding all of TPACK's components (Riedinger & Rosenberg, 2006; Shelton, 2011).

Teachers across all subject areas agreed that training in an adaptive learning environment aided them in developing lesson plans that included technology integration, which supports their claim (Shinas et al., 2015). After going through adaptive training, the teachers' professional development changed because it is now related to their jobs and based on the material they teach (Harris, 2016).

Using a conventional training technique, the in-service teachers were less successful at enhancing their level of TPACK, which often failed in relation to ICT-enhanced educational thought and practice, according to the findings of this study (Timotheou et al., 2017). There is also a possibility that the results can be interpreted

Table 4 Independent samples T-test: TPACK's levels

Equal Variances	F	Sig	t	df	Sig. (2-tailed)		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
	Assumed	5.426	0.021	27.688	171	0.000	38.708	1.398	35.948	41.468
	Not Assumed			27.970	166.185	0.000	38.708	1.384	35.976	41.440

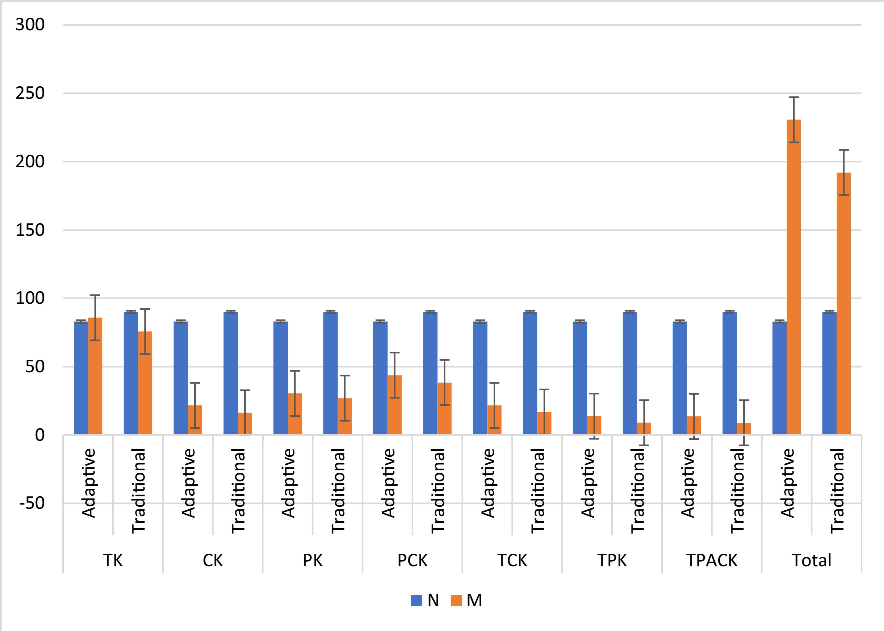

Fig. 5 Means and Standard Deviations for each questionnaire section

Table 5 Means and Standard Deviations for each questionnaire section

Questionnaire sections	Method	N	Mean	Std. Deviation	Std. Error Mean
TK	Adaptive	83	85.8072	5.45817	0.59911
	Traditional	90	75.6556	8.79755	0.92734
CK	Adaptive	83	21.6506	2.36041	0.25909
	Traditional	90	16.2889	2.17361	0.22912
PK	Adaptive	83	30.4458	2.21554	0.24319
	Traditional	90	26.8444	2.38399	0.25129
PCK	Adaptive	83	43.7349	3.11990	0.34245
	Traditional	90	38.3333	2.97556	0.31365
TCK	Adaptive	83	21.6145	2.26226	0.24832
	Traditional	90	16.8889	2.24081	0.23620
TPK	Adaptive	83	13.8072	1.00557	0.11038
	Traditional	90	9.0111	1.31964	0.13910
TPACK	Adaptive	83	13.6145	1.22804	0.13479
	Traditional	90	8.9444	1.36868	0.14427
Total	Adaptive	83	230.67	7.919	0.869
	Traditional	90	191.97	10.216	1.077

