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Concurrent training and reflection model (CTRM) for in-service teachers

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This study investigates the effectiveness of the Concurrent Training and Reflection Model (CTRM) in enhancing the research competencies of in-service teachers. CTRM integrates structured research methodology training with real-time classroom reflection, enabling teachers to apply their learning immediately and evaluate its impact through student outcomes. Seventeen teachers from public schools in Qatar participated in a ten-session training program over 60 days. Each teacher guided a minimum of 20 students in conducting research-based projects, involving a total of 347 students. The study employed an exploratory sequential mixed-methods design, grounded in Research Cognitive Theory (RCT), and guided by Kirkpatrick's Four-Level Evaluation Model. Data were collected through an ad hoc pre-post questionnaire, developed and validated by the research team based on stakeholder interviews and focus group discussions. The researchers used quantitative data to assess changes in teachers' research knowledge and ability, while qualitative data included teacher reflections, facilitator feedback, and student outputs provided contextual insights. During the reflection phase, students worked in small groups designing posters and STEM prototypes, which were evaluated at the school level. One prototype and one presentation from each school were selected for final presentation and evaluation, resulting in 17 shortlisted entries. The results demonstrated significant improvements in teachers' research competencies, including their conceptual knowledge, practical application skills, and attitudes toward research. Student-generated outputs provided tangible evidence of instructional impact and reflective teacher growth. The CTRM model proved effective in promoting inquiry-based teaching and fostering a research-oriented classroom culture.

KEYWORDS
concurrent training and reflection model, teachers' training, research methodology, research skills, promoting inquiry-based teaching

Introduction

As educational expectations become more complex, teachers are expected to do more than deliver content (Taguma et al., 2018), they must respond to diverse student needs, integrate real-world contexts, and foster critical thinking within the classroom (Darling-Hammond et al., 2018). To meet these evolving expectations, effective training for in-service teachers becomes essential (Abu-Tineh and Sadiq, 2018; Al-Thani et al., 2021; Alfaidi and Elhassan, 2020; Nasser, 2017). Professional development programs must not only address foundational pedagogical strategies but also incorporate classroom inquiry, reflective thinking, and research-based skills that empower teachers to lead evidence-informed instruction (Slade et al., 2019).

Recent developments in education have emphasized the value of inquiry-based learning, reflective teaching, and classroom-based research as pathways for continuous teacher growth and improved student outcomes (Meng, 2023). Teachers who possess research competencies such as the ability to frame questions, design studies, interpret findings, and reflect on results are better positioned to make informed instructional decisions and support students in developing higher-order thinking skills (Oestar and Marzo, 2022). These skills are particularly important in promoting student engagement in STEM-based and inquiry-driven projects (Van den Hurk et al., 2019). However, most professional development models still emphasize theoretical content without offering sufficient opportunities for practice, feedback, or contextual application (Leal Filho et al., 2025). As a result, teachers often struggle to apply new learning into their daily instructional practices.

To address this gap, the present study introduces the Concurrent Training and Reflection Model (CTRM). This model integrates formal research instruction with immediate classroom-based application and structured reflection. CTRM is designed with a parallel structure: teachers receive targeted training in research methodology while simultaneously applying those skills with their own students. During this reflection process, teachers guide student groups in creating research posters and STEM-based prototypes. These student outputs serve both as evidence of learning and as a basis for reflective teaching practices (Darling-Hammond et al., 2018). By grounding teacher reflection in actual student work, CTRM helps educators connect theoretical knowledge with instructional impact (Black and Wiliam, 2018).

Literature review

Numerous teacher training programs have contributed to improving classroom practice by focusing on both pedagogical development and subject-specific expertise (Philibert et al., 2019; Zhorova et al., 2022). These initiatives not only enhance instructional quality but also foster teacher confidence, professional growth, and leadership potential (Popova et al., 2022; Dixon and Scott, 2015). Evidence shows that teachers who participate in well-structured training demonstrate stronger classroom management, improved time management, and higher levels of student engagement (Phuong et al., 2018; Guraya and Chen, 2019). For instance, Piryani et al. (2018) observed a rise in teacher self-confidence and clarity in instruction following research-oriented training. Similarly, Popova et al. (2022) emphasized that programs integrating subject-specific content, practical engagement, and in-person delivery were more likely to yield measurable gains in student outcomes.

Despite these strengths, many existing professional development programs still face challenges related to sustainability, limited real-world application, and long-term impact on student learning (Bayar and Kösterelioğlu, 2014; Iftikhar et al., 2022; Nasser and Romanowski, 2011; Öztürk, 2019; Tran Ho et al., 2023). Many initiatives rely on one-time workshops or content-heavy delivery that lacks hands-on integration or classroom-based implementation. Even programs that incorporate collaborative or interactive components often fall short in linking teacher learning directly to measurable student progress. For instance, studies conducted by Jurkowski and Abramczyk (2024), Öztürk (2019), and Tumkaya and Miller (2020) on inclusive education training modules and social–emotional learning programs have provided valuable insights into collaborative teaching, yet they often lacked systematic feedback loops or mechanisms to assess the transfer of training into classroom practice (Jurkowski and Abramczyk, 2024; Öztürk, 2019; Tumkaya and Miller, 2020).

Recent research emphasizes the need for professional development models that are both evidence-based and deeply embedded in authentic teaching contexts. Features such as mentoring, collaborative inquiry, reflective practice, and ongoing feedback have been shown to effectively build teachers' instructional capacity, research skills, and professional confidence (Al-Thani et al., 2023; Dewi and Kartowagiran, 2018; Piryani et al., 2018). However, there remains a gap in models that combine these elements with structured research training and real-time classroom application. The CTRM addresses this gap by integrating formal research instruction with concurrent classroom implementation and teacher-student collaboration. Teachers engage in training while guiding students in inquiry-driven learning, turning the classroom into an action research environment. Student-generated outputs such as STEM prototypes and research posters not only serve as indicators of student learning but also provide tangible tools for teacher reflection (Al-Thani et al., 2022). By aligning professional development with classroom realities, CTRM supports the development of research-competent teachers and directly contributes to improved student outcomes (Putman and Polly, 2021; Lee and Zahir, 2021).

The CTRM is intended to promote professional development of teachers and student engagement by embedding research within the learning environment. Through guided follow-up sessions and feedback, teachers are encouraged to reflect, adapt, and build confidence in using research as a tool for improving instruction (Schön, 1983). This model creates a dynamic feedback loop between teacher development and student performance, offering a practical and sustainable approach to professional learning.

Research questions

1. How effectively does CTRM enhance in-service teachers' knowledge of research methodology?
2. In what ways does CTRM improve teachers' ability to apply research skills in their classroom instruction?
3. How do student-generated outputs (posters and prototypes) serve as reflective tools for assessing and improving teachers' instructional practices?

Theoretical and conceptual framework

The theoretical foundation of the CTRM is grounded in Research Cognitive Theory (RCT) (Al-Thani and Ahmad, 2025), which draws upon Bandura's Social Cognitive Theory (SCT) and its earlier formulation, Social Learning Theory (SLT) (Bandura, 1986; Bandura and Walters, 1977) emphasize that learning occurs most effectively in environments that promote self-efficacy, observational learning, behavioral capability, and reflective practice. RCT extends these principles into the domain of teacher research training, suggesting that educators build research competencies not only through formal instruction but also through socially interactive and cognitively engaging experiences that mirror authentic research processes. These experiences are operationalized through key mechanisms such as peer collaboration, structured mentoring, and guided feedback, which play a vital role in shaping teachers into reflective, research-oriented practitioners (Lee and Zahir, 2021).

