Short thesis for the degree of doctor of philosophy (PhD)

The Impact of an Active Learning – Based Intervention for Indonesian Prospective Mathematics Teachers' Pedagogical and Mathematical Skills

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Abstract

Despite improving education quality over the last decade, Indonesia continues to face educational challenges, such as the need to boost learning. This research contributes to addressing the challenges and supports the implementation of the current curriculum that holds student-centered relevant learning principles. This research focuses on prospective teachers who will be essential in the classroom. Several Indonesian prospective mathematics teachers from private and public universities participated in the intervention. A mathematically rich learning environment was designed to offer them a practical experience they can later implement in their classrooms. They engaged in various activities, including posing and solving mathematical tasks, discussing the tasks with group members for improvement, teaching their self-proposed tasks to school students, and discussing the teaching implementation with group members for teaching improvement. The findings demonstrated the advantages of implementing the intervention to broaden their mathematical and pedagogical perspectives. These are broken down into several facets, including their problem-posing and problem-solving performances, critical manifestations, teaching perspective, and teaching implementation. Given the small number of participants in the current research, the results cannot be generalized. Therefore, ideas for further studies and possible generalizations will be addressed.

Keywords: Active learning, collaborative learning, problem posing, problem solving, critical manifestation, teaching perspective, teaching implementation, prospective teachers.

Research Rationale

This research is carried out by considering the following concerns:

1. Indonesian educational challenge to boost learning.
2. The findings of the cross-national study that Indonesian prospective teachers tend to pose simple rather than challenging mathematical problems, mostly arithmetic in nature, and thus tend to utilize an arithmetic rather than an algebraic approach when solving their self-proposed problems.
3. The current curriculum's cornerstone that places students at the center of learning and encourages relevant learning.
4. Some studies that confirm active learning improves academic performance (Rotgans & Schmidt, 2011) and persistence in learning (Bédard et al., 2012).
5. The absence of research on the teaching implementation of self-formulated tasks.

An intervention was conducted with Indonesian prospective mathematics teachers as participants. During the intervention, the active learning principles are promoted through collaborative learning, and the topics are directed toward problem posing and algebraic thinking. The active learning atmosphere is expected to become a learning model they can later adapt in their classes. Moreover, the problem-posing experience allows them to practice generating problems relevant to their students so that they feel motivated to learn mathematics. Lastly, implementing the self-proposed problem will address the existing research gap.

Research Questions

This research was guided by the main research question: Is the active learning-based intervention successful in helping prospective mathematics teachers to develop their pedagogical and mathematical skills?

To provide a more explicit domain for pedagogical and mathematical skills, the main research question is broken down into several questions as follows:

1. How do Indonesian prospective mathematics teachers perform in problem-posing throughout the active learning-based intervention?
   This question is followed up by categorizing the problem-posing products based on Fitriana's framework (Fitriana et al., 2022) and analyzing the complexity of the problem-posing task based on Kontorovich's framework (Kontorovich et al., 2012).
2. How do Indonesian prospective mathematics teachers perform in problem-solving throughout the active learning-based intervention?
   This question is followed up by categorizing the problem-solving products into blind, correct, and incorrect solutions (along with the errors made). The performance will be analyzed according to Schoenfeld's framework (Schoenfeld, 1985).
3. How do the Indonesian prospective mathematics teachers' critical manifestations look throughout the active learning-based intervention?
   This question is followed up by categorizing the manifestations during the lessons and teaching reflections based on Fitriana's framework (Fitriana, 2022a).
4. How do the Indonesian prospective mathematics teachers' teaching perspectives shift throughout the active learning-based intervention?
   This question is followed up by comparing the results of the teaching perspectives questionnaire in Fitriana (2022b) at the beginning and the end of the intervention.
5. How do the Indonesian prospective mathematics teachers' teaching implementations shift throughout the active learning-based intervention?

This question is followed up by comparing the approaches of the teaching implementations based on Fitriana's framework (Fitriana, 2022b) at the beginning and the end of the intervention.

