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Developing a PMRI Learning Environment for Pre-Service Teachers to Teach Geometry in Elementary Education

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Abstract

There is a need for teachers to possess strong critical thinking skill and pedagogical skills. Unfortunately, many pre-service elementary teachers still struggle to develop these skills adequately, which can hinder the effectiveness of teaching and learning in the classroom. Therefore, this study aims to develop a valid, practical, and effective *Pendidikan Matematika Realistik Indonesia* (PMRI) learning environment to enhance the critical thinking and pedagogical abilities of pre-service elementary teachers. To achieve this aim, the study developed the Campus-Online-School (COS) model using a developmental research approach consisting of three phases: preliminary study, prototype development, and evaluation. Data were collected through observation, interviews, questionnaires, documentation, and tests, and analyzed using both qualitative and quantitative methods. The findings show that the developed learning environment is valid, practical, and effective in improving students' critical thinking and pedagogical skills. Critical thinking was assessed through critical thinking test, while pedagogical ability was evaluated using Guskey's framework. These findings offer important implications for teacher education, emphasizing the need to integrate comprehensive and contextual learning experiences to prepare future teachers who are reflective, adaptive, and equipped to face the challenges of modern classroom practice.

Keywords: Learning Environment, PMRI, Geometry, Pedagogical abilities, Critical Thinking Skills, Education in Developing

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INTRODUCTION

Critical thinking skills are essential competencies that pre-service elementary teachers must possess in the 21st century. These skills are important not only for the professional development of future teachers but also for enabling them to cultivate reflective and analytical thinking in their students (Ahmad et al., 2023). At the higher education level, critical thinking is considered a core leaning outcome and part of the institutional responsibility (Apriliani et al., 2023). This aligns with national education policies, as stated in Ministerial Regulation of Research, Technology, and Higher Education No. 44 of 2015, both of which emphasize the importance of developing critical thinking skills (Kinoshita, 2022).

Mathematics education, particularly geometry, is a highly relevant field for developing critical thinking skills. Geometry is included in the curriculum at every level of education, as indicated in the objectives of mathematics learning (Mursalin, 2016). Furthermore, engaging pre-service elementary teachers in critical thinking through geometry tasks can also enhance their pedagogical skills, as it trains them to design, analyze, and reflect on instructional strategies that foster students' reasoning and problem-solving abilities (Mulbasari et al., 2023). However, various studies indicate that students' critical thinking skills, particularly in mathematics remain low especially when dealing with geometri

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concepts (Iqbal & Akbar, 2021). This low proficiency is attributed to non-contextual teaching methods, limited use of manipulative media, and passive learning engagement (Ali, G. & Awan, 2021). In other words, it relates to the teacher's pedagogical skill.

On the other hand, the pedagogical abilities of pre-service elementary teachers remain suboptimal. Many pre-service elementary teachers struggle to design meaningful learning experiences, understand student characteristics, and select appropriate instructional approaches (Mulbasari et al., 2023; Prasetya & Ardini, 2023). Factors contributing to weak pedagogical abilities include a lack of real teaching practice experience (Rahmawati et al., 2021), the dominance of theoretical instruction in teacher education programs (Loughran, 2010), and limited training that bridges the gap between educational theory and classroom practice (Zeichner, 2009). The urgency of this study lies in the gap between the need for teachers with strong critical thinking and pedagogical skills and the lack of a learning resources for pre-service teacher that comprehensively integrates theory, practice, and pedagogical reflection in a contextual manner. Previous studies have addressed this issue by developing learning environments that combine PMRI approaches, lesson study, and school-university collaborations to enhance both critical thinking and pedagogical skills of pre-service elementary (Mulbasari et al., 2023; Fauziah et al., 2020). Providing learning resources that support critical thinking and pedagogical abilities of pre-service teacher remains under-researched. PMRI is the adaptation of Realistic Mathematics Education (RME) in Indonesian context (Zulkardi et al., 2020).

Zulkardi (2003) successfully developed an RME-based learning environment that was valid, practical, and effective. This design had a positive impact on improving pre-service elementary teachers understanding of RME theory as well as their teaching skills in practice. The method used was development research, which included needs analysis, prototype development, testing, and revision. Furthermore, research on the development of learning environments shows that PMRI-based learning environments, such as the Lesson Study model KSK (Campus-school-campus) and training at PMRI centers, are valid, practical, and have the potential to improve pre-service elementary teachers understanding of the student learning process and their teaching skills (Fauziah et al., 2020). In addition, research on learning environments using the Campus-Application-School (CAS) model shows that the environment has high validity, excellent practicality, and effectiveness in improving the teaching readiness of prospective PAUD teachers (Efriani et al., 2023). PMRI approach is based on the belief that active engagement in meaningful learning environments can improve students' critical thinking and pedagogical abilities. Therefore PMRI - based LE has the potential to support pre-service elementary teachers critical thinking and pedagogical abilities. A learning environment is not merely a physical space but includes the interaction among students, lecturers, media, learning activities, and the overall atmosphere created to support engagement and reflection (Fraser, 2012). Based on the above findings, both the KSK and CAS models show pontential to improve the critical thinking skills of prospective teachers. Therefore, the researchers integrated both models. The researcher is thus interested in developing a PMRI-based learning environment for geometry instruction to be used by pre-service elementary teachers. Therefore, the research question addressed in this study is: 'How to develop a valid, practical, and potentially effective PMRI learning environment for geometry material to be used by pre-service elementary teachers?'. This study contributes by providing a contextual learning environment-based teacher education model that not only focuses on content but also on improving reflection quality, teaching skills, and the critical thinking abilities of pre-service elementary teachers.