While RCT provides the theoretical basis for understanding how teachers acquire and apply research skills, the conceptual framework guiding the implementation and evaluation of CTRM draws on Kirkpatrick's Four-Level Evaluation Model: Reaction, Learning, Behavior, and Results (see Figure 1) (Jain, 2014; Kirkpatrick, 1959). As illustrated in Figure 2, the CTRM is structured into four interrelated phases: *Training, Reflection, Retain and Apply,* and *Establish,* while the *Follow-Up* component functions parallel with the *Reflection* and *Retain and Apply* levels, providing ongoing support and reinforcement. In this structure, Kirkpatrick's Reaction and Learning levels are encompassed within the Training level, during which teachers engage in formal research instruction and begin building confidence in applying research-based practices. The Reflection level aligns with Kirkpatrick's Behavior level, demonstrating how teachers transfer their training into classroom practice by facilitating student research activities and adapting their instructional approaches accordingly.

What makes the CTRM model unique is its parallel structure, in which teachers apply newly acquired research skills directly in their classrooms, and student outcomes serve as authentic reflections of their instructional growth. This design allows teachers to implement what they learn during formal sessions immediately afterward with their students, creating a continuous feedback loop between instruction, reflection, and learning. During the *Reflection* and *Retain and Apply* levels, facilitators provide ongoing parallel *Follow-up* support to guide teachers, reinforce instructional alignment, and address practical challenges in real time. The *Retain and Apply* level enables students to demonstrate their research understanding through collaborative research outputs, such as STEM prototypes and research posters. These artifacts then feed into the *Establish* phase, which aligns with the *Results* level in Kirkpatrick's model, to evaluate the long-term impact of the training on both student outcomes and teacher development. Collectively, these integrated levels form a holistic and sustainable framework for in-service teacher growth, grounded in reflective practice and aimed at achieving measurable classroom impact.

Methodology

This study employed CTRM, a research-informed teacher development framework that integrates structured training with real-time classroom implementation and guided reflection. The model was designed to evaluate its effectiveness in enhancing in-service teachers' research competencies and improving student learning outcomes. CTRM adopted a parallel structure, enabling teachers to receive formal research training while concurrently applying their learning in the classroom. Teachers facilitated student engagement in key research activities such as topic selection, literature review, study design, and data analysis. These student-generated output research posters and STEM-based prototypes served as dual indicators of student learning and reflective evidence of instructional impact. To support this integrated process, the research team conducted concurrent follow-up sessions, offering mentorship, feedback, and troubleshooting support during the implementation period. An exploratory sequential mixed-methods design, combining quantitative and qualitative data analysis, was used to systematically assess the impact of the CTRM. This comprehensive approach enabled the creation of real-time feedback loops linking teacher development, classroom implementation, and measurable student outcomes.

Study phases and implementation

As shown in Figure 3, the research process was structured into three interconnected phases, each aligned with the study's overarching goal of enhancing the research competencies of in-service teachers through a research-oriented training and reflection process (Norouzi and Salajegheh, 2023). The effectiveness of the CTRM was evaluated by measuring improvements in teachers' research understanding, practical capabilities, and perception toward research. Student learning outcomes were also used as key indicators of teacher reflection and instructional impact.

Phase I – assessment and tool development

This initial phase involved conducting semi-structured interviews with key stakeholders, including representatives from the Ministry of Education & Higher Education (MOEHE), school principals, and in-service teachers. The purpose was to gather insights regarding the need for research-based teacher training, as well as to identify practical strategies for promoting a research-oriented learning culture within schools. The findings from these interviews and discussions were subsequently used to design a customized pre- and post-assessment questionnaire aimed at measuring teachers' research knowledge, skills

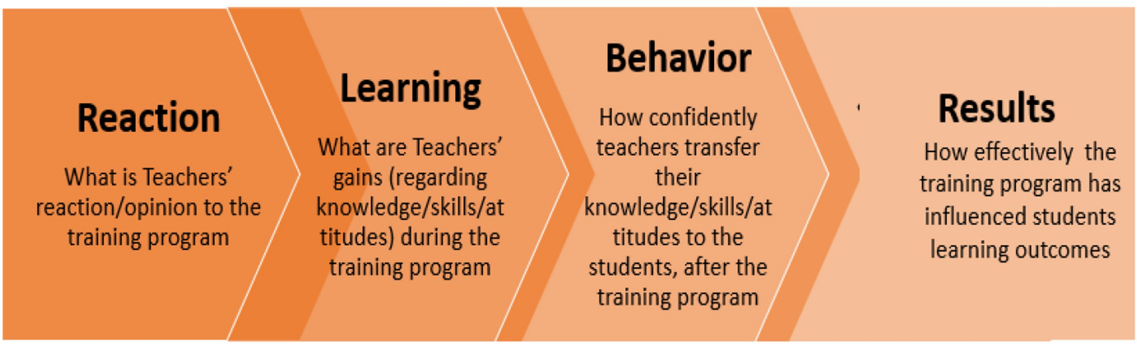

FIGURE 1
Diagrammatic representation of Kirkpatrick's four-level evaluation model for assessing teachers' training program.

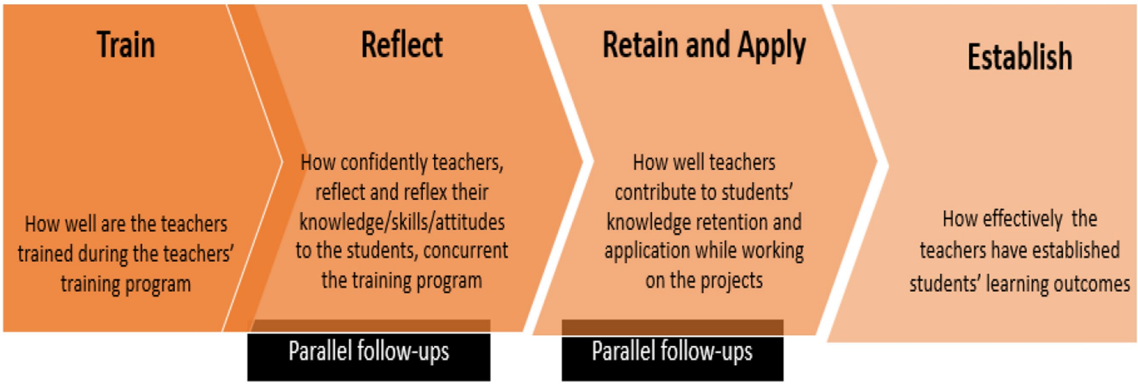

FIGURE 2
Diagrammatic representation of the Concurrent Training and Reflection Model (CTRM) for teacher evaluation.

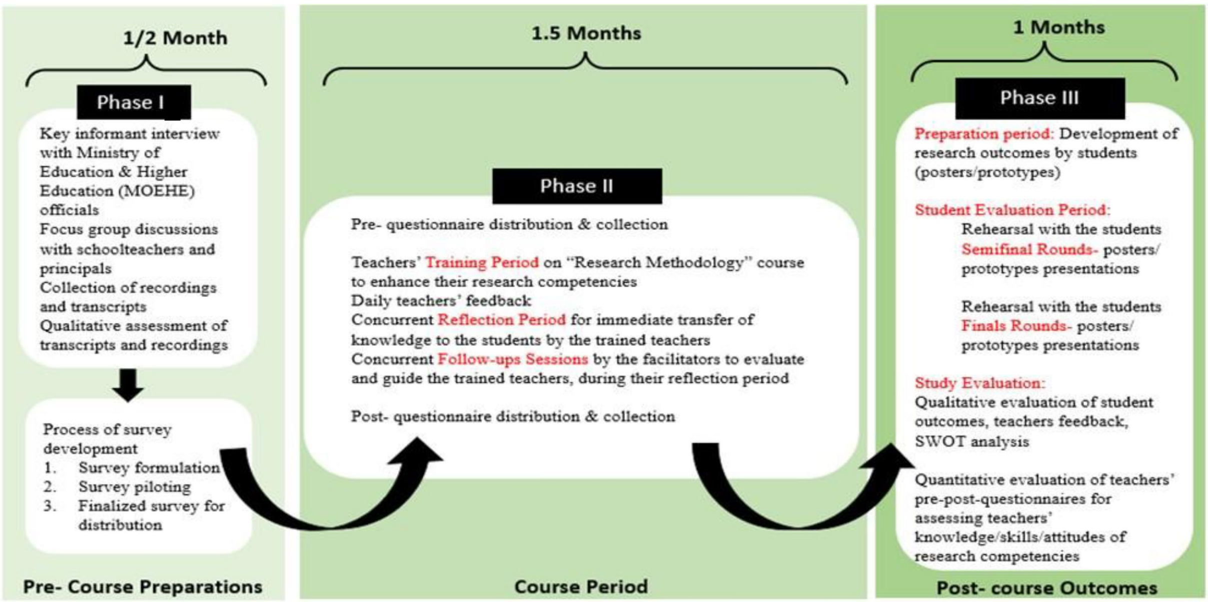

FIGURE 3
Diagrammatic representation of the three phases of CTRM.