Theoretical Backgrounds

The following is an outline of the main components of this research.

a. In the point of view of Prince (2004), active learning is any instructional method that involves students in the learning process. It enables learners to participate, take responsibility, and connect ideas through analysis, synthesis, and evaluation during teaching and learning activities (Gogus, 2012). Edwards (2015) proposed an active learning framework which includes intellectual, social, and physical activities.
b. Polya (1962) stated that having a problem implies consciously seeking an appropriate course of action to achieve a clearly defined but not immediately attainable goal. A problem becomes an exercise or a routine problem when the solver immediately recognizes and knows the correct process for solving it.
c. Problem solving refers to the process by which the problem solver applies previously acquired knowledge, skills, and understanding to meet the demands of an unacquainted situation (Krulik & Rudnick, 1989). Polya (1945) proposed the problem-solving steps that consists of understanding the problem, devising a plan, carrying out the plan, and looking back. Afterwards, Schoenfeld (1985) introduced a framework to analyze success and failure in mathematical problem solving which entails cognitive resources, heuristics, control, and belief systems.
d. Papadopoulos et al. (2021) grouped the definition of problem posing in the existing literatures into five: generating new problems, reformulating existing or given

problems, both generating new and/or reformulating given problems, raising questions and viewing old questions from a new angle, and an act of modeling. Kontorovich et al. (2012) introduced a framework for dealing with the complexities of problem posing. The framework consists of the following components: task organization, knowledge base, problem-posing heuristics and schemes, group dynamics and interactions, and individual considerations of aptness.

e. By paying attention to beliefs in mathematics and conceptions of teaching and learning mathematics in general, the author of this dissertation proposes two possible perspectives about the preferred style in teaching mathematical problem-solving: teaching problem solving as transferring knowledge and teaching problem solving as facilitating students to construct knowledge by themselves.
f. As active learning places students at the center of learning, it enables classroom activities to evolve into critical discussions. Critical discussions are initiated by particular forms of talk that promote a deep understanding of concepts and robust reasoning. Sohmer et al. (2009) classified teachers' various forms of talk into four categories: recitation, stop-and-talk (partner talk), student presentation and group critique, and whole-group 'position-driven' discussion. In addition, Rott (2019) classified teachers' behavior into closely managed, neutral, and emphasizing strategies.

Methodology

This study is action research conducted in the form of an intervention. Six prospective teachers from private (AM, KK, VI) and public university (AI, TK, and AF) were involved as the participants with each group having different mathematical backgrounds. Initially, the intervention was held separately for participants from private and public universities. The class with

private university students was the first cycle, while the class with public university students was the second cycle. In some points, the second cycle was the modification of the first cycle.

a. Research Trajectory

   Preliminary test: Individual problem posing and teaching implementation.

   Topic 1: Teaching reflection and giving feedback to each other.

   Topic 2: Introduction to problem posing (theoretical discussion).

   Topic 3 & 4: Collaborative problem posing.

   Topic 5: Individual problem posing and collaborative improvement of the problems.

   Middle test: Individual problem posing, collaborative improvement of the problems, and teaching implementation.

   Topic 6: Teaching reflection and giving feedback to each other.

   Topic 7, 8, & 9: Individual problem posing and collaborative improvement of the problems.

   Topic 10 & 11: Pattern recognition and generalization.

   Follow-up test: Individual problem posing, collaborative improvement of the problems, and teaching implementation.

b. Evaluation

   Problem posing

   - Product (blind task-exercise-empowered problem).
   - Knowledge base (mathematical topic).
   - Heuristic (symmetry-constraint manipulation-goal manipulation-targeting a particular solution-generalization-specification-focusing on interesting part-introducing an additional condition).
   - Role (initiator-clarifier-challenger-settler-modification provider-solution provider-supporter-follower-viewer).
   - Consideration of aptness (aptness to himself or herself as the poser-aptness to the potential solvers-aptness to the group members).

Problem solving

- Product (blind solution–incorrect solution–correct solution).
- Error (procedural error-conceptual error).
- Cognitive resource (related concept).
- Heuristic (look for patterns-make suppositions-solve part of the problem-act it out-make a systematic list-use a diagram/model).

Critical manifestation

- Simple mathematical or non-mathematical response → non-critical thinking manifestation.
- Mathematical or non-mathematical response with reasoning, comments, or evaluations and valuable mathematical or non-mathematical question → critical thinking manifestation.

Teaching perspective

- Closely managed → teaching as transferring knowledge.
- Neutral and emphasizing strategies → teaching as facilitating students to construct knowledge by themselves.

Teaching implementation

- Recitation + closely managed → traditional approach.
- Partner talk or student presentation or position-driven discussion + neutral or emphasizing strategies → active learning approach.

Results and Conclusions

The main objective of the intervention was to support the implementation of the current Indonesian curriculum by assisting prospective mathematics teachers in developing their mathematical and pedagogical skills. The findings indicate that the intervention had a favorable impact on developing those skills, described in detail as follows.