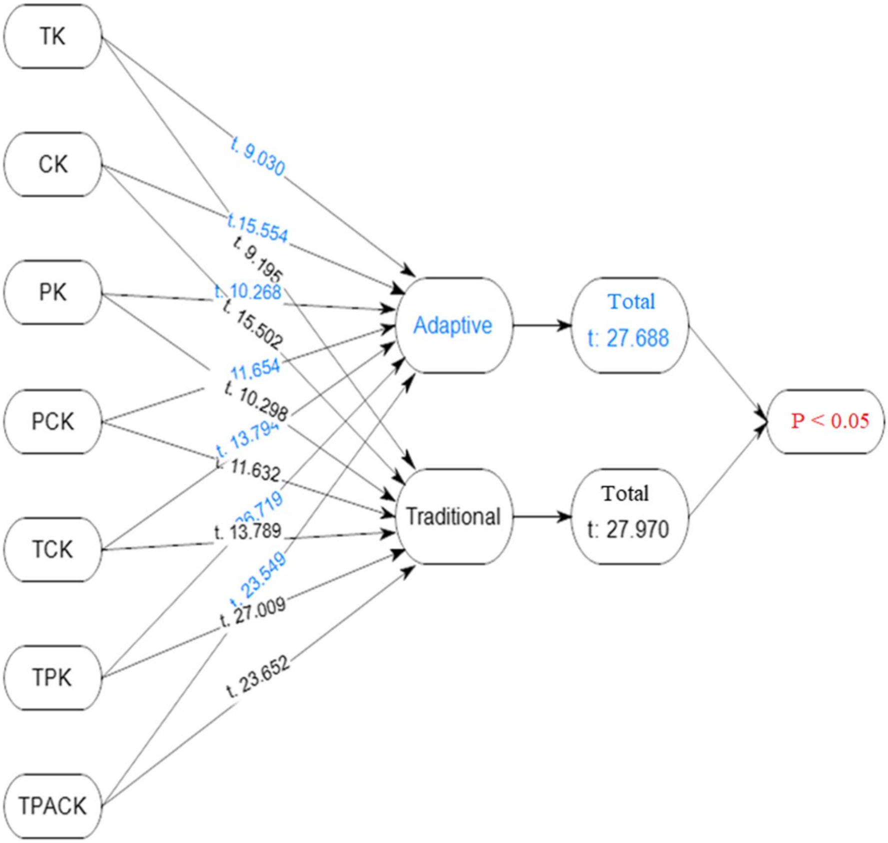

Fig. 6 Independent samples T-test for each questionnaire section

in terms of the characteristics of the Classera learning system which is characterized by flexibility when dealing with and providing teachers with an opportunity to view the training content at any time with clearer, more detailed, systematic, and interesting educational material presentations. This is consistent with the work of Caliskan and Bicen (2016).

The fact that teachers trained in the adaptive learning environment were better can be explained by the fact that the environment was built based on a series of well-designed processes to fit the curriculum, including how to use the teaching methods and technology present in it. This gave teachers the chance to focus on training based on their skills and personal growth.

Because of the wide range of TPACK skills and information that the teachers possess, the system's flexibility is a critical quality that is not often included in traditional teacher training programs. The TPACK framework was established in the twentieth century and has played an important role in the professional development of teachers. The TPACK framework allows researchers and educators to draw conclusions about educational technology and may allow us to make predictions about

Table 6 Independent samples T-test for each questionnaire section

Equal variances		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
TK	assumed	16.168	0.000	9.030	171	0.000	10.15167	1.12418	7.93262	12.37072
	not assumed			9.195	150.367	0.000	10.15167	1.10404	7.97024	12.33311
CK	assumed	0.798	0.373	15.554	171	0.000	5.36171	0.34471	4.68128	6.04215
	not assumed			15.502	166.554	0.000	5.36171	0.34587	4.67887	6.04456
PK	assumed	0.004	0.953	10.268	171	0.000	3.60134	0.35074	2.90900	4.29368
	not assumed			10.298	170.989	0.000	3.60134	0.34970	2.91106	4.29162
PCK	assumed	2.073	0.152	11.654	171	0.000	5.40161	0.46349	4.48671	6.31650
	not assumed			11.632	168.215	0.000	5.40161	0.46438	4.48484	6.31838
TCK	assumed	0.465	0.496	13.794	171	0.000	4.72557	0.34258	4.04934	5.40180
	not assumed			13.789	169.596	0.000	4.72557	0.34271	4.04904	5.40210
TPK	assumed	0.753	0.387	26.719	171	0.000	4.79612	0.17950	4.44180	5.15044
	not assumed			27.009	165.252	0.000	4.79612	0.17757	4.44551	5.14672
TPACK	assumed	1.548	0.215	23.549	171	0.000	4.67001	0.19831	4.27856	5.06147
	not assumed			23.652	170.876	0.000	4.67001	0.19744	4.28027	5.05976
Total	assumed	5.426	0.021	27.688	171	0.000	38.708	1.398	35.948	41.468
	not assumed			27.970	166.185	0.000	38.708	1.384	35.976	41.440

the practical methods of utilizing technology in teaching and learning (Kopcha, 2012).