and attitudes before and after the training program. The questionnaire was developed using an *ad hoc* method, meaning it was specifically designed for this study based on contextual needs and program objectives. To ensure validity and clarity, the instrument was pilot tested with a representative sample of in-service teachers. Feedback from the pilot phase was used to refine the questionnaire in terms of content relevance, clarity, and linguistic appropriateness. After necessary modifications, the final version of the tool was prepared and distributed for official use during the training program.

Phase II – concurrent training and reflection

In this phase, the selected 17 in-service teachers participated in a structured ten-session training program focused on research methodology. The program spanned 60 days, with sessions conducted twice per week. At the beginning of the training, the pre-training questionnaire was administered to collect baseline data on the teachers' research competencies. During the training sessions, teachers received instructions in guided research activities, including formulating research questions, and designing basic study protocols (Shah et al., 2017). After each session, teachers engaged in a 10-day classroom reflection period, where they applied this knowledge and skills with at least 20 students each (347 students total). Students worked in small groups to develop research posters and STEM-based prototypes (Alkhair et al., 2022).

These outputs were evaluated during follow-up sessions conducted in Phase II, in which the research team visited classrooms to observe implementation, offer feedback, and support teacher reflection. Under each teacher, the participating students were divided into groups of four to five. Each group developed one prototype and designed one research poster, both of which were evaluated by the research team during follow-up sessions. From each school, the best-performing prototype and poster were selected for semi-final and final presentation and evaluation. In total, 17 prototypes and 17 posters one from each participating school were selected for the final round of assessment. These artifacts served as tangible indicators of student learning outcome and were considered as reflective outputs of teachers' instructional impact. The concurrent reflection model not only supported knowledge transfer but also encouraged immediate implementation and positively influenced teachers' attitudes toward research-based instruction. At the end of this phase, a post-training questionnaire was administered to the participating teachers to collect quantitative data on the effectiveness of the training and to measure changes in research-related knowledge, skills, and attitudes. The outputs created during this phase were later formally assessed by the three external research experts in Phase III using predefined evaluation rubrics. These rubrics are detailed in Supplementary Table S1.

Phase III – post-training evaluation

The final phase focused on evaluating the outcomes of both teachers and students to determine the overall effectiveness of CTRM. Key activities included semi-final and final student presentations, formal expert assessments of student research outputs (e.g., posters and prototypes), and quantitative analysis of teacher post-program data. As in Phase II, follow-up sessions continued during this phase, offering sustained guidance, monitoring, and encouragement to teachers as they completed their reflective teaching cycles. This continuity reinforced professional growth and helped embed reflective practice into everyday instructional routines. The outcomes of both teachers and students were systematically analyzed to assess the overall effectiveness of the CTRM model in promoting inquiry-based learning and sustainable professional development. Student presentations provided tangible evidence of their ability to apply structured research methodologies in creative and meaningful ways, thereby reflecting the instructional efficacy of their teachers. These sessions further reinforced teacher development and sustained their engagement in reflective teaching practices.

Sampling and participants

This study focused on evaluating a specific teacher training intervention; therefore, a purposive sampling approach was employed. The participating schools were selected randomly, and teacher participation was entirely voluntary. A total of 17 in-service teachers from public schools across Qatar were participated for the study, with one teacher representing each school. Although the direct participants were the 17 teachers, the study's impact extended further. Each teacher trained a minimum of 20 students during the concurrent reflection phase, resulting in a total reach of 347 students. This student engagement formed a critical component of the teachers' reflection process, as their observations and learning outcomes were used to assess the effectiveness of the training. Prior to the commencement of the program, informed consent was obtained from all teacher participants. Most of the participants were female teachers, comprising 76.5% of the total. The largest age group represented was 31 to 40 years old (64.7%). In terms of academic qualifications, the majority (64.7%) held Diploma degrees. Regarding teaching level, 35.3% of the teachers were from preparatory schools and 64.7% were from secondary (high school) levels, and all participating schools were STEM-focused institutions. A summary of the demographic details is provided in Table 1.

TABLE 1 Teacher participants' demographics.

Variable	Sub-categories	Percentage
Gender	Male	23.5
	Female	76.5
Age Group	31–40	64.7
	41–50	35.3
Educational Qualification	Diploma	64.7
	Bachelor's degree	17.6
	Educational specialists	17.6
Teaching Level	Preparatory	35.3
	High school	64.7

Program content and structure

The main objective of the program was to empower teachers in several key aspects of research. The training covered foundational and advanced research topics, including research question formulation, literature review, PRISMA diagram, study design, data collection (qualitative and quantitative), analysis techniques, and scientific communication. A detailed breakdown of the training sessions is presented in Table 2 and a detailed breakdown of session-wise activities is demonstrated in Supplementary Table S2. Teachers immediately reflected and applied concepts learned in each session within their classrooms.

Data collection instruments

To evaluate the effectiveness of the CTRM in enhancing teachers' research competencies specifically their knowledge, skills, and attitudes related to educational research, both quantitative and qualitative data collection tools were employed.

Quantitative data collection

A pre-post questionnaire was developed by the facilitators (authors) to systematically measure the impact of the CTRM training program on teachers' research competencies. The instrument aimed to assess how the model contributed to improvements in teachers' knowledge of research methodology and their ability to conduct and guide research activities. The complete version of the instrument is provided in Supplementary Table S6. The development and implementation of the survey followed three structured steps:

Step 1: survey development

The questionnaire was developed based on findings from stakeholder interviews with Ministry of Education and Higher Education (MOEHE) professionals and focus group discussions with school principals and in-service teachers. A comprehensive literature review (Liu et al., 2011; Hassanein et al., 2021) further informed its design. The survey consisted of three main sections: Demographic Information, Teachers' Knowledge Regarding Research Methodology,

TABLE 2 Course breakdown (session-wise).

Days	Topics
Session 1	Introduction to research: Selection of research topics, formulation of research questions, and research problem statement
Session 2	Effective literature search and citing research documents and sources
Session 3	Introduction to PRISMA (preferred reporting items for systematic reviews and meta-analyses) flow diagram and efficient retrieval of precise research materials
Session 4	Types of research and studies: Introduction to study designs and a systematic review of studies.
Session 5	Quantitative study design: designing a questionnaire, sampling (sample size and sampling technique), and quantitative data collection.
Session 6	Qualitative study design: introduction to qualitative research; qualitative sampling techniques; qualitative data collection techniques; qualitative research approaches
Session 7	Data analysis and presentation of research findings
Session 8	Introduction to referencing tools
Session 9	Familiarization with research ethics and hands-on practice in poster designing
Session 10	Scientific writing and standard research protocol format: How to develop a competitive research protocol?