This study aims to examine the effectiveness of an Indonesian Realistic Mathematics Education (PMRI) learning environment in geometry that is both valid and practical for developing the pedagogical and critical thinking skills of pre-service elementary teachers. The environment includes pedagogical and PMRI theory training, teaching simulations, instrument design, implementation in partner schools, and reflective evaluation based on Guskey's evaluation framework. Critical thinking skills are assessed using critical thinking skills indicators developed by (Ennis, 2011), while pedagogical ability is evaluated through Guskey's five-level framework (Guskey, 2016).

METHODS

In order to integrate the K-S-K and C-A-S model to develop the LE that support pre-service elementary teachers. This research employed a development approach (Plomp, 2013). As study sought to develop a valid, practical, and potentially effective learning environment, it was conducted in three stages: preliminary research, development or prototyping, and assessment (Plomp & Nieveen, 2013). The participants were pre-service elementary teachers Education Study Program (PGSD) at PGRI University of Palembang. Data were collected through documentation, comments, photos, and videos taken during the study, as well as field notes, questionnaire responses, interview transcripts and test results. The data were analyzed quantitatively and interpreted qualitatively.

Research Procedure

Preliminary Research

In the preliminary research stage, several activities were conducted. First, the researcher administered a test to PGSD pre-service elementary teachers to assess their critical thinking skills and distributed questionnaires to gather information on their understanding of 21st century skills, especially critical thinking as well as their, knowledge of geometry material and the PMRI approach. Second the researcher conducted a literature review on critical thinking and pedagogical skills using PMRI, reviewed elementary school geometry materials and examined the PGSD curriculum to identify suitable courses for developing the learning environment. Third, the researcher designed the learning activities be used during the simulation. Fourth, the researcher designed the PMRI learning environment.

Prototyping

In the prototyping phase, the researcher conducted five stages following the formative evaluation framework, see Figure 1, (Tessmer, 2013).

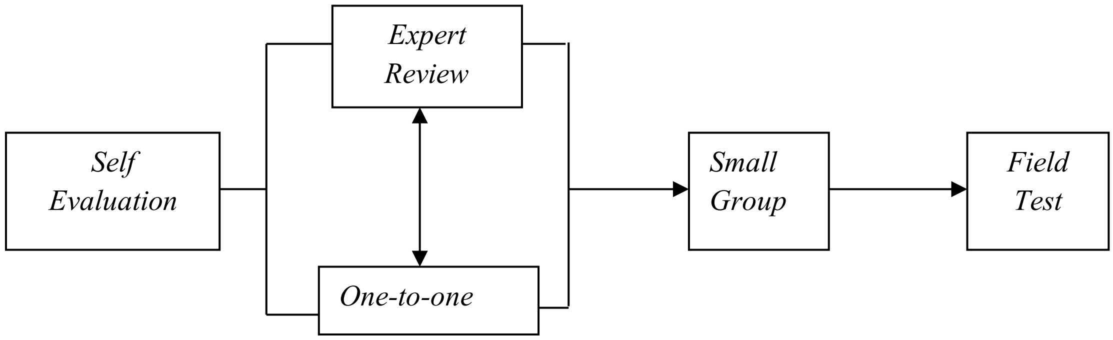


Figure 1. Formative evaluation design

At the self-evaluation stage, the researcher reviewed and revised the initial prototype by reviewing the sequence of activity stages or topics in the PMRI geometry learning environment, the suitability of topics and tasks and the usability of the PMRI learning environment process. The results of this stage are referred to as prototype I. Prototype I then underwent qualitative validation by experts who assessed the content, construct, and language to determine the validity of the learning environment. In parallel, the prototype I was tested on one-to-one trial to assessed the clarity, ease of use and the suitability of activity stages to strengthen the designed learning environment. The result of this stage served as the basis for improvement, resulting in a revised version referred to as prototype 2. Third, the prototype II was tested on 6 PGSD pre-service elementary teachers to assess the practicality of the developed learning environment. The students followed the structure stages of the learning environment, and their responses and comments were used for further improvement, resulting in a revised version referred to as prototype 3. Fourth, at the field test stage. Prototype 3 was tested on 36 pre-service elementary teachers through the implementation stages of the learning environment to evaluate its pontential effects.

Assessment Phase

The assessment phase, conducted to determine the potential effect of the learning environment on pre-service elementary teachers pedagogical and critical thinking skills. Pedagogical skills were evaluated using Guskey's five levels of professional development evaluation (Guskey, 2016), which include: (1) Participant reactions assessing student satisfaction and engagement; (2) Participant learning assessing changes in knowledge and attitudes; (3) Organizational support and change assessing institutional support and any resulting changes; (4) Application of new skills assessing the extent to which students apply learning outcomes; and (5) Student learning outcomes evaluating the impact of the learning environment on students' learning processes. Critical thinking skills were analyzed using critical thinking indicators proposed by Ennis (2011) namely focusing on questions, analyzing arguments and drawing conclusions. Students' responses were then analyzed, and the scores were converted into qualitative data by the categorizing of learning outcomes. The following Table 1 presents the learning outcomes categories used as benchmarks.

Table 1. Critical thinking ability level categories

Mark	Level of critical thinking ability of students
13,8 – 18,3	Very Critical
9,2 – 13,7	Critical
4,6 – 9,1	Quite Critical
0 – 4,5	Less Critical

Modification Arikunto**:** (Farhatin, 2011)

RESULTS AND DISCUSSION

This study developed a learning environment based on the PMRI approach, focusing on geometry and integrating the Campus-Online-School (COS) model. The following are the stages of the research findings.

