Development of a creative collaborative with critical experience learning model to improve technological pedagogical and content knowledge of preservice chemistry teachers

Mohan Taufiq Mashuri[1], Suyatno Sutoyo[2*], Utiya Azizah[3]

[1,2,3]State University of Surabaya, Jl. Kampus Unesa Ketintang, Surabaya, Indonesia.

*Corresponding author: Suyatno Sutoyo (Email: suyatno@unesa.ac.id)

ABSTRACT

Purpose: This research aims to produce a valid, practical and effective 3CEL learning model which is an abbreviation of creative collaborative with critical experience learning to improve the Technological Pedagogical and Content Knowledge (TPACK) of preservice chemistry teachers.

Design/Methodology/Approach: This is development research that was carried out in four main stages: 1) preliminary stage (literature and field study), 2) development stage (hypothetical model or prototype), 3) validation stage and 4) model implementation stage (final 3CEL model). The data collection techniques used in this research are validation, observation, test and questionnaires.

Findings: The final 3CEL learning model along with supporting learning tools and validated TPACK measurement instruments. The results of validation showed that the 3CEL learning model along with its supporting learning tools and TPACK measurement instruments were very valid and reliable. The results of the 3CEL learning model implementation in the experimental class and the control class proved that the 3CEL learning model was very effective in improving the TPACK abilities of preservice chemistry teachers.

Conclusion: This research produced a new learning model (3CEL) that is valid, practical and effective in improving the TPACK of preservice chemistry teachers. The syntax of the resulting 3CEL learning model consists of five phases: 1) orientation, 2) collaborative planning, 3) presenting, 4) simulation and 5) reflection based on critical experience.

Keywords: *3CEL learning model, Collaboration, Creativity, Critical experience, Preservice chemistry teacher, TPACK.*

1. INTRODUCTION

Indonesia still has problems related to teacher quality (Agustin, Liliasari, Sinaga, & Rochintaniawati, 2019). The quality of teachers greatly determines the implementation of the learning process. The data shows that the academic qualifications of teachers in Indonesia are lower than the requirements. In addition, technological developments in the 4.0 era require teachers to master technology and use it in the learning process (Oduro-Okyireh et al., 2024; Sutoyo, Agustini, & Fikriyati, 2023; Werner, 2020) because the very rapid development of technology will have a significant impact on education. Thus, teachers must be able to integrate technology into the learning process to achieve learning goals. Other research also shows that teachers have not mastered and applied technology to support the learning process (Budiana, Sjarifah, & Bakti, 2015). Research at the elementary, middle and high school levels shows that 1) 52.75% of teachers rarely use laptops for learning. 2) 62.15% of teachers rarely use Information and Communications Technology (ICT) in learning. 3) 34.95% of teachers lack mastery of ICT and 4) 10.03% of facilities and infrastructure do not support the process of learning using ICT (Syukur, 2014).

The latest concepts that can be applied to integrating technology into the learning process are Technological Pedagogical and Content Knowledge (TPACK) (Shulman, 1986). This concept is very helpful in representing abstract concepts in science learning, especially chemistry subjects. Some research that has previously been carried out

Nurture**: Volume 18, Issue 3, 686-697, **2024
***Online ISSN**: 1994-1633/ **Print ISSN**: 1994-1625*
***DOI**: 10.55951/nurture.v18i3.751| **URL**:* www.nurture.org.pk
***Publisher:** Nurture Publishing Group*

related to TPACK is TPACK-P (Technological Pedagogical Content Knowledge-Programming) (Kim & Lee, 2018), Microteaching Lesson Study (MLS) (Cavin, 2007), Workshop and Training (Ersanli, 2016) teacher design teams (Kafyulilo, Fisser, & Voogt, 2013) teacher preparation programs (Wang, 2016), preparation program (Sickel, 2016), online professional development (Nazari, Nafissi, & Estaji, 2020) and TPACK-based courses (Tanak, 2020). However, the author has not come across any model development that is intended to enhance preservice chemistry teachers' TPACK.

Experience is another crucial component of a teacher's professionalism in addition to their technological proficiency (Kopish & Nestor, 2019). Inexperienced teachers tend to abstract concepts only by providing theoretical descriptions. This places a particular burden on students. It will be easier to perform abstraction by using technology or representation. Creative and collaborative skills are essential to support a teacher's experience and technological proficiency. Creativity will become an important skill in the coming decades (Brahim, Mohamed, Lahoussine, Hicham, & Said, 2024). Context and collaboration are also important to improve the quality of learning (European Political Strategy Centre, 2017).

The results of the literature review, theoretical support and empirical evidence that have been obtained strengthen the fact that innovation is currently needed in the form of learning models to equip preservice chemistry teachers and increase their TPACK. These learning innovations must be able to integrate and accommodate the importance of creative thinking skills, collaborative skills and critical experiences for preservice chemistry teachers. Researchers developed a learning model termed Creative Collaborative with Critical Experience Learning (3CEL) to provide a solution. The 3CEL learning model has advantages that can cover the shortcomings of previous learning models. The research question asked in this study is whether the 3CEL learning model is valid, practical and effective in improving the TPACK of preservice chemistry teachers. The hypothesis put forward in this research is that the 3CEL learning model can significantly increase the TPACK ability of preservice chemistry teachers. The results of this research can be an alternative solution for increasing the TPACK of preservice chemistry teachers which has not previously been studied in more depth.

2. LITERATURE REVIEW

2.1. Technological Pedagogical and Content Knowledge (TPACK)

The use of technology has now entered the world of education on a large scale as science and technology continue to develop. Information related to education can now be easily accessed using technology. However, the use of technology in learning also has its challenges. Technological pedagogical and content knowledge also commonly called TPACK is an idea for integrating technology in learning that is widely discussed in the field of education. TPACK has broad coverage in various elements of education. The concept of TPACK first appeared in 2003 to make pronunciation easier (Chai, Koh, & Tsai, 2013). TPACK is a framework that is considered to be a link between the use of technology in the learning process in the classroom (Koehler, Mishra, & Cain, 2013).