Teachers' Research Ability. The questionnaire consisted of close-ended questions in 5-point Likert and true/false format. For coding purposes, the following scale has been employed for section 2 (−1 = very poor, 0 = poor, 1 = fair, 2 = good, 3 = very good). For section 3, the following scale has been utilized (0 = None, Minimal, 1 = Moderate, 2 = Considerable, 3 = Very familiar).

Step 2: pilot testing and refinement

The questionnaire underwent pilot testing through two focus group discussions, conducted separately in Arabic and English. These focus groups were essential in refining the instrument, especially with regard to the clarity and wording of questions. The discussions helped identify areas of ambiguity and provided opportunities to rephrase unclear items, ensuring that the final survey was concise, culturally appropriate, and capable of capturing accurate data. The questionnaire aimed to: (1) gather key background information from participants, (2) systematically document the training process, and (3) identify challenges faced during the training and reflection phases.

Step 3: administration of the survey

The third step involved the actual administration of the survey. After obtaining signed informed consent from both the teachers and school authorities, facilitators distributed the questionnaire to participants, offering them the option to complete it in either English or Arabic. On average, participants require between 13 and 17 min to complete the instrument. In addition to the quantitative data through survey, qualitative data were collected through various sources to supplement and deepen the understanding of program outcomes. These sources included transcripts of interviews and focus group discussions, teachers' reflective feedback, facilitator notes from follow-up sessions, evaluations of student posters and prototypes using rubrics, and documented observations of student performance and engagement. These data are referenced in detail in the Supplementary Tables S4a–d, S5.

Quantitative measures

Two core constructs were measured through the quantitative survey instrument. The first construct focused on teachers' knowledge of research methodology, aiming to assess the level of conceptual understanding they had before and after the training. This included their familiarity with essential components such as research design, data collection techniques, and analysis strategies. The second construct examined teachers' research ability, specifically evaluating the extent to which their practical research skills and confidence improved because of their participation in the training program. The responses for each of these constructs were analyzed separately to track measurable changes in knowledge and ability from the beginning to the end of the program, and the results are presented in the subsequent sections of this paper.

Data analysis

Quantitative analysis of the CTRM was performed using the Statistical Package for the Social Sciences (SPSS) software. To determine the reliability of the questionnaire, Cronbach's Alpha and McDonald's Omega were calculated for each construct. Both metrics exceeded 0.95, indicating excellent internal consistency. Data distribution was assessed using the Shapiro–Wilk and Kolmogorov–Smirnov tests, which confirmed that the data did not follow a normal distribution ($p < 0.05$) (see Supplementary Tables S3, S4). Accordingly, the Wilcoxon Signed-Rank Test, a non-parametric method, was used to evaluate significant differences between pre- and post-test scores for both constructs: teachers' knowledge of research methodology and their research ability. In addition to inferential statistics, descriptive statistics including means, standard deviations, and frequency distributions were used to summarize responses. These descriptive analyses offered further insights into shifts in teacher perceptions, self-efficacy, and research competencies before and after participation in the CTRM intervention. To complement the significance testing, Cohen's *d* effect sizes were calculated to estimate the magnitude of pre-post changes for each construct. These were computed using the Campbell Collaboration Effect Size Calculator, applying the pooled standard deviation method for paired samples. This method aligns with APA Journal Article Reporting Standards (Appelbaum et al., 2018) and offers a clearer interpretation of the intervention's practical significance.

For the qualitative analysis, a thematic approach was applied to data collected from focus group transcripts, facilitators' observational notes, and teacher reflections. These reflections were further interpreted through student-generated outputs such as posters and prototypes. Emerging themes included the relevance of the training, levels of student engagement, institutional barriers, and teacher motivation. Additionally, a SWOT analysis was conducted to evaluate the strengths, weaknesses, opportunities, and threats related to the implementation of the CTRM model, drawing on facilitators' perspectives. Together, these qualitative and quantitative methods provided a comprehensive evaluation of the CTRM model, offering both measurable outcomes and rich contextual insights.

Results

The results section encompasses a quantitative evaluation of two constructs, i.e., (1) Teacher's knowledge regarding research methodology, and (2) Teachers' research ability, to understand the program's efficiency. Followingly, the findings from the qualitative evaluations, involving focus group discussions and SWOT analysis have been presented.

Validation of the instruments

For internal consistency and data reliability, *Cronbach's Alpha,* and *MacDonald's Omega* values for each survey construct (pre- and post-) have been calculated and illustrated in Table 3. The Alpha and Omega values typically range from 0 to 1, with acceptable values greater than 0.7. Wherein, the values above 0.70 are regarded as reliable and above 0.8 as highly reliable (Cohen et al., 2017). The reliability test revealed that all the questions used in analyzing this study's data were reliable.

Research findings

The descriptive statistics concerning the average mean scores before and after the CTRM indicate that the teacher's knowledge regarding research methodology has increased for most of the measures (questions). On average, there was an improvement from a mean score of 2.76 in the pre-test to a mean score of 3.82 in the post-test (see Figure 4). To investigate the statistical significance of this mean difference, the Wilcoxon signed-rank test was performed (see Table 4). The findings show that for the 'construct' and all corresponding measures, there is a statistically significant improvement in the post-test scores, indicating that teachers have gained knowledge in research methodology (*p-value* < 0.001). The results suggest that teachers display a high degree of adaptability and have enhanced their knowledge of research. In addition to statistical significance, the effect sizes (Cohen's *d*) for the pre-post differences in teachers' research knowledge were large, ranging from 1.22 to 1.54. This suggests that the CTRM intervention had a strong practical impact, indicating substantial gains in teachers' conceptual understanding of research methodology.

TABLE 3 Reliability analysis for the pre and post surveys.

Test	Construct	No. of Items	Cronbach Alpha	McDonald's Omega
Pre-test	Teacher's knowledge regarding research methodology	6	0.953	0.953
	Teacher's research ability	12	0.967	0.967
Post-test	Teacher's knowledge regarding research methodology	6	0.974	0.980
	Teacher's research ability	12	0.961	0.965

Similarly, the analysis of mean average scores before and after the CTRM reveals that teachers' research abilities improved across most measures (questions). On average, the scores increased from a mean of 2.02 in the pre-test to a mean of 2.56 in the post-test (see Figure 5). To assess the statistical significance of this mean difference, the Wilcoxon signed-rank test was performed (see Table 5). The results indicate a statistically significant improvement in teachers' perception of their research abilities for both the overall construct and all the corresponding measures (*p-value* < 0.001).

The student-designed research posters and STEM-based prototypes created under teacher supervision reflect the effective application of research practices taught through CTRM. These outputs were evaluated during follow-up sessions and presented in the final review phase and evaluated by external experts. The evaluation of student-developed posters and prototypes was conducted using a structured rubric (see Supplementary Table S1), which assessed criteria such as presentation, originality, sustainability, and overall design quality. Examples of these outputs are shown in Figures 6, 7.

The Cohen's *d* effect sizes for teachers' research abilities ranged from 0.78 to 1.57, demonstrating a large practical impact across most research tasks, including data analysis, project reporting, and scientific presentations. These findings emphasize that the improvements were not only statistically significant but also educationally meaningful.

Following the quantitative analyses, a qualitative evaluation was conducted to explore the design and implementation of the CTRM program in greater depth. During Phase I of the program, focus group discussions were held with stakeholders from the Ministry of Education & Higher Education (MOEHE), school principals, and in-service teachers. These discussions were designed to inform the CTRM training model by exploring participants' perspectives on the need for research training, current practices, and contextual challenges (refer to Supplementary Tables S5a–c).