Preliminary Stage

First, the researchers conducted a literature review of studies related to the critical thinking skills of prospective elementary school teachers and the pedagogical skills of teachers in the context of implementing the PMRI approach. The findings inform the theoretical basis for the development of the learning environment that the application of the PMRI approach can improve students' critical thinking skills and provoke high enthusiasm for learning mathematics (Mulbasari et al., 2023). On the other hand, in terms of pedagogical skills, the findings indicate that strengthening teacher pedagogy through the PMRI approach positively impact the quality of mathematics learning in Indonesia. Therefore, there are the need for ongoing teacher training, increased collaboration between teachers and academics, and policy support for the provision of PMRI-based learning resources and teaching tools (Mulbasari et al., 2025).

Next, the researcher reviewed relevant elementary school geometry material to be simulated in a PMRI-based learning environment. The selected material focused on the area and volume of flat-sided geometric shapes, especially cubes and cuboids. This selection was based on the consideration that geometric shapes are an important topic in geometry learning, requiring spatial visualization skills, symbolic representation, and complex logical reasoning (Mursalin, 2016; Verawati et al., 2020). In addition, this material is considered to have strong contextual potential for development with the PMRI approach through activities that reflect students' real experiences (Zulkardi, 2003). The researcher also reviewed the curriculum of the Elementary School Teacher Education Study Program (PGSD) to determine the courses most relevant to the objectives of developing a learning environment. Based on curriculum document review, the course "Elementary School Mathematics Learning" in semester 4 was selected, as it includes a substantive focus on geometry and is designed to strengthen both content mastery and the pedagogical abilities of prospective teachers. The selection of semester 4 is also deemed appropriate, students at this stage have acquired foundational knowledge in mathematics pedagogy and content, making them ready to start integrating theory and practice contextually (Widodo & Jatmiko, 2016). Thus, the development of the learning environment in this course is strategically positioned to support the achievement of 21st century competencies, especially critical thinking and pedagogical skills.

Next, researchers conducted a preliminary study with pre-service elementary teachers, employing two instruments a test and a questionnaire to measure students' critical thinking skills in the context of elementary school geometry, while the questionnaire gathered their knowledge of 21st-century skills especially critical thinking, their mastery of geometry material, and their understanding of the PMRI approach. The researchers found that there is a decreasing trend in geometry mastery, along with the need for a more contextual learning approach, which leads to a requirement of a PMRI-based learning environment for geometry to address weaknesses in critical thinking skills (Mulbasari et al., 2023). Thereby reinforcing the urgency and relevance of developing a PMRI learning environment in the context of prospective teacher education.

After that, researchers designed an instrument in the form of learning activities to be used in the learning environment during simulations. The students' worksheets were developed through a series of validation stages, and the resulting design was validated and tested with students. The development of teaching materials using the PMRI approach for geometry material is considered valid, as evidenced by expert validation revisions in terms of content, construct, and language, as well as the outcomes of one-on-one evaluations (Mulbasari et al., 2024). The materials were revised and tested again in a larger class to examine the practicality of the students' worksheet. The analysis revealed several editorial and contextual issues that students had difficulty understanding, but these were addressed in the revisions. Consequently, the revised students' worksheet is now suitable for effective use in the PMRI learning environment.

The last, the researchers designed a PMRI based learning environment that integrates Campus-Online-School elements. This environment combines the KSK model (Fauziah et al., 2020) with the CAS approach (Efriani et al., 2023). The design aims to create a more interactive and immersive learning experience while enhancing the effectiveness of mathematics education at the foundational level. The structure of integrated learning environment is depicted in Figure 2.

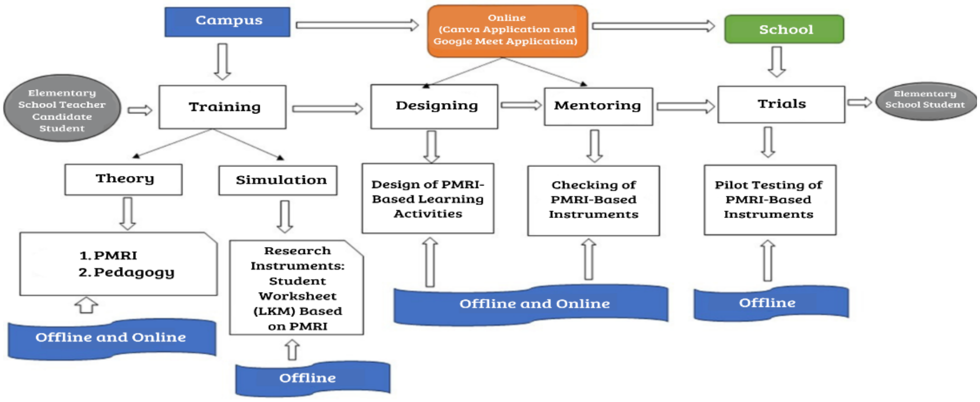


Figure 2. Integration of KSK and CBS learning environments

The goal is to create a more interactive and immersive learning experience, and to increase the effectiveness of mathematics learning, especially in geometry at the elementary education level. This learning environment is designed as an ecosystem comprising three main components: campus, online platform, and school

At the Campus Stage

Pre-service elementary teachers are introduced to pedagogical theory and the PMRI approach through interactive discussions and literature reviews led by lecturers. Additionally, students conduct geometry learning simulations using PMRI-based learning instruments, such as learning activities, concrete media. These simulations are conducted in groups, to allowing students to directly apply their lesson designs, while receiving feedback from lecturers and peers. The purpose of this simulation is to deepen students' understanding of the PMRI approach, not only theoretically but also practically, enabling them to design and implement contextual and meaningful learning in the classroom.