TPACK is divided into three main components, Technological Knowledge (TK), Content Knowledge (CK) and Pedagogical Knowledge (PK) (Mishra & Koehler, 2006). The other components of TPACK were TK, PK and CK, Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK) and Technological Pedagogical and Content Knowledge (TPACK), so that overall TPACK consists of seven components. All TPACK components are important for teachers or preservice teachers to master in the learning process. These seven knowledge components are the characteristics of the TPACK concept in the process of development, implementation and assessment in the learning process. Researchers have conducted various studies to improve the TPACK of students, teachers or preservice teachers to provide a variety of learning models. Some of the models applied include TPACK-Programming (Kim & Lee, 2018), Microteaching Lesson Study (MLS) (Cavin, 2007), Workshop and Training (Ersanli, 2016), Teacher Design Teams (Kafyulilo et al., 2013), Teacher Preparation Programs (Wang, 2016), Preparation Program (Sickel, 2016), Online Professional Development (Nazari et al., 2020) and TPACK-Based Course (Tanak, 2020).

2.2. Collaborative Learning

Learning by small groups of students who work together to obtain maximum results is called collaborative learning (Wardhani, Sunandar, Asim, Samawi, & Ediyanto, 2022). Collaborative learning places students with diverse

Nurture**: Volume 18, Issue 3, 686-697, **2024
***Online ISSN**: 1994-1633/ **Print ISSN**: 1994-1625*
***DOI**: 10.55951/nurture.v18i3.751| **URL**:* www.nurture.org.pk
***Publisher:** Nurture Publishing Group*

backgrounds and abilities together in small groups to achieve certain learning goals (Sopiani, Ratminingsih, & Saputra, 2022). Researchers developed a learning model termed Creative Collaborative with Critical Experience Learning (3CEL) to provide a solution. Students are taught cooperation through collaborative learning which prepares them to share responsibility for completing assignments and achieving significant group success.

The duties, roles and functions of each group member are different to achieve the same goal. Collaborative learning allows all participants to benefit because information or data sources and references in collaborative learning are spread across all group members, not just one or two members. Students can learn from their friends, teachers and even a teacher can gain new insights or knowledge from the opinions, ideas or experiences of their students during the learning process. Collaboration is the key to success in collaborative learning. If one member of the group does not carry out its function then the task will not be fulfilled and it will be detrimental to the group itself. This character or learning is important to get used to so that it can be applied in everyday life.

Collaborative learning is often associated with cooperative learning. Several researchers point out the differences between collaborative learning and cooperative learning (Amiruddin, 2019; Veldman & Kostons, 2019). Cooperative learning is a process carried out to help students interact with each other to achieve learning goals. Cooperative learning places the teacher as the main control and has a role in managing learning whereas in collaborative learning, the teacher provides more opportunities for students to collaborate and find new ideas to achieve the desired learning goals (Rifani & Lobja, 2019; Wardhani et al., 2022). Collaborative learning indicators consist of seven main components: (1) sense of dependence, (2) intensive interaction, (3) group responsibility, (4) interpersonal communication, (5) teacher as mediator, (6) knowledge sharing and (7) group evaluation (Amiruddin, 2019).

2.3. Creative Thinking Skills

Creative thinking is a process or ability that refers to the ability to generate and develop various ideas to solve various problems with various alternative solutions (Putri & Alberida, 2022). Creative thinking skills are consistent and original so they are specific to each individual (Magdalena, Saridevita, Novyanti, & Destiyantari, 2021). The four core components of creative thinking skills are originality, elaboration, flexibility and fluency (Kaufman, Plucker, & Baer, 2008). Each component has an important part and is also an indicator that can be used to measure a person's level of critical thinking skills. Creative thinking skills are also often called divergent thinking skills. This skill is oriented towards an answer that can be trained in students (Ramalingam, Anderson, Duckworth, Scoular, & Heard, 2020). This skill is intended to accustom students to having varied or diverse perspectives. Students will subsequently be able to develop solutions with a more accurate probability.

3. METHOD

3.1. Research Design

This research uses an Educational Design Research (EDR) design (Plomp, 2007). The aim is to develop the Creative Collaborative with Critical Experience Learning (3CEL) learning model as a valid, practical and effective product for increasing the TPACK of preservice chemistry teachers. The implementation of the 3CEL learning model is supported by various learning tools consisting of Semester Learning Plans (SLP), Lecture Program Units (LPU), Preservice Teacher Activity Sheets (PTAS), Critical Experience Sheets (CES), microteaching textbooks and instruments to measure the validity, practicality and effectiveness of the 3CEL model. In general, the development of the 3CEL learning model is divided into four stages. The first stage is a preliminary study consisting of a literature study, a field study as well as a description and analysis of the findings. The second stage is model development which consists of developing a model book and supporting learning tools. The third stage is validation. The fourth stage is model implementation which consists of limited trials and extensive trials. This is as seen in Figure 1.

Nurture**: Volume 18, Issue 3, 686-697, **2024
***Online ISSN**: 1994-1633/ **Print ISSN**: 1994-1625*
***DOI**: 10.55951/nurture.v18i3.751| **URL**: www.nurture.org.pk*
***Publisher:** Nurture Publishing Group*