Participants consistently reported that student research activities in schools were generally limited to annual competitions organized by MOEHE. Teachers indicated that there was a limited integration of research methodology into the regular curriculum, and few opportunities existed for students to engage in sustained inquiry-based projects. Several teachers shared that they lacked prior experience and training in research, which made it difficult to effectively mentor students. Time constraints were frequently mentioned, with teachers noting that mentoring students in research projects added responsibilities beyond their standard workload, often without additional compensation. Principals highlighted the lack of laboratory infrastructure and noted that equipment availability varied widely across schools. Some principals expressed a preference for building partnerships with external research institutes to address equipment gaps and enhance student exposure. Across the sessions, participants emphasized a shared need for more structured support, training, and follow-up mechanisms to embed research experiences more meaningfully into the school environment. Following the focus group exploration, a SWOT analysis was performed from the facilitators' perspectives to gain deeper insights into the program's effectiveness regarding its design and implementation. This analysis

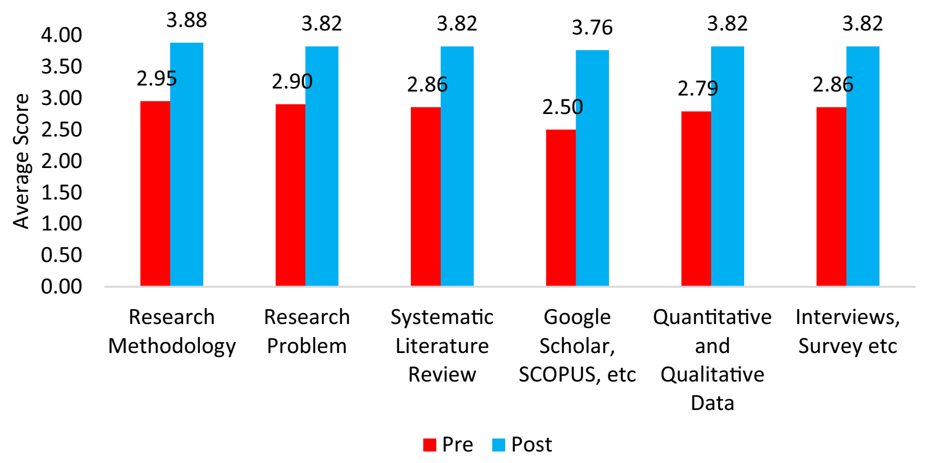

FIGURE 4
Pre-post average score for each measure of the teacher's knowledge regarding research methodology construct.

offered a structured overview of the program's internal strengths and weaknesses, as well as external opportunities and threats (refer to Table 6).

Discussion

Research has consistently demonstrated the critical role of teacher training programs in enhancing educators' leadership, knowledge, and instructional skills (Philibert et al., 2019; Phuong et al., 2018; Guraya and Chen, 2019; Popova et al., 2022). These programs are central to educational discussions, as there is a consensus that high-quality teaching directly contributes to improved educational outcomes. While the literature is replete with various teacher training models, few have integrated concurrent training and reflection phases, particularly for in-service teachers. Such an integrated approach is rarely explored in existing studies, which often emphasize theoretical training without adequately addressing practical application and reflection. This gap is particularly relevant in STEM education, where inquiry-driven, research-oriented instruction requires teachers to develop not only knowledge, but also applied competencies and reflective teaching practices.

The findings of this study demonstrate that the Concurrent Training and Reflection Model (CTRM) effectively enhanced the research competencies of in-service teachers, aligning with the theoretical foundations of RCT, and guided by Kirkpatrick's Four-Level Evaluation Model. RCT emphasizes the development of teacher competency through contextualized, cognitively engaging, and socially mediated learning experiences. The significant improvements in teachers' research knowledge, application skills as reflective practices, as evidenced by the quantitative results (Wilcoxon test), can be directly attributed to the principles of RCT, which emphasize that learning is most effective when it occurs through observation, active engagement, and reflective practice. Unlike conventional training models that are predominantly theoretical, CTRM is designed to provide in-service teachers with research-based training while simultaneously enabling them to apply these skills in their classrooms. Teachers not only acquired new knowledge in research but also immediately applied these skills within their classrooms, reinforcing their understanding through real-world application (Morrison et al., 2021). This dual focus on training and reflection aligns with the growing demand for training models that not only impart knowledge but also foster critical thinking, creativity, and innovation among both teachers and students. This aligns with RCT, which suggests that educators build research competencies through contextual experiences and cognitive engagement rather than passive learning. By enabling teachers to move beyond passive acquisition of content toward active integration of research practices, CTRM supports the development of sustained instructional transformation.

The quantitative findings of this study, which revealed statistically significant improvements in teachers' research knowledge and abilities, are consistent with previous research (Kurniawati et al., 2017; Rodriguez et al., 2020). The post-training gains observed among teachers demonstrate that CTRM effectively enhanced their understanding of research design, data collection, and analysis which are core components of research literacy. These improvements directly address the primary research objective of this study, which was to enhance teachers' research competencies through a structured training model.

The effectiveness of the CTRM model, guided by Kirkpatrick's Four-Level Evaluation Model, is evident across its conceptual levels *Training, Reflection, Retain and Apply*, and *Establish* each corresponding to progressive stages of teacher development. During the *Training* level, teachers expressed positive feedback and demonstrated significant improvements in research competencies, including their ability to formulate research questions, conduct literature reviews, and analyze data. These gains reflect the impact of structured, research-oriented instruction in building foundational knowledge and applied skills. In the *Reflection* level, teachers began implementing their learning by guiding students in developing research posters and STEM prototypes. This shift from learning to doing reflects the experiential learning emphasized in RCT, where teachers build confidence by using their skills in real classroom settings. This process was continuously supported by the Follow-Up component of the model, which worked in parallel to the *Reflection*

TABLE 4 Wilcoxon signed-rank test results for each measure of the teacher's research knowledge regarding the research methodology construct.

Measure	Test	*M*	SD	Cohen's *d*	*Z*	*p*
Knowledge regarding Research Methodology	Pre	3.87	0.92	1.44	−2.877	0.004
	Post	4.87	0.35			
Knowledge regarding Research Problem Statement	Pre	3.80	1.08	1.22	−2.913	0.004
	Post	4.80	0.41			
Knowledge regarding Systematic Literature Review	Pre	3.73	1.03	1.36	−2.859	0.004
	Post	4.80	0.41			
Knowledge regarding Google Scholar, SCOPUS, Science Direct, Web of Science	Pre	3.40	1.12	1.49	−3.126	0.002
	Post	4.73	0.59			
Knowledge of Quantitative and Qualitative Data	Pre	3.60	1.06	1.49	−2.877	0.004
	Post	4.80	0.41			
Knowledge regarding Interviews, Surveys, Case Studies, and Group Discussion	Pre	3.67	1.05	1.42	−2.774	0.006
	Post	4.80	0.41			
Total Score (All Items)	Pre	22.07	5.64	1.54	−3.184	0.001
	Post	28.80	2.48			

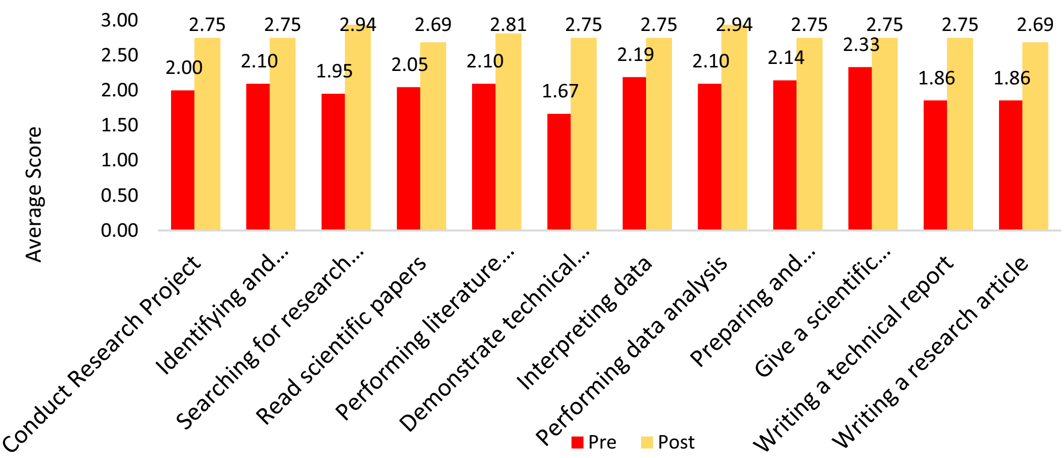

FIGURE 5
Pre-post average score for each measure of the Teacher's Research ability construct.