The Online Stage

This stage serves as a communication and monitoring platform between lecturers and pre-service elementary teachers. At this stage, students compile and develop learning instruments based on the results of on campus simulations, which are then reviewed through an online forum. Lecturers provide periodic guidance and feedback through the digital learning platform. This stage also serves as a means of documenting the design process and as a place to strengthen concepts through both asynchronous and synchronous learning activities.

The School Stage

This stage includes direct teaching practice at partner schools. Pre-service elementary teachers implement the PMRI-based learning tools they have developed, observe pre-service elementary teachers responses, and document their field experiences. This activity is followed by a learning reflection, guided by lecturers and mentor teachers, to evaluate the effectiveness of the implementation and the quality of learning tools used.

Prototyping Evaluation Stage

Self Evaluation

This activity was conducted collaboratively with the course development team through intensive discussions to obtain constructive input and comments. The review focused on the sequence of stages, the suitability of topics and tasks in PMRI-based geometry content, and the ease of implementing the learning process in the environment. Based on the discussion, the team provided several corrections, especially concerning the linguistic clarity of activity instructions and the phrasing of descriptions, which were considered unclear or insufficiently communicative. Although the overall structure of the learning environment was considered aligned with the intended learning outcomes, minor revisions to the language and delivery of the learning activities became the primary focus.

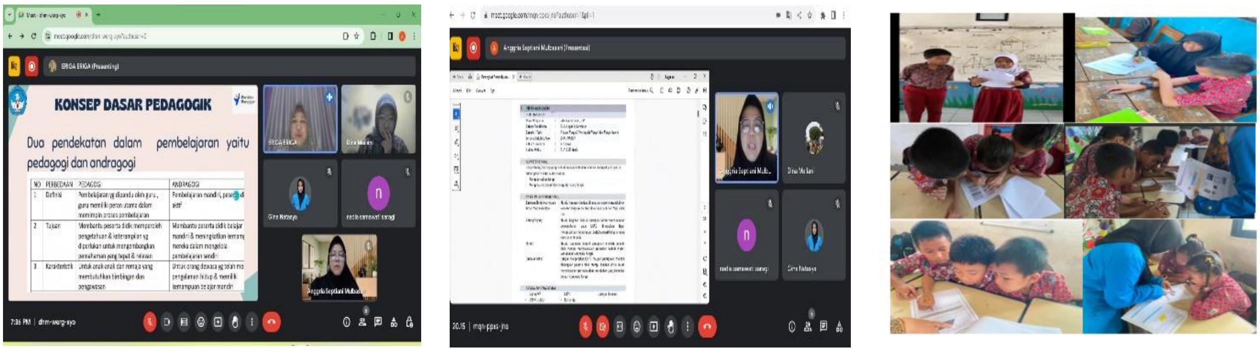
Expert Review

The experts included 3 educational practitioners. One of them is also a lecturer and research mathematics education. According to the review, the content of the learning environment is appropriate to provide an understanding of PMRI in geometry for elementary school students. In regard to the construct of the learning environment, the expert agree that an asynchronous activity is needed during the training. They further recommended that PMRI scenarios should be provided through the asynchronous activity. The expert also agree that the learning environment followed the Indonesian language standards.

To address the review from the experts, the researchers added an asynchronous activity for the participants. The activity is learning the material before the training stage. The material can be accessed though https://lingkunganbelajarpmri9.wordpress.com/2023/11/20/pendekatan-matematika-realistik-indonesia-pmri/

One-to-one

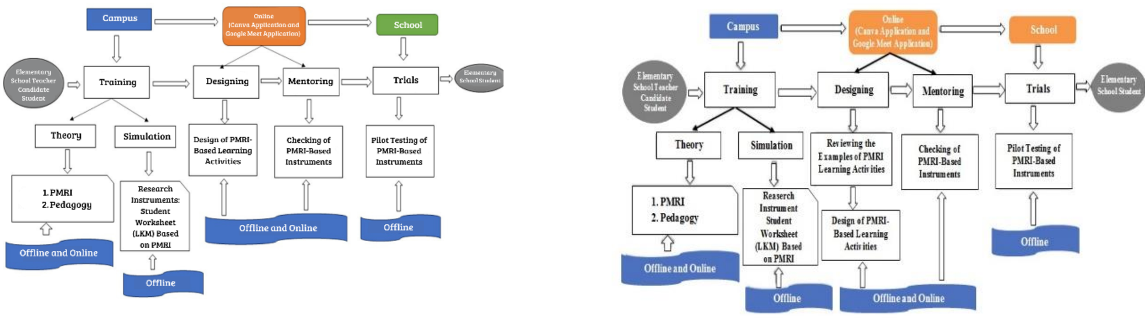
At the one-to-one stage, prototype I was tested on three pre-service elementary teachers who completed all activities in the structure of the designed learning environment. The one-to-one trial focused on clarity and suitability of the activity stages in strengthening the designed learning environment. Figure 3 depicts the process of one-to-one.



a. Campus activities b. Online activities c. School activities

Figure 3. One-to-one trial

After completing the series of activities in the learning environment structure, the pre-service elementary teachers were asked to provide comments on the stages they had experienced. All pre-service teachers faced difficulty in designing the learning activity. They asked for more guidance in designing the learning activity. Therefore, to assist the pre-service teachers more examples of PMRI learning activities is provided. Figure 4 presents the comparison between the structure of the learning environment before and after the revision.