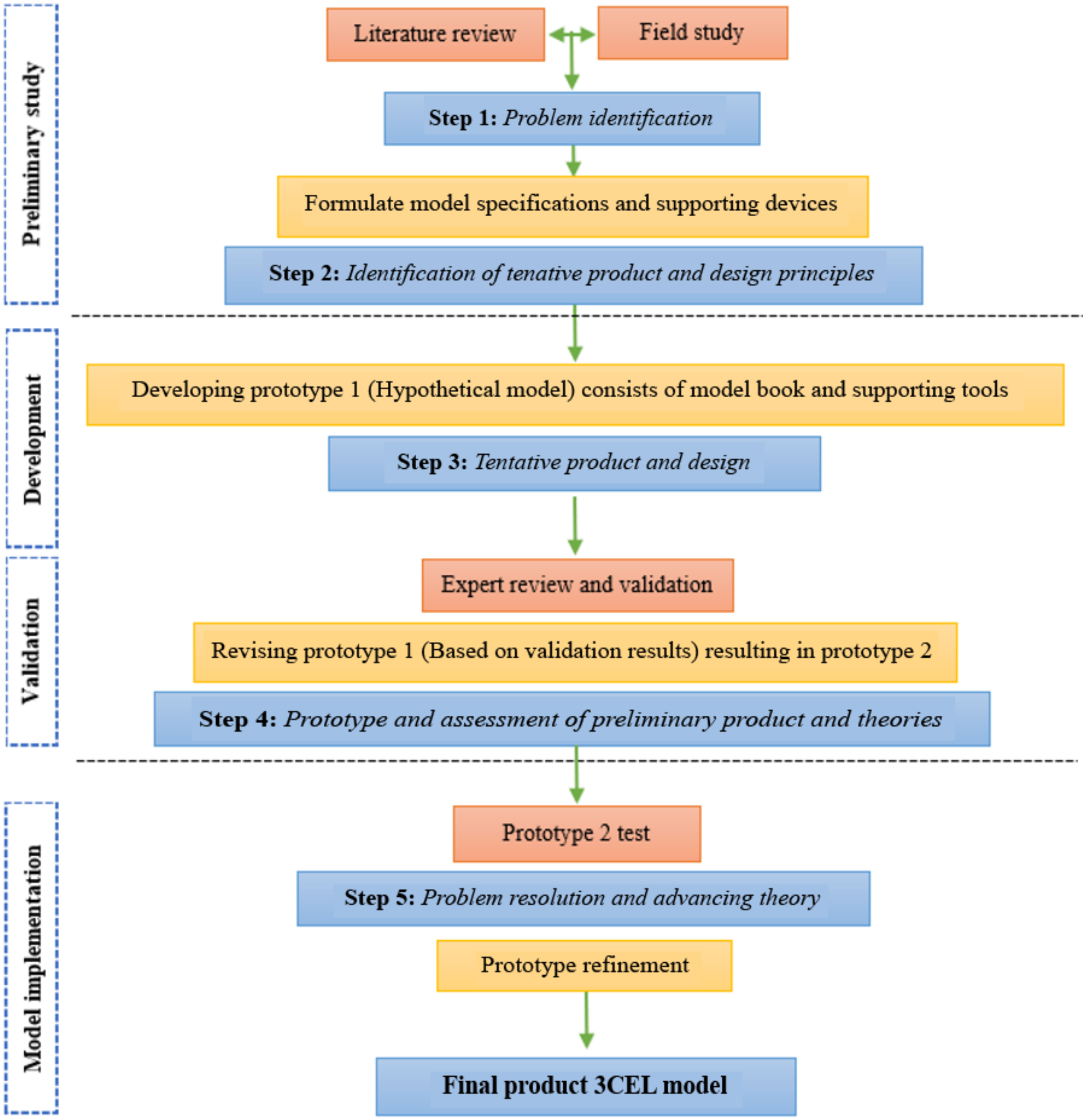


Figure 1. Research stages.

3.2. Research Population

The study's participants consisted of 26 preservice chemistry teachers who participated in microteaching courses at the Tadris Chemistry Study Programme of the Mataram State Islamic University. All preservice chemistry teachers who take microteaching courses in the fifth semester of the Tadris Chemistry Study Program of the Mataram State Islamic University were divided into two classes, namely class A and class B. Class A was the experimental class and class B was the control class and they were determined randomly.

3.3. Instrument

The data collection techniques used in this research are validation techniques, observation, tests and questionnaires. The research instruments used were 3CEL learning model validation instruments, 3CEL learning model device validation instrument, implementation observation sheet, obstacle observation sheet during learning using the 3CEL learning model, TPACK assessment instrument and response questionnaire for preservice

Nurture: *Volume 18, Issue 3, 686-697,* ***2024***
Online ISSN*: 1994-1633/* ***Print ISSN****: 1994-1625*
DOI*: 10.55951/nurture.v18i3.751|* ***URL****: www.nurture.org.pk*
Publisher: *Nurture Publishing Group*

chemistry teachers. The results obtained were then analyzed descriptively, qualitatively and quantitatively. Quantitative analysis was carried out by calculating N-gain and carrying out an independent t-test.

3.4. Validity and Reliability of the 3CEL Learning Model and Learning Tools

Validation tools were developed based on predetermined parameters (indicators). The instrument used to measure the validity of the 3CEL learning model is the 3CEL learning model validation sheet. It will be possible to evaluate the validity of the learning model tools which include the Critical Experience Sheets (CES), Lecture Programme Units (LPU), Preservice Teacher Activity Sheets (PTAS), Microteaching Textbooks and Semester Learning Plans through the use of validation sheets. Research instruments such as TPACK questionnaires, student response questionnaires, TPACK observation sheets, tests TPACK, model implementation observation sheets, notes on learning barriers and teaching practice assessment tools are used to ascertain validity. Students use the validation sheet for the TPACK questionnaire, the observation sheet for TPACK, the TPACK for the test, the student response questionnaire, the models for the implementation observation sheet, the comments on learning barriers, and the teaching practice assessment tools. Validity is determined by calculating the average value of each aspect (indicators) based on the results of the assessment of three validators. Learning tools are said to have a degree of validity which is good if the minimum level of validity achieved is valid enough. The validity of the learning model and supporting learning tools for the 3CEL learning model was analyzed using qualitative and descriptive techniques. The average score (P) obtained from the results is adjusted to the assessment criteria (Purwanto, 2010) presented in Table 1. The calculation of the reliability of the 3CEL learning model and learning tools is based on interobserver agreement obtained from statistical analysis of percentages of agreement (Borich, 2011).

Table 1. Evaluation criteria for validation of learning models and learning tools.

Score interval	Criteria	Description
$3.25 < P \leq 4.00$	Very valid	Can be used without revision.
$2.50 < P \leq 3.25$	Valid	Can be used with minor revisions.
$1.75 < P \leq 2.50$	Less valid	Can be used with multiple revisions.
$1.00 \leq P \leq 1.75$	Not valid	It cannot be used yet and still requires consultation.