A fun and culturally relevant teaching environment was developed by teachers in the same specialty, exchanging ideas and views and sending messages in the adaptive learning environment. As a result, if the teachers are from the same town or school, the chances of this kind of engagement are much greater.

As a result of the research experiment's implementation, some challenges arose during the teacher training to use the adaptive learning environment on Classera, particularly for teachers who had never previously worked in an online learning environment. However, it did not take a long time for the teachers to adapt to the new and unfamiliar technology. They quickly became comfortable with the learning environment. A new system may be imposed on teachers due to the presence of alternative learning solutions in the school and the need for them to spend time developing the skill to integrate technology into their teaching, both of which may make them feel that they have to take responsibility for their professional development. This may represent an additional burden and stress but many teachers were able to adapt to this new way of teaching and thrive. The trainer and other teachers in the chat room used many ways to encourage and help their trainees, such as by giving them pointers, making comments, and helping them figure out how to solve any problems.

In addition, some teachers were unable to join conventional Zoom sessions or had their broadcasts cut off due to Internet connection limitations which may have affected their ability to learn the necessary TPACK skills during training. The best situation would be if all teachers had free and equal access to all of the services and technological tools that they need.

Finally, a training course for in-service teachers to improve their use of TPACK requires a great deal of effort and the inclusion of specialists to transform the curriculum from one taught in the traditional classroom way to one where the curriculum, teaching methods, and educational technology are used to facilitate optimal access for teachers to the content. This is why TPACK training is so important. There is also the financial and logistical burden of subscriptions and the designing of different learning materials that are appropriate for content that is taught online. It takes more work to come up with formative assessments and feedback questions and to respond to questions and discussions while learning.

6 Conclusion and implications

The adaptive learning environment has proven to be an excellent tool for raising the level of the in-service teachers in terms of integrating technology into teaching and using all components of the TPACK model. In addition, these learning settings have become a need that educational institutions must pay attention to. It is also something that they should consider a fundamental demand if they are exposed to catastrophes, crises, and epidemics in the future. In the framework of TPD (Teacher Professional Development), teachers need a good professional development program to help them improve their basic teaching and learn new skills that will help them be successful with technology-enhanced learning.

Even if this study's findings are positive, the involvement of the relevant authorities in teacher training and their desire for professional growth must be taken into consideration. Adaptive learning environments can help to achieve the goals of training and development before and during service depending on the skills and circumstances of each teacher and his or her desire to grow at the time.

We make sure that the key decision-makers and professional development stakeholders are important partners in the design and implementation of this form of online training since they have the time they desire. There are many stakeholders involved in the education process but they must all build positive relationships through communication. Stakeholders are required to make significant decisions at all levels of curriculum development and learning environment creation. Each decision will have an impact on the quality of the overall educational experience. Consequently, imagining learning environments that may be utilized and implemented, such as adaptive learning environments, and gathering adequate evidence of their efficacy makes them accessible in terms of dialogue, discussion, and proper decision-making. This information may pertain to the modernity, cost, and services provided by the learning environment which enhances the teaching and learning process. This collaborative data source should not be owned by a single entity—rather, it should be a joint effort. The objective should also be to provide each learning environment's justification and decision-making procedure. If we have access to this information, we can predict the likelihood of positive change and reach the goals of the learning process.

It was pointed out that the current results cannot be generalized due to the small sample size, the limitation of the study to only several scientific subjects, and the specificity of the study population (Saudi society and schools). Both the study's strengths and weaknesses, as well as its potential future applications, have been explored. While this sample size and these out-of-the-ordinary conditions were useful for controlling the outcomes and regulating the study variables during the COVID-19 pandemic, future studies should entail a larger sample size and a wider range of disciplines and geographies.

There may be a need to look into the impact of adopting an adaptive learning environment at the TPACK level for secondary and university-level teachers since the existing study has only looked at elementary school teachers. The short length of the experiment and the use of the Classera system only restricts its generalizability. Using a diverse learning environment may provide varied outcomes. Furthermore, the present data shows the participants' impressions and judgments regarding their degree of TPACK growth, whether due to the conventional technique or in relation to the adaptive learning environment. Adaptive learning environments can affect the growth of both the students and teachers in several ways such as the development of critical thinking, computational thinking, and problem-solving skills.

We anticipate that this study will point the researchers' attention to the need to devote more time and effort to identifying how to best utilize the TPACK approach in adaptive learning environments, building a design framework to do so. To be used in the professional development of in-service teachers, the design framework must be comprised of a design model and a set of learning design principles.

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Declarations

Conflict of interest The authors declare that there is no conflict of interest.

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