and *Retain and Apply* levels to provide regular mentoring, feedback, and implementation support. These ongoing sessions helped teachers adjust their teaching strategies, solve challenges, and stay engaged in the research process. The strong link between the structure of the CTRM model and the improvement in teachers' research skills shows that the model successfully promotes ongoing, and well-supported professional learning. This finding reinforces the strength of concurrent application and structured follow-up as a mechanism for developing confident, research-active educators. In addition to statistical significance, the results showed large effect sizes for both constructs. For teachers' research knowledge, Cohen's *d* values ranged from 1.22 to 1.54, indicating strong gains in conceptual understanding. For teachers' research ability, effect sizes ranged from 0.78 to 1.57, reflecting substantial improvements in applying research skills. These findings align with RCT, which emphasizes that guided research experiences and reflective practice can enhance both cognitive development and instructional effectiveness.

The qualitative findings derived from stakeholder interviews and focus group discussions (see Supplementary Tables S5a–d) revealed several critical insights into the design, reception, and contextual challenges of implementing research-based teacher training. The instruments used to guide these discussions were developed based on the research objectives and aligned with the CTRM framework, as detailed in Supplementary Table S5a. The instruments used to guide these discussions were developed in alignment with the CTRM framework and are described in Supplementary Table S5a. Teachers reported limited exposure to research methodology prior to the intervention and highlighted institutional barriers such as insufficient incentives, inadequate laboratory infrastructure, and the absence of dedicated support staff (Karkouti et al., 2022; Nasser, 2017; Nasser and Romanowski, 2011). These concerns were echoed by school leaders, who noted time constraints and limited resources for sustained research engagement. Despite these limitations, participants expressed strong interest in structured, hands-on training programs. There was

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TABLE 5 Wilcoxon signed-rank test results for each measure of the Teacher's Research Ability construct.

Measure	Test	*M*	SD	Cohen's *d*	*Z*	*p*
Conduct research related to the project	Pre	3.87	0.74	1.4	−2.667	0.008
	Post	4.73	0.46			
Identifying and formulating a research problem for a project	Pre	3.93	0.80	1.23	−2.652	0.008
	Post	4.73	0.46			
Searching for research articles through online databases	Pre	3.80	1.01	1.53	−2.859	0.004
	Post	4.93	0.26			
Read scientific papers	Pre	4.00	1.00	0.85	−2.332	0.020
	Post	4.67	0.49			
Performing a literature review	Pre	4.00	1.07	0.99	−2.588	0.010
	Post	4.80	0.41			
Demonstrate technical skills in a project	Pre	3.60	0.91	1.57	−3.002	0.003
	Post	4.73	0.46			
Interpreting data	Pre	4.13	0.99	0.78	−2.264	0.024
	Post	4.73	0.46			
Performing data analysis	Pre	3.93	0.96	1.42	−2.714	0.007
	Post	4.93	0.26			
Preparing and presenting a research poster	Pre	3.93	0.88	1.14	−2.588	0.010
	Post	4.73	0.46			
Give a scientific presentation	Pre	4.13	0.92	0.82	−2.124	0.034
	Post	4.73	0.46			
Writing technical report	Pre	3.73	1.03	1.25	−2.714	0.007
	Post	4.73	0.46			
Writing a research article	Pre	3.80	1.01	1.1	−2.511	0.012
	Post	4.67	0.49			
Total Score (All Items)	Pre	46.87	9.78	1.36	−3.185	0.001
	Post	57.13	4.34			

widespread support for a STEM-centered curriculum that integrates modern educational technologies including artificial intelligence and robotics to foster inquiry-based learning. Participants also emphasized the importance of flexible delivery formats that balance theoretical instruction with practical application, tailored to both preparatory and secondary education levels. These findings underscore the importance of holistic capacity-building models like CTRM, which aim to align pedagogical practices with institutional readiness and teacher needs.

In addition to these perspectives, further qualitative insights from focus group discussions, SWOT analysis (Table 6), and teacher reflections reinforced the perceived value of the CTRM approach. Teachers reported increased confidence, improved instructional skills, and greater flexibility in guiding students through the research process. The program's strengths such as its tailored design to meet diverse teacher backgrounds, hands-on research methodology training, and consistent follow-up sessions contributed to high engagement and full retention of participants. Moreover, the integration of interactive activities and student-led poster and prototype presentations created meaningful opportunities for applying research in real classroom contexts (Tao et al., 2022). These experiences reflect key principles of Schön's Reflective Practice, where critical reflection enables deeper professional learning. Nevertheless, the analysis also revealed persistent obstacles, such as limited training time, inconsistent access to research resources, and variability in teacher motivation. These challenges are consistent with previous studies that have identified similar barriers in the implementation of research-focused professional development (Genvieve, 2017; Siddiqui et al., 2021).

This study distinguishes itself by providing a comprehensive perspective that integrates both qualitative and quantitative evaluations, offering a more nuanced understanding of the impact of teacher training. This mixed-methods approach is particularly significant, as most existing studies have relied solely on quantitative measures, thereby overlooking the contextual insights that qualitative data can provide. By combining these two dimensions, this study contributes to the broader discourse on teacher training models, providing a more holistic understanding of how training can be effectively designed and implemented.

In light of the above, CTRM offers a sustainable model for professional development, one that not only enhances teachers' research skills but also directly impacts student learning outcomes. The successful implementation of CTRM demonstrates that a balanced approach, which combines structured training with reflective practice, can bridge the gap between theoretical knowledge and

FIGURE 6
Student outcomes in the form of poster presentations (during the reflection period of the CTRM).

FIGURE 7
Student outcomes in the form of prototype presentations (during the reflection period of the CTRM).

practical application. This model not only addresses existing gaps in teacher training literature but also provides a foundation for future research aimed at refining and expanding teacher training practices.

Limitations

While the CTRM model showed promising results, several limitations should be acknowledged. Its concurrent design requires substantial coordination and cognitive effort, which may be difficult to manage in schools without adequate structural support. Time constraints also limited the depth of teacher training and reflection activities, and the absence of long-term follow-up restricted insights into the model's sustained impact. The study involved only STEM teachers, which aligns with CTRM's inquiry-based focus but limits the generalizability of the findings to non-STEM disciplines. Given the limited sample size and scope, further research involving larger and more diverse participant groups is needed to strengthen generalizability. Teacher responses relied on self-reported data, which may introduce response bias, even though their instructional impact was indirectly reflected in student outputs evaluated by external experts using standardized rubrics. Additionally, the lack of a control group limits the ability to establish causal relationships, as the improvement observed

TABLE 6 SWOT analysis of the concurrent training and reflection model (CTRM).