4. RESULTS

The results of the development of the 3CEL learning model can be explained in the following section:

4.1. 3CEL Hypothetical Model

The 3CEL learning model was developed with the aim of increasing the TPACK of preservice chemistry teachers. This model was developed based on various studies of learning models aimed at facilitating students in improving teaching skills and integrating technology. In addition, this approach was developed to support microteaching learning which is one of the primary professional development programmes is for preservice teachers. Several models previously applied or used to improve and develop TPACK include TPACK-P, (1) Microteaching Lesson Study (MLS), (2) workshop and training, (3) teacher design teams, (4) teacher preparation programs, (5) preparation program, (6) online professional development, (7) TPACK-based courses (8).

It showed the importance of developing learning models that can enhance preservice teachers' TPACK particularly in chemistry courses by examining previously conducted research and preliminary data. The model developed must meet several criteria, including 1) it must have several advantages that differentiate it from models that have previously been developed by researchers (experts). 2) It must be able to be applied within the curriculum framework of preservice teachers (Nazari et al., 2020; Tanak, 2020).

These various theoretical and empirical studies and reviews show the importance of creativity and collaboration in learning for preservice teachers. The combination of these two components has been proven in various studies to show positive results in improving student performance, competence and achievement compared to individual or competitive models. The model developed to increase the TPACK of preservice chemistry teachers is named 3CEL (Creative Collaborative with Critical Experience Learning) which will later be implemented in microteaching courses to prepare preservice chemistry teachers to become better teacher candidates. The development of the 3CEL learning model based on each stage or model syntax is based on the collaborative learning model (Husain, 2020),

Nurture: Volume 18, Issue 3, 686-697, ***2024***
Online ISSN*: 1994-1633/* ***Print ISSN****: 1994-1625*
DOI*: 10.55951/nurture.v18i3.751|* ***URL****: www.nurture.org.pk*
Publisher: *Nurture Publishing Group*

microteaching (Karlström & Hamza, 2019; Remesh, 2013) and Microteaching Lesson Study (MLS) (Cavin, 2007). Each of the models underlying 3CEL, namely the collaborative learning model, microteaching and microteaching lesson study (MLS) has several differences from one another. This is shown in Figure 2.

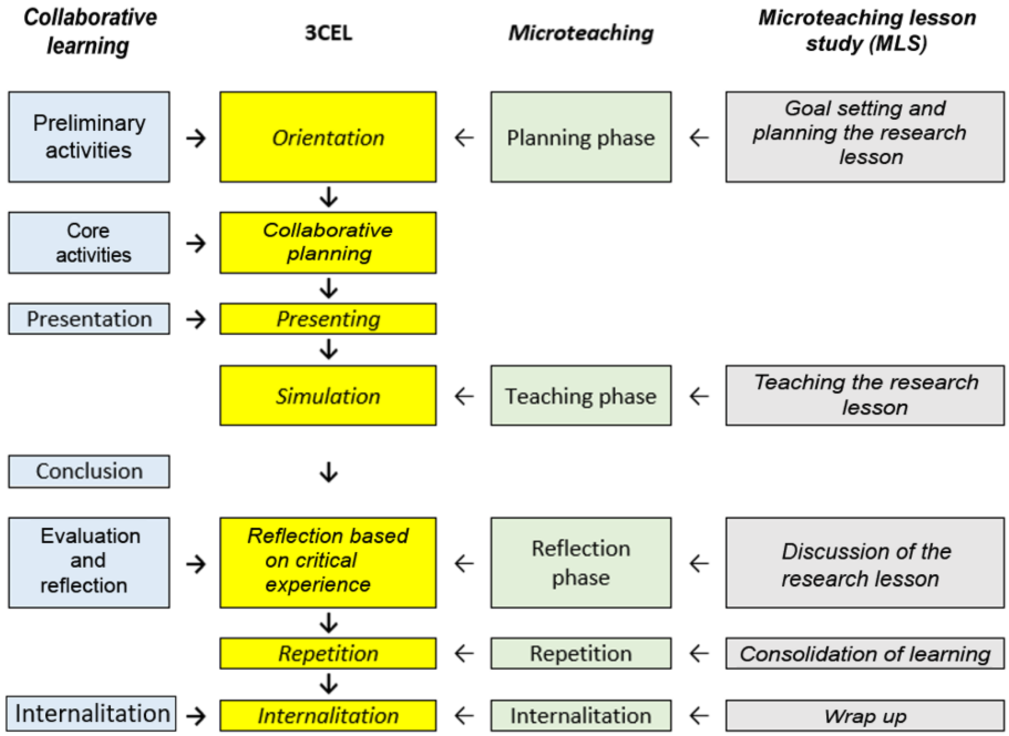


Figure 2. 3CEL hypothetical model.

4.2. 3CEL Learning Model Validation Results

The validation of the 3CEL learning model was carried out with the help of three experts in chemistry education. Learning model validity testing includes content validity and construct validity. The content validity assesses the need for model intervention and the construct validity assesses how the intervention model has been designed constructively and logically. All aspects of the validity of the content and construct of the 3CEL learning model have very valid criteria and categorized as reliable. The results of this research indicated that the 3CEL learning model has fulfilled the requirements for both content and construct validity. The validation results of the 3CEL hypothetical model are presented in Table 2.

Table 2. 3CEL learning model validation results.

No.	Component	Average	Category of validity	Reliability (%)	Category of reliability
1.	Content validity of the 3CEL learning model.	3.85	Very valid	96.83	Reliable
2.	Construct validity of the 3CEL learning model.	3.84	Very valid	96.82	Reliable

4.3. Result of Validation of 3CEL Learning Model Tools

The tools tested for content and construct validity were Semester Learning Plans (SLP), Lecture Program Units (LPU), Preservice Teacher Activity Sheets (PTAS), Microteaching Textbooks and Critical Experience Sheets (CES). Three validators assessed the construct validity of the learning tools supporting the 3CEL learning model that had been developed. The learning tools that have been developed have a very valid and a reliable category. These indicate that all learning tools are very suitable to be used to support the implementation of the 3CEL learning model. The validation results of the 3CEL learning model tools are presented in Table 3.