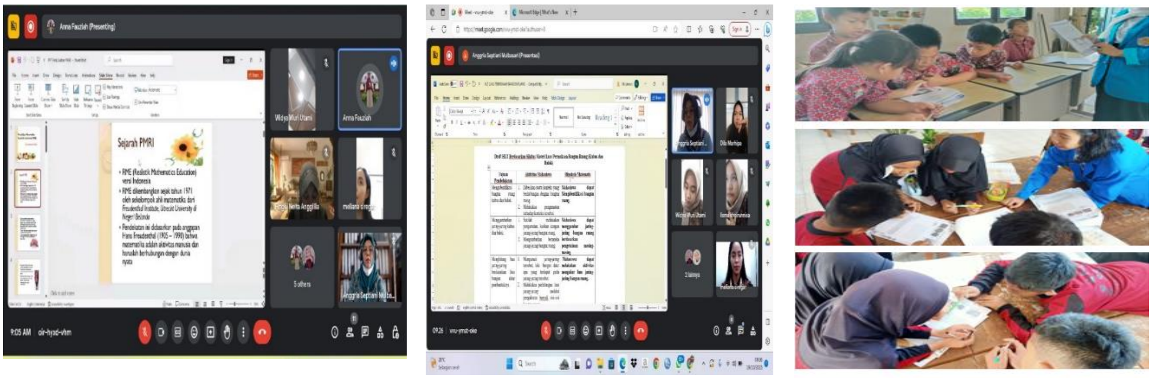


a. Before structure revision b. After structure revision

Figure 4. The revision of the structure of the learning environment

Small Group

At the Small group stage, prototype II was tested on 6 pre-service elementary teachers who completed all the activities in the designed learning environment structure. The small group trial focused on the practicality of the developed learning environment. Figure 5 depicted the small group activity.



a. Campus activities b. Online activities c. School activities

Figure 5. Small group trial

During the small group trial, all participants faced similar difficulty as the one-to-one participants faced. They need further guidance in designing the PMRI learning activities. Therefore, not only providing examples of PMRI learning activities, the research includes validation process with the participants. The validation process will last 3 weeks and the participants will receive revisions and guidance from the researchers to improve the learning activities design by the pre-service elementary teachers. This indicates that both pre-service elementary teachers and lecturers (or other experts) found each lecture session engaging and applicable under normal conditions (Bakker, 2018).

Field Test

Campus

At the training stage, 36 pre-service teacher received theoretical reinforcement from a PMRI expert and pedagogical expert. Prior to this, the researcher had distributed an open questionnaire regarding PMRI and Pedagogical material. The results indicated that most students were unfamiliar with and did not understand these topics. Before receiving reinforcement on PMRI and Pedagogical theories, students were instructed to study asynchronously through PMRI articles and learning videos available at https://lingkunganbelajarpmri9.wordpress.com/2023/11/20/pendekatan-matematika-realistik-indonesia-pmri/. Subsequently the speakers delivered the material. Figure 6 is depicting the training stage.

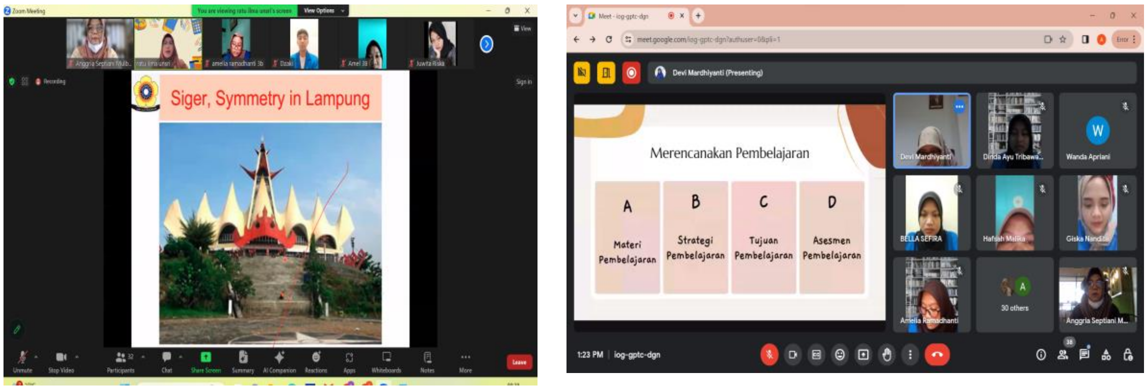


Figure 6. Training stage on campus

At this stage, pre-service elementary teachers demonstrated high enthusiasm in participating and training. Upon completion, the researchers administered a test to assess their knowledge about PMRI and pedagogical theory, their answer indicating a good understanding of both PMRI and pedagogical concepts. In the simulation stage, 36 pre-service elementary teachers were given a lesson using instruments previously designed by the researcher. Figure 7 depicts the simulation stage on campus.

Figure 7. Simulation activities on campus

After completing the simulation activity on campus, pre-service elementary teachers filled out a questionnaire on their perception of PMRI learning via a Google form: https://bit.ly/Angketpersepsimahasiswaterhadappembelajaransiklus2. The questionnaire results are presented in Table 2 below.

Table 2. Student Perceptions of PMRI learning

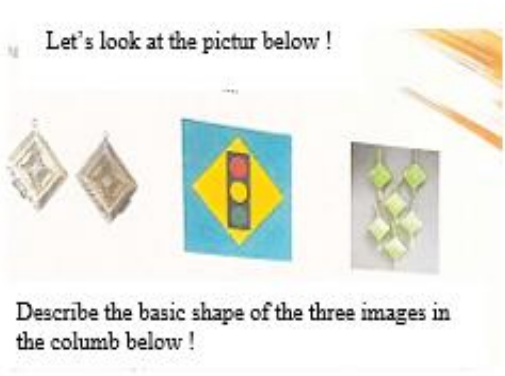
Indicator	Number of students	Average
Reality Principle	36	3,29
Activity Principle	36	3,18
Level Principle	36	3,04
Intertwinement Principle	36	3,14
Interactivity Principle	36	3,14
Guidance Principle	36	3,24

Based on the average score of 3 obtained from the questionnaire for each PMRI principle indicator, it can be concluded that pre-service elementary teachers have a positive perception and agree that the learning aligns with PMRI principles.