Strengths	Weaknesses	Opportunities	Threats
Comprehensive research training provides teachers with essential skills and knowledge.	Short course timeline limiting in-depth skill mastery.	Extend course duration to a full semester for better learning outcomes.	Difficulty in implementing research-based techniques without ongoing support.
Emphasis on practical, application-focused learning with immediate classroom application.	Content misalignment with excessive focus on social science methods over STEM.	Enhance course content to include advanced skills (e.g., digital tools, data analysis).	Institutional resistance to adopting research-based methodologies.
Tailored to meet the specific needs and backgrounds of participating teachers.	Challenging follow-up logistics, especially in rural and remote schools.	Development as a platform for ongoing professional development.	Teachers are struggling to balance training with existing responsibilities.
Incorporation of a groundbreaking research course for students beyond standard curriculum.	Complex course content for high school students.	Promote a culture of inquiry and research among teachers and students.	Teacher resistance to adopting new research methodologies.
High teacher engagement and 100% retention rate among participants.	Resource-intensive implementation requires significant time, funding, and personnel.	Encourage teacher collaboration on research projects for knowledge-sharing.	Lack of innovation in teacher projects, relying on existing ideas.
Interactive workshop design, promoting active learning for both teachers and students.	Limited accessibility for teachers in remote or underprivileged areas.	Integrate the research-based training model into the school curriculum.	–
Positive learning environment with motivated teachers and students.	Complex impact assessment due to the need for continuous monitoring.	–	–
Statistically significant improvements in teachers' research knowledge and skills.	Limited innovation among teachers, with reliance on existing research ideas.	–	–
Student skill showcase through research posters and STEM prototypes.	–	–	–
Constructive feedback mechanism for continuous program improvement.	–	–	–
Adaptable teaching practices with teachers integrating new skills effectively.	–	–	–
Sustained support through regular follow-up sessions, maintaining engagement.	–	–	–

improvements could be influenced by prior training or concurrent initiatives. Student perceptions of their learning experiences were not collected, which limits the understanding of how the intervention was received at the learner level. Finally, disparities in school infrastructure such as access to laboratories and research tools affected the consistency of implementation across sites. As the study was conducted within Qatar's public school system, the transferability of findings to other educational settings may also be limited.

Broader implications and future applications

This study contributes to ongoing discussions about teacher professional development by introducing CTRM, a phased and research-based model grounded in RCT. The model supports teacher growth through classroom implementation, reflective practice, and continuous mentoring. It helps bridge the gap between theoretical learning and actual classroom practice. Beyond the current implementation, CTRM shows strong potential for use in other subject areas and educational levels. Future studies could explore its application in fields like the humanities and arts, where research may be more interpretive. The model also offers a useful structure for including research training in pre-service teacher education and national licensing systems. At the policy level, CTRM supports global education goals by encouraging inquiry-based teaching and collaboration across disciplines. Including the model in ongoing professional development programs could improve teaching quality and help build a research-driven school culture. Facilitators suggested that future implementations span a full academic semester to allow more time for student projects and deeper learning. In addition, partnerships between schools and universities could help provide access to resources like laboratories and data analysis tools. With continued refinement and wider testing, CTRM has the potential to become a scalable and sustainable model for professional development, one that supports both teacher growth and student engagement.

Conclusion

This study introduced the Concurrent Training and Reflection Model (CTRM), a research-based professional development framework designed for in-service teachers. CTRM successfully integrated structured research training with reflective teaching strategies, enabling teachers to strengthen their research skills while guiding students in inquiry-based projects. The model led to significant improvements in teachers' understanding of research methodology and research practices, as validated through a mixed-methods evaluation. These findings highlight the value of combining training and reflection to bridge theoretical learning with practical application. The CTRM model, tested with in-service teachers in Qatar, demonstrates how research-based and reflective strategies can be transformed into a sustainable and practical approach to teacher development. Moreover, it supports the broader implementation of informal learning modules for K–12 educators and promotes STEM-integrated research literacy across educational contexts.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was approved by the ethics committee of Qatar University with the ethical approval reference QU-IRB 136/2024-EA and informed consent was obtained from all subjects involved in the study.

Author contributions

NA-T: Writing – review & editing, Methodology, Project administration, Resources. ZA: Methodology, Writing – review & editing, Validation. JB: Validation, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1583071/full#supplementary-material

References

Abu-Tineh, A. M., and Sadiq, H. M. (2018). Characteristics and models of effective professional development: the case of school teachers in Qatar. *Prof. Dev. Educ.* 44, 311–322. doi: 10.1080/19415257.2017.1306788

Alfaidi, S. D. A., and Elhassan, F. A. M. (2020). The role of in-service training programs in teachers development. *Int. J. Learn. Teach.* 6, 191–195. doi: 10.18178/ijlt.6.3.191-195

Alkhair, S., Ali, R. A. A., Elhawary, E. F. M., Al-Ejji, M. M., Ahmad, Z., Al-Thani, N. J., et al. (2022). Cultivating STEM interest in high school students through computer-assisted COVID-19 pandemic awareness course, Singapore: International Institute of Knowledge Innovation and Invention. 2.

Al-Thani, N. J., and Ahmad, Z. (2025). Teaching and learning with research cognitive theory: unlocking curiosity and creativity for problem-solving skills. Berlin, Germany: Springer Nature.

Al-Thani, W. A., Ari, I., and Koç, M. (2021). Education as a critical factor of sustainability: case study in Qatar from the teachers' development perspective. *Sustain. For.* 13:11525. doi: 10.3390/su132011525

Al-Thani, N. J., Saad, A., Siby, N., Bhadra, J., and Ahmad, Z. (2022). The role of multidisciplinary chemistry informal research programs in building research competencies and attitudes. *J. Chem. Educ.* 99, 1957–1970. doi: 10.1021/acs.jchemed.2c00088

Al-Thani, N. J., Santhosh, M. E., Bhadra, J., and Ahmad, Z. (2023). The prominent roles of undergraduate mentors in an online near-peer mentoring model. *Sustain. For.* 15:3020. doi: 10.3390/su15043020

Appelbaum, M., Cooper, H., Kline, R. B., Mayo-Wilson, E., Nezu, A. M., and Rao, S. M. (2018). Journal article reporting standards for quantitative research in psychology: the APA publications and communications board task force report. *Am. Psychol.* 73:3. doi: 10.1037/amp0000191

Bandura, A. (1986). Social foundations of thought and action, The book Social Foundations of Thought and Action: A Social Cognitive Theory. vol. *2*. Englewood Cliffs, NJ, 23–28.

Bandura, A., and Walters, R. H. (1977). Social learning theory, vol. *1*. New Jersey, USA: Prentice hall Englewood Cliffs, NJ.

Bayar, A., and Kösterelioğlu, İ. (2014). Satisfaction levels of teachers in professional development activities in Turkey. *Turk. Stud.* 9, 321–333. doi: 10.7827/TurkishStudies.6354

Black, P., and Wiliam, D. (2018). Classroom assessment and pedagogy. *Assess. Educ. Prin. Policy Pract.* 25, 551–575. doi: 10.1080/0969594X.2018.1441807

Cohen, L., Manion, L., and Morrison, K. (2017). Inferential statistics: difference tests, in research methods in education, 2017 Oct 12, pp. 776–801. Routledge. Available online at: http://www.taylorfrancis.com/chapters/edit/10.4324/9781315456539-41/inferential-statistics-louis-cohen-lawrence-manion-keith-morrison

Darling-Hammond, L., Hyler, M. E., Sheffield, R., and Gardner, M. (2018). How California school districts can support best practices in effective teacher professional development. Learning Policy Institute. Available online at: https://learningpolicyinstitute.org/sites/default/files/productfiles/CA_Effective_Teacher_Professional_Development_FACTSHEET.pdf (Accessed January 2018).

Dewi, L. R., and Kartowagiran, B. (2018). An evaluation of internship program by using Kirkpatrick evaluation model. *REID* 4, 155–163. doi: 10.21831/reid.v4i2.22495

Dixon, K., and Scott, S. (2015). Quality in higher education the evaluation of an offshore professional-development programme as part of a university's strategic plan: a case study approach, Philadelphia, USA: Taylor & Francis, Ltd. 37–41.