Nurture**: Volume 18, Issue 3, 686-697, **2024
***Online ISSN**: 1994-1633/ **Print ISSN**: 1994-1625*
***DOI**: 10.55951/nurture.v18i3.751| **URL**: www.nurture.org.pk*
***Publisher:** Nurture Publishing Group*

Table 3. Result of validation of 3cel learning model tools.

No.	Learning tools	Aspects	Average	Category of validity	Reliability (%)	Category of reliability
1.	Semester learning plans (SLP)	Content	3.93	Very valid	97.88	Reliable
		Construct	3.93	Very valid	98.09	Reliable
2.	Lecture program units (LPU)	Content	3.89	Very valid	95.77	Reliable
		Construct	3.83	Very valid	96.19	Reliable
3.	Preservice teacher activity sheets (PTAS)	Content	3.86	Very valid	95.92	Reliable
		Construct	3.85	Very valid	99.13	Reliable
4.	Microteaching textbooks	Content	3.83	Very valid	95.24	Reliable
		Construct	3.76	Very valid	98.64	Reliable
5.	Critical experience sheets (CES)	Content	3.83	Very valid	95.24	Reliable
		Construct	3.79	Very valid	95.83	Reliable

4.4. TPACK Measurement Instrument Validation Results

The TPACK assessment in this research was carried out using three types of instruments namely questionnaires, tests and observation sheets. Each TPACK assessment instrument was validated by three validators regarding content validity, construct validity, and language aspects. The TPACK questionnaire used consisted of 38 statement items. The TPACK test used in this research consists of 29 questions in multiple choice form. The TPACK observation sheet used in this research consists of 12 observation indicator items used to measure the seven components of TPACK. The TPACK measurement instrument showed a very valid category and an overall reliability value in the reliable category. A summary of the validation results of the TPACK measurement instrument is presented in Table 4.

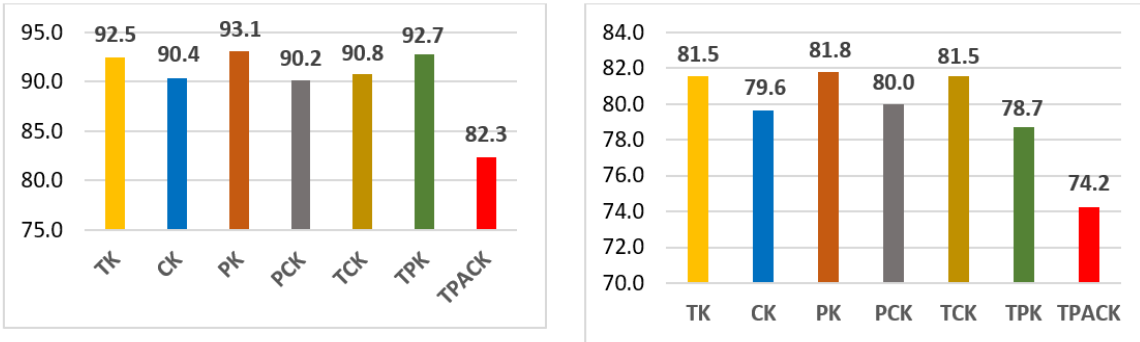
Table 4. TPACK measurement instrument validation results.

No.	Learning tools	Aspects	Average	Category of validity	Reliability (%)	Category of reliability
1.	Questionnaire	Content	3.78	Very valid	93.98	Reliable
		Construct	3.92	Very valid	97.99	Reliable
		Language	3.95	Very valid	98.50	Reliable
2.	Test	Content	3.76	Very valid	94.74	Reliable
		Construct	3.78	Very valid	95.40	Reliable
		Language	3.90	Very valid	97.04	Reliable
3.	Observation sheet	Content	3.67	Very valid	95.24	Reliable
		Construct	3.67	Very valid	92.86	Reliable

4.5. Results of the TPACK Ability Measurement of Preservice Chemistry Teachers

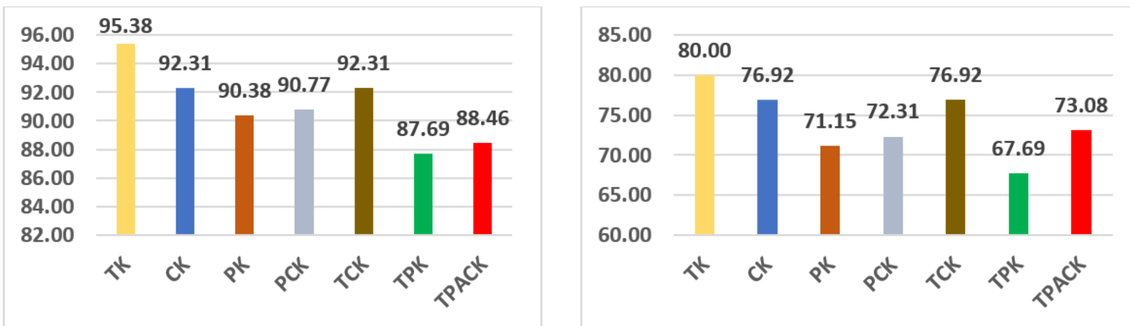
The implementation or trial of the 3CEL learning model was carried out in four meetings. The subjects were 26 fifth semester students of the Tadris Chemistry Study Program of the Mataram State Islamic University who were divided into two classes, namely class A and class B. Class A was the experimental class and class B was the control class and they were determined randomly. The TPACK abilities of preservice chemistry teachers were obtained using questionnaires and TPACK tests that had previously been validated. The questionnaire scores and test scores obtained were then analyzed to determine the effect of implementing the 3CEL learning model on the TPACK abilities of preservice chemistry teachers. It was 90.89 which was greater than the average for the control class, (79.88) based on the average score obtained from the questionnaire for the posttest for the experimental class. The results of the TPACK test scores also showed that the experimental class was superior to the control class, namely with an average score of 91.51 compared to 74.01. Figure 3 shows the findings of the TPACK questionnaire analysis and Figure 4 illustrates the results of the TPACK test.