Online

Before designing their own instruments, pre-service elementary teachers were given reinforcement on the development of teaching modules, after that the activity continued to design and assistance stage. At design stage, 36 pre-service elementary teachers designed learning activities based on the PMRI approach. At the assistance stage, researchers conducted online reviews of the PMRI-based instruments developed by the pre-service elementary teachers and provided feedback for revisions. The revised versions from each group were documented. Figure 8 present the result.

Group: Rhombus



Group: Rectangle

Observe the picture below! What kind of flat shapes are these objects?

Group: Volume of cone

Mother made a tumpeng for a competition. In the competition, several provisions were written, including the area of the tumpeng -base must be the same as the place provided by the committee and the height of the tumpeng must be 24 cm.if the tumpeng place provided by the committee has a radius of 14 cm, what is the volume of the tumpeng?

Group: Perimeter and area of a square

Mr. Roni is a carpenter. He received an order from his customer to make a square mirror. Then around the mirror will be installed a wooden molding. If the lenght of the side of the mirror that Mr. Roni will make is 35 cm. Then how wide is the mirror that willbe made? And how long is the wooden molding needed by Mr. Roni in making the mirror?

Figure 8. Students' worksheet design results

School

At this stage, pre-service elementary teachers tested the results of their design at SD Negeri 38 Palembang (4 groups), SD Negeri 118 Palembang (4 groups), and SD Negeri 204 Palembang (3 groups). Figure 9 depicts the implementation to school activity and example of student's answer in Figure 10.

Figure 9. Implementation to school

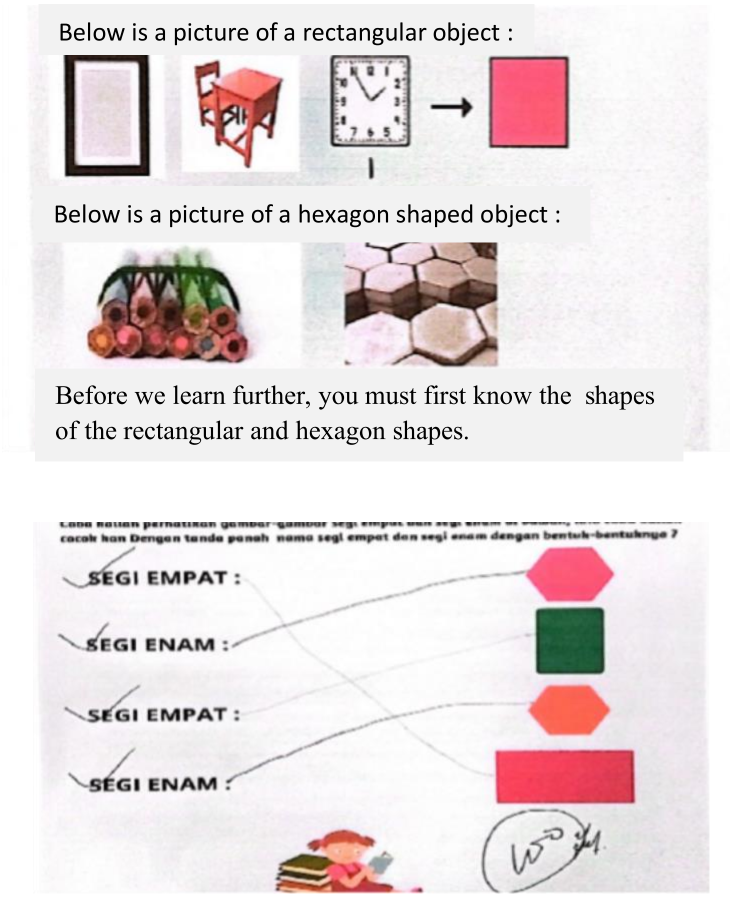


Figure 10. Sample student answers

Assessment Stage

The assessment stage presents the potential effect of the learning environment related to pedagogical skills and critical thinking abilities. The evaluation of the learning environment concerning pedagogical skills was conducted using Guskey's five levels of professional development evaluation. Meanwhile, the critical thinking skill was assessed through written test, critical thinking test.

Participants' Satisfaction

At this level, pre-service elementary teachers satisfaction was measured through a questionnaire regarding the learning environment. The questionnaire consisted of 5 positive questions and 5 negative questions. Each question, both in positive and negative, corresponded to each other. Therefore, the questionnaire revealed 5 ideas: the speakers, topic, learning activity, material, and participants' understanding. In general, for each idea, the majority of the participants (more than 70%) satisfied with the learning environment.

Participants' Learning

This level measured the knowledge, skills, and attitudes acquired by pre-service elementary teachers within the PMRI learning environment, which facilitated their understanding of the PMRI approach through assessing pre-service elementary teachers ability to plan the lesson and implement the lesson. To assess pre-service elementary teachers ability to plan the lesson using the PMRI approach, the researchers utilized the learning planning ability assessment sheet. A summary of the assessment results is presented in the Table 3 below.

Table 3. Summary of learning planning ability assessment

Component	Average score	Percentage
Learning objectives	4	80%
Learning materials	4	80%
Instructional Media	3.18	63.6%
Evaluation	3	60%
Average percentage		70.9%

In general, the average score of the pre-service elementary teachers ability to plan the lesson are more than 3, with the highest score is 5. This result showed that the pre-service elementary teachers are able to plan the lesson with PMRI approach. Regarding the ability to conduct learning, the researchers utilized observations sheets during the peer teaching sessions in schools, the following is a summary of the evaluation results for the learning implementation, as presented in the Table 4 below.