RQ1:

The proposed tasks that fall into the exercises category appeared the most. The dual-task design and peer discussion had advantageous effects on the quality improvement of the task. The first submitted tasks, considered either exercise or blind because unrealistic and unsolvable, were modified to make more sense and be solvable with a better formulation. More specifically, one (AI) out of six participants tended to pose empowered problems, even from the beginning of the intervention.

RQ2:

Most of the solutions were correct, meaning the participants had appropriate cognitive resources, controlled the process, and utilized suitable heuristics when solving their proposed tasks. The use of an algebraic approach is visible in their solutions to the problems discussed during the lesson and the solutions to their proposed tasks, indicating that the organized topics fostered the algebraic approach to emerge. On the other hand, several incorrect solutions also existed because of the procedural or conceptual errors, or a careless problem-solving process. One (VI) out of six participants performed errors in two cases showing both procedural and conceptual errors.

RQ3:

Critical manifestations appeared as mathematical or non-mathematical responses with reasoning, comments, or evaluations and valuable mathematical or non-mathematical questions. They evaluated their practice by highlighting key issues to shape their understanding of their practice while taking a practical approach to the task they discussed during the lesson. Throughout the intervention, all participants expressed their critical attitude.

RQ4:

The preliminary and the final results show a shift in their perspectives, becoming more oriented toward perspective

teaching as assisting students in constructing knowledge, particularly emphasizing strategies. In particular, the two participants (AM and KK) who previously chose to be closely managed the class changed their preferred behavior into neutral or emphasizing strategies. In addition, one participant (TK) whose perspective was neutral and emphasizing strategies changed her view into closely managed for the first two problem-solving steps. Her teaching experience might influence her perspective in this case.

RQ5:

There was a gradual progression toward active learning in the participants' teaching implementation. Those whose implementation had been considered active learning since the beginning tended to maintain their styles, while others (KK and VI) attempted to interact more with their pupils by asking for their ideas on subsequent occasions. Besides the teaching perspective, other factors might influence their teaching implementation, i.e., role models come from the previous learning experience, and intrinsic, altruistic, and extrinsic motivation.

Pedagogical Implications and Concluding Remarks

This study makes the following recommendations: (1) teacher trainee programs should form study groups of prospective teachers with explicit instructions to do the abovementioned activities, not merely practice teaching together in their last year and report their teaching after several months of practicing, (2) there should be problem-posing and discussion sections in the group accompanied by an instructor to make improvements during their teaching internship, and (3) given that some (not all) universities provide courses to support prospective teachers during their teaching internships, such as lesson planning and learning module development, the above activities can be incorporated into these courses.

Finally, the following points are worth noting: (1) as this study involved a small number of prospective teachers and was conducted online, further research topics could be a similar model applied to in-service teachers or implemented in face-to-face meeting, and (2) the results could not be generalized due to the small number of participants. A scheme that allows the results to be generalized is to conduct research involving several small groups of students with a different instructor for each group.

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Attended Conference as Presenter

1. 13th Congress of the European Society for Research in Mathematics Education (CERME13)
   Presentation title:
   A promising path toward infinite improvement in mathematics teaching and learning.
   Budapest, Hungary. 10-14 July 2023.
2. Didactic Research Conference on Mathematics and Computer Science (MIDK)
   Presentation title:
   A promising path toward infinite improvement in mathematics teaching and learning.
   Oradea, Romania. 31 March - 2 April 2023.
3. International Conference on Mathematics and Science Education (ICoMSE)
   Presentation title:
   Generated worthwhile problem promoting algebraic thinking: from pattern exploration to generalization.
   Malang, Indonesia. 9-10 August 2022.
4. Conference on Contemporary Mathematics Education (CME)
   Presentation title:
   First experience with problem-posing: What can be done with a multiplication table?
   Gdańsk, Poland. 27-30 June 2022.

5. 12th Congress of the European Society for Research in Mathematics Education (CERME12)
   Presentation title:
   Exploring Indonesian prospective teachers' teaching belief and teaching practice.
   Bolzano, Italy. 2-6 February 2022.
6. Didactic Research Conference on Mathematics and Computer Science (MIDK)
   Presentation title:
   First experience with problem-posing: what can be done with a multiplication table?
   Baja, Hungary. 1-3 April 2022.
7. Conference on Contemporary Mathematics Education (CME)
   Presentation title:
   How do students with different personality types show their critical thinking when solving a mathematical problem?
   Gdańsk, Poland. 28-29 June 2021.
8. Didactic Research Conference on Mathematics and Computer Science (MIDK)
   Presentation title:
   Problem Solving: How Do Students with Different Personality Solve Mathematical Problem?
   Sárospatak, Hungary. 24-26 January 2020.
9. Science and Mathematics International Conference (SMIC)
   Presentation title:
   Translation among mathematical representations: How do moslem students with different gender perform the process?
   Jakarta, Indonesia. 2-4 November 2018.
10. International Conference on Science, Technology, Education, Arts, Culture, and Humanity (STEACH)
    Presentation title:

Dynamism of open-ended problem solving: study on junior high school students' behavior based on Keirsey personality type
Surabaya, Indonesia. 29 October 2018.