Nurture: Volume 18, Issue 3, 686-697, ***2024***
Online ISSN*: 1994-1633/* ***Print ISSN****: 1994-1625*
DOI*: 10.55951/nurture.v18i3.751|* ***URL****:* www.nurture.org.pk
Publisher: *Nurture Publishing Group*



(a) (b)

Figure 3. TPACK questionnaire post-test score analysis results (a) Experimental class (b) Control class.



(a) (b)

Figure 4. TPACK post-test score analysis results (a) Experimental class (b) Control class.

Next is a different test to determine the significance of the 3CEL learning model on the TPACK of preservice chemistry teachers. The TPACK test scores and TPACK questionnaire scores were tested for normality using the Shapiro-Wilk test before the difference test was carried out. The test results show that the TPACK test score data and TPACK questionnaire scores are normally distributed because the p value is more than 0.05 (Santoso, 2014). The results of the normality test are presented in Table 5. The difference test was carried out using an independent t-test assisted by the Windows-based SPSS version 22. The test was carried out twice for the TPACK questionnaire score and for the TPACK tests score. The t-test for the TPACK questionnaire score between the control class and the experimental class indicated that there is a significant difference between the TPACK questionnaire scores for the experimental class and the control class as shown in Table 6. The t-test for the TPACK test score between the control class and the experimental class also indicated that there is a significant difference between the TPACK test scores for the experimental class and the control class as shown in Table 7. Thus, the 3CEL learning model is very effective in improving the TPACK abilities of preservice chemistry teachers.

Table 5. Results of the normality test for data for the experimental class and the control class.

Sample	Shapiro-Wilk			
	Data	Statistic	Sig	Result
Experimental class	Post-test TPACK questionnaire	0.944	0.200	Normal
	Post-test TPACK test	0.886	0.085	Normal
Control class	Posttest TPACK questionnaire	0.977	0.200	Normal
	Posttest TPACK test	0.964	0.812	Normal

Nurture: Volume 18, Issue 3, 686-697, ***2024***
Online ISSN*: 1994-1633/* ***Print ISSN****: 1994-1625*
DOI*: 10.55951/nurture.v18i3.751|* ***URL****: www.nurture.org.pk*
Publisher: *Nurture Publishing Group*

Table 6. Results of the t test for the TPACK questionnaire of the experimental class and the control class.

Data	N	df	t	Sig	Mean difference	Result
Post-test score of the TPACK questionnaire	26.000	24.000	3.753	0.001	11.012	Significantly difference

Table 7. Results of the t test for the TPACK test of the experimental class and the control class.

Data	N	Df	t	Sig	Mean difference	Result
Post-test score of the TPACK test	26.000	24.000	4.061	0.000	17.242	Significantly difference

5. DISCUSSION

5.1. 3CEL Hypothetical Model

The development of the 3CEL learning model based on the collaborative learning model (Husain, 2020), microteaching (Karlström & Hamza, 2019; Remesh, 2013) and Microteaching Lesson Study (MLS) (Cavin, 2007) construct five main phases. The first phase of the 3CEL model is orientation. This phase is designed to convey learning objectives, foster motivation, see initial abilities and equalize perceptions regarding planning and implementing learning. In this preparation phase, preservice chemistry teachers are given the challenge of reviewing the lesson plan, not being asked to prepare the lesson plan. Our goal is to learn more about the preservice chemistry teacher’s accurate level of lesson planning abilities as well as their attitude and areas of weakness. The second phase of the 3CEL learning model is collaborative planning. Preservice chemistry teachers work in collaborative groups to plan or develop a chemistry learning design that is considered most appropriate. The first step for each group is to determine the Basic Competency Achievement Indicators (BCAI) from the Core Competency (CC) and Basic Competency (BC) for chemical topics. This stage will be followed by a class discussion to determine the BCAI for all agreed-upon topics and the distribution of topics or BCAI to each group. Everyone still must participate and provide ideas even though it is done cooperatively in their various groups. This is in accordance with Vygotsky's social constructivist theory. The role of the lecturer is needed to provide direction in the distribution of material so that each face-to-face activity is not boring. The steps in this phase are carried out by peer teaching and other preservice teachers in one group and reflection is held to get suggestions for improvement. Work together in groups to practice documenting instructional experiences as Critical Experience Learning (CEL) narratives (Permana, Renda, & Margunayasa, 2020).

The third phase of the 3CEL learning model is presented. In this phase, preservice chemistry teachers conduct class discussions (in each collaborative group) to determine the BCAI for all agreed topics and the distribution of material or BCAI in each group in the previous phase. Each group presented the results of the design they had prepared. A complete learning design is obtained from all groups in one class. The fourth phase of the 3CEL learning model is simulation. In this phase, the activity of preservice chemistry teachers is to carry out learning independently. The teaching practice carried out individually by each student teacher will be a simulation of a design that was previously prepared in a collaborative group and has been provided with input in the collaborative group and in class discussions. In this stage, every preservice teacher who carries out the simulation is given feedback by his colleagues and lecturers in addition to completing critical experience in each teaching process which is the key experience when carrying out teaching practice. The goal of this method is to provide all preservice teachers with sufficient expertise and abilities to plan and carry out instructional strategies (Hasbullah, 2021). The fifth and final phase of the 3CEL learning model is reflection based on critical experience. In this phase, lecturer and student activities include 1) conducting program evaluations carried out after all preservice chemistry teacher students in the class have completed teaching practice. 2) Fill out a student and lecturer response questionnaire and 3) provide suggestions and opinions regarding the implementation of microteaching lessons.