Genvieve, N. (2017). Challenges of administering teacher education programme in Kenyan universities. *J. Educ. Pract.* 8, 30–33. https://eric.ed.gov/?id=EJ1143854

Guraya, S. Y., and Chen, S. (2019). The impact and effectiveness of faculty development program in fostering the faculty's knowledge, skills, and professional competence: a systematic review and meta-analysis. *Saudi J. Biol. Sci.* 26, 688–697. doi: 10.1016/j.sjbs.2017.10.024

Hassanein, E. E., Alshaboul, Y. M., and Ibrahim, S. (2021). The impact of teacher preparation on preservice teachers' attitudes toward inclusive education in Qatar. *Heliyon* 7, 1–8. doi: 10.1016/j.heliyon.2021.e07925

Iftikhar, S., Fu, Y., Naureen, S., Cao, Y., and Zhou, C. (2022). Cascading of teachers training at higher education in Pakistan: an evaluation of a faculty professional development program. *Eval. Program Plann.* 94:102130. doi: 10.1016/j.evalprogplan.2022.102130

Jain, S. (2014). Methods of training programmes evaluation: a review. *J. Commer.* 6:19. doi: 10.1007/s43621-025-01024-z

Jurkowski, S., and Abramczyk, A. (2024). Collaboration in in-service teacher training-the missing link between empirical evidence and practice? *J. Educ. Teach.* 50, 550–563. doi: 10.1080/02607476.2024.2327062

Karkouti, I. M., Abu-Shawish, R. K., and Romanowski, M. H. (2022). Teachers' understandings of the social and professional support needed to implement change in Qatar. *Heliyon* 8:8818. doi: 10.1016/j.heliyon.2022.e08818

Kirkpatrick, D. L. (1959). Techniques for evaluating training programs. *J. Am Soc Train Direct.* 13, 3–9.

Kurniawati, F., De Boer, A. A., Minnaert, A. E. M. G., and Mangunsong, F. (2017). Evaluating the effect of a teacher training programme on the primary teachers' attitudes, knowledge and teaching strategies regarding special educational needs. *Educ. Psychol.* 37, 287–297. doi: 10.1080/01443410.2016.1176125

Leal Filho, W., Viera Trevisan, L., Sivapalan, S., Mazhar, M., Kounani, A., Mbah, M. F., et al. (2025). Assessing the impacts of sustainability teaching at higher education institutions. *Discov. Sustain.* 6:227. doi: 10.52547/edcj.15.48.44

Lee, S. S., and Zahir, L. (2021). Applying global models of teacher development to improve student outcomes: insights from a teacher development & leadership program in Qatar. *Gulf Educ. Soc. Policy Rev.* 2, 46–68. doi: 10.18502/gespr.v2i1.9308

Liu, J., Hasson, E. P., Barnett, Z. D., and Zhang, P. (2011). A survey on computer science K-12 outreach: teacher training programs. Frontiers in education conference (FIE), Rapid City, SD, USA, T4F-1–T4F-6.

Meng, S. (2023). Enhancing teaching and learning: aligning instructional practices with education quality standards. *Res. Adv. Educ.* 2, 17–31. doi: 10.56397/RAE.2023.07.04

Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., and French, B. (2021). Teachers' role in students' learning at a project-based STEM high school: implications for teacher education. *Int. J. Sci. Math. Educ.* 19, 1103–1123. doi: 10.1007/s10763-020-10108-3

Nasser, R. (2017). Qatar's educational reform past and future: challenges in teacher development. *Open Rev. Educ. Res.* 4, 1–19. doi: 10.1080/23265507.2016.1266693

Nasser, R., and Romanowski, M. (2011). Teacher perceptions of professional development in the context of national educational reform: the case of Qatar. *Int. J. Train. Dev.* 15, 158–168. doi: 10.1111/j.1468-2419.2011.00377.x

Norouzi, S., and Salajegheh, M. (2023). A systematic approach in design, planning and implementation of purposeful faculty empowerment program. *J. Med. Educ. Dev.* 15, 44–51. doi: 10.31098/ijtaese.v4i2.1020

Oestar, J., and Marzo, C. (2022). Teachers as researchers: skills and challenges in action research making. *Int. J. Theory Appl. Element. Sec. Sch. Educ.* 4, 95–104. doi: 10.17051/ilkonline.2020.696690

Öztürk, M. (2019). An evaluation of an innovative in-service teacher training model in Turkey. *Int. J. High. Educ.* 8, 23–36. doi: 10.5430/ijhe.v8n1p23

Philibert, I., Konopasek, L., and Riddle, J. (2019). The international literature on teaching faculty development in English-language journals: a scoping review and recommendations for core topics. *J. Grad. Med. Educ.* 11, 47–63. doi: 10.4300/JGME-D-19-00174

Phuong, T. T., Cole, S. C., and Zarestky, J. (2018). A systematic literature review of faculty development for teacher educators. *Higher Educ. Res.* 37, 373–389. doi: 10.1080/07294360.2017.1351423

Piryani, R. M., Dhungana, G. P., Piryani, S., and Sharma Neupane, M. (2018). Evaluation of teachers training workshop at kirkpatrick level 1 using retro–pre questionnaire. *Adv. Med. Educ. Pract.* 9, 453–457. doi: 10.2147/AMEP.S154166

Popova, A., Evans, D. K., Breeding, M. E., and Arancibia, V. (2022). Teacher professional development around the world: the gap between evidence and practice. *World Bank Res. Obs.* 37, 107–136. doi: 10.1093/wbro/lkab006

Putman, S. M., and Polly, D. (2021). Examining the development and implementation of an embedded, multi-semester internship: preliminary perceptions of teacher education candidates, clinical educators, and university faculty. *Peabody J. Educ.* 96, 99–111. doi: 10.1080/0161956X.2020.1864250

Rodriguez, J. A., Condom-bosch, J. L., Ruiz, L., Oliver, E., and Oliver, E. (2020). On the shoulders of giants: Benefits of participating in a dialogic professional development program for in-service teachers. *Front. Psychol.* 11, 1–10. doi: 10.3389/fpsyg.2020.00005

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books.

Shah, A. A., Sarwar, M., and Hussain, S. (2017). Higher education personnel trainers competence. *Sindh Univ. J. Educ.* 46, 103–124. doi: 10.1080/19415257.2017.1306788.

Siddiqui, K. A., Mughal, S. H., Soomro, I. A., and Dool, M. A. (2021). Teacher training in Pakistan: overview of challenges and their suggested solutions. *Int. J. Educ. Res.* 2, 215–223. doi: 10.46245/ijorer.v2i2.91

Slade, M. L., Burnham, T. J., Catalana, S. M., and Waters, T. (2019). The impact of reflective practice on teacher candidates' learning. *Int. J. Sch. Teach. Learn.* 13:15. doi: 10.55056/etq.11

Taguma, M., Feron, E., and Lim, M. H. (2018). "Future of education and skills 2030: conceptual learning framework" in eds. Taguma, M. Feron, E. and Hwee Lim, M. Organization of economic co-operation and development. Paris, France: OECD Publishing.

Tao, Y., Meng, Y., Gao, Z., and Yang, X. (2022). Perceived teacher support, student engagement, and academic achievement: a meta-analysis. *Educ. Psychol.* 42, 401–420. doi: 10.1080/01443410.2022.2033168

Tran Ho, U., Lepage, B. A., and Fang, W.-T. (2023). Environmental education in pre-school teacher training programs in Vietnam: situations and challenges. *J. Early Child. Teach. Educ.* 44, 703–722. doi: 10.1080/10901027.2022.2136552

Tumkaya, G. S., and Miller, S. (2020). The preceptions of pre and in-service teachers' self-efficacy regarding inlcusive practices: a systematised review. *Element. Educ.* 19, 1061–1077.

Van den Hurk, A., Meelissen, M., and van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *Int. J. Sci. Educ.* 41, 150–164. doi: 10.1080/09500693.2018.1540897

Zhorova, I., Kokhanovska, O., Khudenko, O., Osypova, N., and Kuzminska, O. (2022). Teachers' training for the use of digital tools of the formative assessment in the implementation of the concept of the new Ukrainian school. *Educ. Technol. Quart.* 2022, 56–72.