11. International Conference on Mathematics and Science Education (ICMScE)
    Presentation title:
    Student's critical-metacognition activitiy based on their personality type.
    Bandung, Indonesia. 5 May 2018.
12. Mathematics, Informatics, Science, and Education International Conference (MISEIC)
    Presentation title:
    Student's critical thinking in solving open-ended problems based on their personality type.
    Surabaya, Indonesia. 6 September 2017.

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Idegen nyelvű, külföldi könyvrészletek (1)

1. **Fitriana, L. D.**: First experience with problem-posing: What can be done with a multiplication table. In: Critical Thinking Practices in Mathematics Education and Beyond. Eds.: Bozena Maj-Tatsis; Konstantinos Tatsis, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów, 137-146, 2022. ISBN: 9788382770131

Idegen nyelvű tudományos közlemények külföldi folyóiratban (1)

2. **Fitriana, L. D.**, Ekawati, R., Kovács, Z.: Perspectives on the problem-posing activity by prospective teachers: a cross-national study. *J. Math. Educ. 13* (1), 149-172, 2022. ISSN: 2087-8885. DOI: http://dx.doi.org/10.22342/jme.v13i1.pp149-172

Idegen nyelvű konferencia közlemények (2)

3. **Fitriana, L. D.**: Generated Worthwhile Problem Promoting Algebraic Thinking: From Pattern Exploration to Generalization. In: ICoMSE 2022 : 6th International Conference on Mathematics and Science Education Online Virtual Conference, 9-10 August 2022, [s.n.], "Accepted by publisher" [s.l.], 1-8, 2023.
4. **Fitriana, L. D.**: Exploring Indonesian prospective teachers' teaching belief and teaching practice. In: Proceedings of the Twelfth Congress of the European Society for Research in Mathematics Education. Eds.: Jeremy Hodgen; Eirini Geraniou; Giorgio Bolondi; Federica Ferretti, Free University of Bozen-Bolzano, Italy and ERME, Bozen, 3577-3584, 2022. ISBN: 9791221025378

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További közlemények

Idegen nyelvű, külföldi könyvrészletek (1)

5. **Fitriana, L. D.**: Problem solving: how do students with different personality types show their critical thinking when solving a mathematical problem?
   In: Critical thinking in mathematics : perspectives and challenges. Eds.: Bozena Maj-Tatsis; Konstantinos Tatsis, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów, 153-163, 2021. ISBN: 9788379969036

Idegen nyelvű tudományos közlemények külföldi folyóiratban (2)

6. Fuad, Y., Ekawati, R., Sofro, A., **Fitriana, L. D.**: Investigating Covariational Reasoning: What Do Students Show when Solving Mathematical Problems?
   J. Phys. Conf. Ser. 1417 (1), 1-9, 2019. ISSN: 1742-6588.
   DOI: http://dx.doi.org/10.1088/1742-6596/1417/1/012061
7. **Fitriana, L. D.**, Fuad, Y., Ekawati, R.: Student's Critical Thinking in Solving Open-Ended Problems Based on Their Personality Type.
   J. Phys. Conf. Ser. 947, 1-8, 2018. ISSN: 1742-6588.
   DOI: http://dx.doi.org/10.1088/1742-6596/947/1/012007

Idegen nyelvű konferencia közlemények (1)

8. **Fitriana, L. D.**, Fuad, Y., Rosyidi, A. H.: Dynamism of Open-Ended Problem Solving: Study on Junior High School Students Behavior Based on Keirsey Personality Type.
   Advances in Social Science, Education and Humanities Research. 277, 1-5, 2019. ISSN: 2352-5398.
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List of publications related to the dissertation

Foreign language international book chapters (1)

1. **Fitriana, L. D.**: First experience with problem-posing: What can be done with a multiplication table. In: Critical Thinking Practices in Mathematics Education and Beyond. Eds.: Bozena Maj-Tatsis; Konstantinos Tatsis, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów, 137-146, 2022. ISBN: 9788382770131

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Foreign language conference proceedings (2)

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Foreign language scientific articles in international journals (2)

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