5.2. 3CEL Learning Model Validation

The 3CEL learning model that has been developed is in line with various theoretical and empirical supports that support the preparation of the 3CEL learning model. The 3CEL learning model which was developed by prioritizing

Nurture: Volume 18, Issue 3, 686-697, ***2024***
***Online ISSN**: 1994-1633/* ***Print ISSN**: 1994-1625*
***DOI**: 10.55951/nurture.v18i3.751|* ***URL**:* www.nurture.org.pk
***Publisher:** Nurture Publishing Group*

the principles of collaboration, creativity and emphasizing differences in the critical experiences of each student can be the right solution for increasing the TPACK of preservice chemistry teachers. Various important factors have been accumulated in the 3CEL learning model so that it is very suitable to be used in microteaching learning to increase the TPACK of preservice chemistry teachers. This has been demonstrated by the validation results from each validator both in terms of content and construct. The 3CEL learning model has been created in accordance with the need to improve TPACK and by prioritizing updates from a scientific perspective, especially 21st century skills and mastery of technology. It is also believed that the 3CEL learning model presentation is adequate and suitable for use in the educational process.

5.3. TPACK Ability Measurement of Preservice Chemistry Teachers

Each phase of the 3CEL learning model has advantages as planned. The first phase, namely orientation provides a comprehensive overview of what preservice chemistry teachers must prepare for when implementing microteaching learning. In regular microteaching, preservice chemistry teachers prepare everything on their own but in implementing the 3CEL learning model, preservice chemistry teachers can share tasks for analyzing the lesson plan. The lack of knowledge of preservice chemistry teachers regarding various technologies is also overcome by joint studies in the second phase, collaborative planning. Each preservice teacher has diverse knowledge regarding chemistry learning applications together they can produce a learning plan that is expected to achieve chemistry learning objectives by integrating appropriate technology for each chemical concept being taught. The simulation phase also increases the confidence of preservice chemistry teachers in carrying out chemistry learning. Preservice teachers would feel afraid to carry out learning simulations because they would be assessed by lecturers and other preservice teachers for their work individually before using the 3CEL learning model. However, this did not occur after employing the 3CEL learning paradigm since the simulation was the outcome of cooperative teacher candidates' work.

The TPACK of preservice chemistry teachers increases rapidly if they use the 3CEL learning model. In its implementation, the 3CEL learning model is fun and lightens the burden on preservice chemistry teachers to create and implement lesson plans. This is caused by the implementation of collaborative work and repetition carried out in the 3CEL learning model. The 3CEL learning model is able to overcome teachers' difficulties in creating programs or applying learning technology (Kim & Lee, 2018). In its implementation, the 3CEL learning model does not require teachers to master programming languages. Furthermore, the 3CEL learning model can also increase the learning independence of preservice chemistry teachers in preparing for learning due to a lack of experience in teaching (Cavin, 2007; Ersanli, 2016; Kafyulilo et al., 2013). The 3CEL learning model can overcome various problems for students and teachers. Preservice teachers will participate in more learning replications when the 3CEL model is used. This will affect the quality of the learning. This is in line with the concept of critical experience learning promoted in the 3CEL learning model. Preservice chemistry teachers can increase the TPACK through learning experiences and critical experiences (Cooper, 2019).

6. CONCLUSION

The results of content and construct validation show that the 3CEL learning model along with its supporting learning tools and TPACK measurement instruments are very valid and reliable. The results of the independent t-test on the post-test scores of the experimental class and the post-test scores of the control class show that there is a significant difference between the TPACK abilities of preservice chemistry teachers who use the 3CEL learning model compared to preservice chemistry teachers who use the regular learning model. These prove that the 3CEL learning model is very valid, practical and effective in improving the TPACK abilities of preservice chemistry teacher students.

FUNDING

This research is supported by the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia (Grant number: B/ 51264/UN38.III.1/LK.04.00/2023).

INSTITUTIONAL REVIEW BOARD STATEMENT

The Ethical Committee of the Research Institutions and Community Service of the State University of Surabaya, Indonesia has granted approval for this study (Ref. No. 003/UN38.III.1/DL.01.02/2024).

TRANSPARENCY

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Designed and first drafted this study, S.M.K.; revised the paper, Y.J.P. and H.C.S. All authors have read and agreed to the published version of the manuscript.

ARTICLE HISTORY

Received: 17 January 2024/ Revised: 8 April 2024/ Accepted: 30 April 2024/ Published: 12 June 2024

REFERENCES

Agustin, R., Liliasari, S., Sinaga, P., & Rochintaniawati, D. (2019). Assessing pre-service science teachers' technological pedagogical content knowledge (TPACK) on kinematics, plant tissue and daily life material. *Journal of Physics: Conference Series, 1157*, 1-5. https://doi.org/10.1088/1742-6596/1157/2/022013

Amiruddin. (2019). Cooperative and collaborative learning. *Journal of Education Science, 5*(1), 24–32.

Borich, G. D. (2011). *Effective teaching methods research-based practice*. Boston: Pearson Educatio.

Brahim, D., Mohamed, A., Lahoussine, M., Hicham, B., & Said, B. (2024). Concept maps: A creative tool in university pedagogy. *Nurture, 18*(1), 35-43.

Budiana, H. R., Sjarifah, N. A., & Bakti, I. (2015). Utilization of information and communication technology in learning for teachers at SMPN 2 Kawali, Citeureup Village, ciamis regency. *Dharmakarya: Jurnal Aplikasi Ipteks Untuk Masyarakat, 4*(1), 59–62.

Cavin, R. M. (2007). *Developing technological pedagogical content knowledge in preservice teachers through microteaching lesson study.* [PhD Thesis, Florida State University]. FSU Digital Library. Retrieved from http://purl.flvc.org/fsu/fd/FSU_migr_etd-4017.

Chai, C. S., Koh, J. H. L., & Tsai, C.-C. (2013). A review of technological pedagogical content knowledge. *Journal of Educational Technology & Society, 16*(2), 31-51.

Cooper, R. (2019). The role of dispositions in the development of pedagogical knowledge for pre-service science teacher education. *Asia-Pacific Journal of Teacher Education, 47*(5), 508-523. https://doi.org/10.1080/1359866x.2018.1517407

Ersanli, C. Y. (2016). Improving technological pedagogical content knowledge (TPACK) of pre-service English language teachers. *International Education Studies, 9*(5), 18-27. https://doi.org/10.5539/ies.v9n5p18

European Political Strategy Centre. (2017). *10 trends transforming education as we know it*. Brussels: European Political Strategy Centre.