Table 4. Summary of learning implementation assessment results

Component	Average score	Percentage
Opening Lessons	4.55	91%
Core activities	3.64	72.8%
Closing the Learning	3.45	69%
Average Percentage		77.6%

In general, the average score of the pre-service elementary teachers ability to implement the lesson are more than 3,4, with the highest score is 5. This result indicated that the pre-service elementary teachers are able to implement the lesson pretty well.

Organizational Support and Change

This stage measured the organizational support from the School Teacher Education study program at PGRI University of Palembang and from three partner schools (SD Negeri 38, SD Negeri 118, and SD Negeri 204 Palembang) for the developed learning environment. This support was assessed based on the university's research permit and the schools' approval to implement student-designed trials.

Participants' Use of New Knowledge and Skills

This stage measured the benefits of the learning environment through on-campus training for prospective teachers, enabling them to apply new knowledge and skills using the PMRI approach in schools. During implementation, students applied the acquired knowledge in classroom teaching and also acted as observers. The roles and responsibilities of observers had been introduced during the campus training. Following the teaching sessions, students engaged in reflections on the lessons. Several students presented their observation findings to peers they had observed. The researcher's assessment of their reports indicated that students demonstrated the ability to serve as effective observers.

Participants' Learning Outcomes

In this stage, an evaluation of students' reactions and experiences during the learning process was conducted. Based on observations and documentation, elementary students were able to engage with the learning activities. Some students showed considerable enthusiasm in completing the provided worksheet. The students' worksheet results indicated that most students were able to answer the problems effectively. Figure 11 is an example of a participant's response during a school trial.

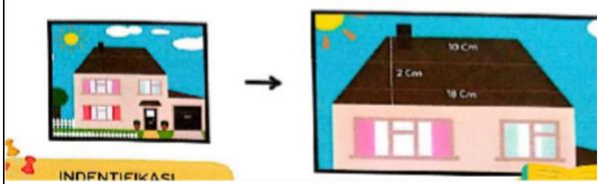
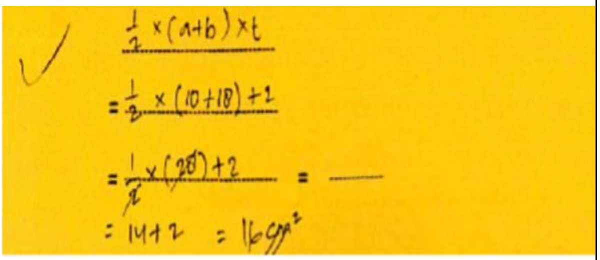
Mr. Anton will fix the roof of his house which is in the form of in the form of an isosceles trapezoid. With the leghth of the two parallel lines being 10 cm and 18 cm respectively. If the height of the roof is 2 cm then what is the area of the roof of the house? 	Calculate the area of the roof of a trapezoidal house: 

Figure 11. Sample of students' answer

The assessment of the learning environment, utilizing Guskey's five levels, reveals that pre-service elementary teachers feel satisfied with the learning experiences provided. They recognize substantial benefits from the PMRI-based environment, which imparts new knowledge and enhances their pedagogical skills. This is supported by previous studies for example, by Fauziah et al. (2020) found that developing a PMRI learning environment through lesson study improves pre-service elementary teachers understanding of mathematical concepts. In this context, the present research demonstrates that students acquire both theoretical knowledge and practical teaching skills, emphasizing that positive learning experiences can enhance student motivation and engagement. Furthermore, Nabila & Putri (2022) emphasized that the PMRI approach helps participants better understand the material by starting with relevant real- world contexts. In this study, pre-service elementary teachers involved in designing and implementing PMRI learning instruments reported that the approach made learning more engaging and effective. This indicates that the designed learning environment meets the needs of both pre-service elementary teachers teachers and educators. These findings align with Garbin et al. (2021), who show that a well-designed learning environment can increase student motivation and academic performance. In this research, pre-service elementary teachers who applied the learning instruments in schools created a positive learning environment, which in turn increased student motivation and engagement in mathematics. This highlights the role of pre-service elementary teachers not only as teachers but also as facilitators in creating a conducive learning atmosphere.

In the simulation session, pre-service elementary teachers were provided with two PMRI work sheets, which demonstrated their ability to complete tasks effectively, although some phrasing required revision. The instrument design process revealed that pre-service elementary teachers initially struggled to select appropriate context. However, through discussion and guidance, they were able to identify more relevant contexts. This highlights the importance of collaboration and discussion in the learning process, aligned with PMRI principles that emphasize contextual learning (Aprilia & Awalia, 2020). Aryani & Wilyanita (2022) also emphasized the importance of integrating character education into learning, demonstrating that collaboration between students and lecturers in designing learning instruments foster positive values and improve pre-service elementary teachers social skills. The discussions that occurred during the design of the PMRI learning instruments enables pre-service elementary teachers to learn from one another and develop important interpersonal skills within an educational context. Ryantini et al (2022) emphasized that a context-based approach can enhance pre-service elementary teachers understanding of the material. In this research, students who designed PMRI learning instruments successfully identified more relevant contexts after engaging in discussions and receiving guidance. This demonstrates that collaborative learning supports pre-service elementary teachers in developing a deeper understanding of how to connect theory with practice.