Hasbullah. (2021). Teacher education curriculum: Simulation methods in learning during the pandemic. *ADAARA: Jurnal Manajemen Pendidikan Islam, 11*(2), 155-162.

Husain, R. (2020). *Application of the collaborative model in learning in elementary schools*. Proceedings of the Master of Basic Education Postgraduate Webinar, Gorontalo State University.

Kafyulilo, A. C., Fisser, P., & Voogt, J. (2013). *TPACK development in teacher design teams: Assessing the teachers' perceived and observed knowledge.* Paper presented at the Proceedings of Society for Information Technology & Teacher Education International Conference.

Karlström, M., & Hamza, K. (2019). Preservice science teachers' opportunities for learning through reflection when planning a microteaching unit. *Journal of Science Teacher Education, 30*(1), 44-62. https://doi.org/10.1080/1046560x.2018.1531345

Kaufman, J. C., Plucker, J. A., & Baer, J. (2008). *Essentials of creativity assessment hoboken*. New Jersey: John Wiley & Sons, Inc.

Kim, S.-W., & Lee, Y. (2018). Development and application of the TPACK-P education program for pre-service teachers' TPACK. *International Journal of Engineering & Technology, 7*(3.34), 636-643. https://doi.org/10.14419/ijet.v7i3.34.19408

Koehler, M. J., Mishra, P., & Cain, W. (2013). What Is technological pedagogical content (TPACK)? *Journal of Education, 193*(3), 13–19.

Kopish, M., & Nestor, S. (2019). After the content course: An expert-novice study of disciplinary literacy practices. *Journal of Social Studies Education Research, 10*(2), 1-30.

Magdalena, I., Saridevita, A., Novyanti, A., & Destiyantari, S. (2021). Improving creative thinking skills using the paikem model in class v social sciences subjects at sdit tiara aksara. *BINTANG: Jurnal Pendidikan Dan Sains, 3*(2), 244–259.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Nazari, N., Nafissi, Z., & Estaji, M. (2020). The impact of an online pro-fessional development course on EFL teachers' TPACK. *Journal of Language Horizons, 4*(1), 59–86.

Oduro-Okyireh, T., Mulyanti, B., Rohendi, D., Oduro-Okyireh, G., Mensah, A. C., & Acheampong, K. (2024). The mediating role of higher-order thinking skill in the relationship between mathematics strength and achievement in electrical and electronic engineering education. *Nurture, 18*(1), 73-90. https://doi.org/10.55951/nurture.v18i1.544

Permana, K. B. A., Renda, N. T., & Margunayasa, I. G. (2020). Collaborative learning model improves student mathematics learning outcomes. *Jurnal Pedagogi dan Pembelajaran, 3*(2), 223-232.

Plomp, T. (2007). Educational design research: An introduction in Plomp, T. & Nieveen, N. (Eds.) An introduction to educational design research. In (pp. 9-35). Enschede: SLO Netherlands Institute for Curriculum Development.

Purwanto, M. N. (2010). *Principles and techniques of teaching evaluation*. Bandung: PT Remaja Rosdakarya.

Putri, Y. S., & Alberida, H. (2022). Creative thinking skills of class X students for the 2021/2022 academic year at SMAN 1 pariaman. *BIODIK, 8*(2), 112–117. https://doi.org/10.22437/bio.v8i2.17356

Ramalingam, D., Anderson, P., Duckworth, D., Scoular, C., & Heard, J. (2020). *Creative thinking: Skill development framework camberwell*. Australia: The Australian Council for Educational Research Ltd.

Remesh, A. (2013). Microteaching, an efficient technique for learning effective teaching. *Journal of Research in Medical Science, 18*(2), 158-163.

Rifani, I., & Lobja, X. E. (2019). Implementation of collaborative learning in the department of geography education, Manado State University. *Jurnal Penelitian Pendidikan Geografi, 5*(1), 45-49.

Santoso, S. (2014). *Parametric statistics SPSS concepts and applications*. Bogor: PT: Elex Media Komputindo.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.2307/1175860

Sickel, J. L. (2016). *TPACK development in science teacher preparation: A case study in Queensland*. Australia: Dissertation. Ohio University.

Sopiani, K. M., Ratminingsih, N. M., & Saputra, I. N. P. H. (2022). Teaching reading with collaborative learning: An experiment study in SMPN 4 Busungbiu. *Jurnal Penelitian Mahasiswa Indonesia, 2*(2), 62–67.

Sutoyo, S., Agustini, R., & Fikriyati, A. (2023). Online critical thinking cycle model to improve pre-service science teacher's critical thinking dispotitions and critical thinking skills. *Pegem Journal of Education and Instruction, 13*(2), 173-181.

Syukur, I. A. (2014). Teacher professionalism in implementing information and communication technology in Nganjuk District. *Jurnal Pendidikan dan Kebudayaan, 20*(2), 200-2010.

Tanak, A. (2020). Designing TPACK-based course for preparing student teachers to teach science with technological pedagogical content knowledge. *Kasetsart Journal of Social Sciences, 41*(1), 53-59.

Veldman, M. A., & Kostons, D. (2019). Cooperative and collaborative learning: Considering four dimensions of learning groups. *Pedagogische Studien, 96*(2), 76–81.

Wang, W. (2016). *Development of technological pedagogical content knowledge (TPACK) in prek-6 teacher preparation programs.* [PhD Thesis, Iowa State University]. Digital Repository. Retrieved from https://lib.dr.iastate.edu/etd/15833.

Wardhani, A. E., Sunandar, A., Asim, E., M., Samawi, A., & Ediyanto. (2022). Implementation of collaborative learning in inclusive schools at Diponegoro Batu middle school. *Refleksi Edukatika: Jurnal Ilmiah Kependidikan, 12*(2), 134–138. https://doi.org/10.1080/00940771.2002.11495348

Werner, D. (2020). *Exploring hpe teachers' self-efficacy toward technology integration*. Bridgewater College: Honors Project.