The school implementation demonstrated pre-service elementary teachers enthusiasm for the learning activities. They found it easier to understand the material when presented in real-world context, although some still experienced difficulties with reasoning-based questions. This indicates that while the PMRI approach is effective, challenges remain such as insufficient time to complete tasks and students' adaptation to new teaching methods (Palavan, 2020). Ruspanah et al. (2021) also found that the use of contextual learning models can improve pre-service elementary teachers academic performance. In this research, pre-service elementary teachers who engaged in a contextual learning exhibited a better understanding of the material, especially when it was related to everyday life. This suggests that pre-service elementary teachers comprehend concepts more easily when they recognize their relevance to real-world contexts. Hamida et al. (2023) emphasizes that problem-based and contextual learning can enhance pre-service elementary teachers critical thinking skills. In this study, pre-service elementary teachers who applied PMRI learning instruments in school effectively connected the material to relevant contexts, thereby facilitating their understanding and application of mathematical concepts.

The evaluation results regarding the learning environment's impact on pedagogical skills and critical thinking abilities are described in Table 5 below. The results presented in the table indicate that 55.6% of pre-service elementary teachers demonstrated very high critical thinking ability, 19.4% were critical, 11.1% were somewhat critical, and 13.9% were less critical.

Table 5. Results of critical thinking ability

Mark	Level of ability	Results	Percentage
13.8 – 18.3	Very Critical	20	55.6%
9.2 – 13.7	Critical	7	19.4%
4.6 – 9.1	Quite Critical	4	11.1%
0 – 4.5	Less Critical	5	13.9%

The developed COS model not only aims to support the professional development of pre-service elementary teachers but also focuses on strengthening critical thinking skills, key components of 21st-century skills. Based on the critical thinking ability test, 55.6% of students showed very good abilities, while 19.4% showed sufficient abilities. These findings indicate that the COS learning environment has the potential to support students' critical thinking skills in line with the 21st-century learning objectives. This shows that the designed learning environment successfully enhances students' critical thinking skills, one of the main objectives of 21st-century education (Iqbal & Akbar, 2021; Palavan, 2020).

A study by Rizal et al. (2020) demonstrates that evaluating effective teacher training programs can improve pedagogical competence and critical thinking abilities among pre-service elementary teachers. In the context of the COS model, which integrates campus training and school practice, students have the opportunity to develop critical thinking skills through direct experience. This indicates that practical teaching can enhance students' self-confidence and competence as prospective teachers. Sukinem et al. (2022) emphasize the importance of educational innovation to enhance 21st-century skills. In this study, students applying the COS model not only learned how to teach but also gained insights from their teaching experiences an essential aspect of developing professionalism in future educators.

In general, this study shows that a PMRI-based learning environment integrating campus, online, and school components can provide a positive learning experience for pre-service elementary teachers in understanding and applying geometry concepts. By combining theory and practice, students gain both pedagogical knowledge and teaching experience that supports their professional development. Although limited to a specific group of students, the findings indicate that the COS model has the potential to make a meaningful contribution to preparing pre-service elementary teachers to apply the realistic mathematics approach at the elementary level.

From the discussion above, it can be seen that the PMRI-based learning environment (COS model) is declared valid and practical. Validity is obtained through qualitative revisions from expert reviews and one-to-one, which highlight improvements in content, construction, and language in the structure of the learning environment, namely campus training, online design, and school implementation. Practicality is proven through revisions in small groups, which show the ease of implementation and understanding of activities in the three COS components and have a potential effect on the pedagogical abilities of the Guskey assessment results and critical thinking skills based on critical thinking ability indicators.

Furthermore, this study contributes meaningfully to the development of PMRI-based learning environments through the integration of campus, online, and school (COS) elements to improve the pedagogical and critical thinking skills of prospective elementary school teachers. The implication is that structured integration between theoretical learning and teaching practice can serve as a strategic model in teacher education programs, especially in mathematics education. The COS model offers a promising framework to provide prospective teachers with real teaching experiences and reflective opportunities that support their professional development. However, this study has several limitations. The sample size is relatively small and limited to a single study program at one university, thus limiting the generalizability of the findings. In addition, the evaluation primarily focuses on pre-service elementary teachers learning process and their reflections, without directly measuring the impact on elementary school students' learning outcomes. The short duration of implementation also limited the ability to observe the long-term impact of the developed model. Further research is recommended to test the COS learning environment in broader and more diverse educational contexts. Longitudinal research with larger samples and direct observation of pre-service elementary teachers learning outcomes would be valuable for assessing the model's sustained impact. In addition, stronger stakeholder engagement in schools is needed to enhance the relationship between teacher education institutions and the school environment more effectively.

CONCLUSION

This research has developed a valid, practical, and potentially impactful COS learning environment model that significantly enhances the critical thinking and pedagogical skills of prospective teacher students. Through two structured training sessions, pre-service elementary teachers not only gain a deep understanding of PMRI and pedagogy but also have the opportunity to design and implement relevant learning instruments at three model schools. As a result, 83.4% of pre-service elementary teachers demonstrated a good understanding of the material, with 70.9% successfully planning and 77.6% effectively implementing PMRI lessons. Support from the Elementary School Teacher Education Program at Universitas PGRI Palembang and the model schools has been essential to the success of this program, allowing students to apply theoretical knowledge in practical settings. Pre-service elementary teachers enthusiasm during the lessons indicated that the use of real-world context in instruction facilitated their understanding of the material. Furthermore, the improvement in pre-service elementary teachers critical thinking skills, with 55.6% demonstrating excellent ability, underscores that the KOS model supports not only professional development but also enhancement of critical thinking skills, which are essential in 21st-century education. These findings have the potential to influence the mathematics learning of pre-service elementary teachers and demonstrate the model's effectiveness in enhancing their academic and professional competence. Additionally, the results can serve as a reference for further research using other subject matter within the context of the PMRI learning environment and pre-service elementary teachers teaching practices.

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	RIIP	: Writing-Review & Editing, Methodology, Validation, Formal Analysis, and Supervision.
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