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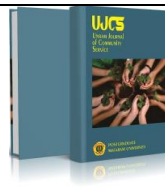

Fostering Higher Order Thinking Skills in Mathematics Learning: A Scoping Review of Teacher Development Initiatives

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Abstract: This community service program aimed to enhance both the understanding and application of Higher-Order Thinking Skills (HOTs) in mathematics instruction for participating teachers. Employing a targeted professional development approach informed by the Community-Based Participatory Research (CBPR) framework, the program equipped 21 mathematics teachers from Musyawarah Guru Mata Pelajaran (MGMP) in Aceh Tengah District, Indonesia, with the necessary knowledge and pedagogical strategies to foster and cultivate high-level thinking skills in their students. The program demonstrably improved teachers' knowledge, skills, and commitment towards implementing HOTs-oriented instruction. While areas like solving HOTs questions necessitate further attention, the overall results suggest success, paving the way for continued advancements in promoting deep-thinking and problem-solving skills in mathematics education. Analysis of the data reveals a positive impact of the program on teachers' understanding of HOTs. While areas such as problem-solving and critical thinking require further development, the program evidently achieved its goals of raising awareness, knowledge, and application skills related to HOTs. Building upon this foundation, future interventions can delve deeper into these advanced skills, further empowering teachers to cultivate critical thinking and problem-solving abilities in their students.

Keywords: CBPR; HOTs; Mathematics; Professional development; Teacher Training

Introduction

The Indonesian educational landscape often leans towards teacher-centered approaches (Zulfikar, 2009), leading to concerns about teacher competency (Azra, 2002). This issue manifests in mathematics education within Aceh Tengah District, where traditional, lecture-based methods and repetitive practice questions dominate, despite attempts to incorporate active learning strategies in lesson plans (Gradini, 2021; Gradini & Firmansyah, 2020).

Curricula emphasize the development of crucial 21st-century skills, including critical thinking, higher-order thinking (HOTs), collaboration, technological fluency, and effective intrapersonal and interpersonal skills. Assessing HOTs, often evaluated through national standardized assessments like the National Competency Assessment, plays a pivotal role in preparing students for success in the dynamic landscape of Industry 4.0. Cultivating these skills is instrumental in fostering a competent and adaptable citizenry.

Both the 2013 Curriculum and the Merdeka Belajar Curriculum, aligned with contemporary educational philosophies, prioritize the development of critical and creative thinking, collaboration, creativity and innovation, problem-solving, independence, and a growth mindset. This shift towards learner-centered pedagogies aims to cultivate well-rounded students

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capable of not only excelling in the classroom but also thriving in diverse real-world situations.

Literature reinforces these observations. Heong et al. demonstrate that problem-based learning, crucial for nurturing Higher-Order Thinking Skills (HOTs), remains underutilized by teachers (Heong et al., 2019). They prioritize direct concept explanation and rote practice, citing efficiency and material completion as justifications. This aligns with a study findings regarding low teacher proficiency in solving HOTs problems (Arifin & Retnawati, 2018; Pratama & Retnawati, 2018), attributing it to difficulties in identifying suitable techniques and strategies (Yuliati & Lestari, 2018).

A study investigating students' Higher-Order Thinking Skills (HOTs) in mathematics within Aceh Tengah District revealed concerning outcomes. The research identified inadequate student mastery in tackling HOTs-based questions (Gradini, Firmansyah, & Noviani, 2018), indicating low skill levels. Moreover, the study highlighted the significant challenge mathematics teachers face in effectively stimulating students' development of HOTs. Additionally, the research pointed to a lack of appropriate pedagogical instruments among the majority of teachers for both teaching and assessing HOTs competencies (Gradini, 2022; Gradini, Khairunnisak, & Noviani, 2022).

In response to these identified needs, a service team developed and implemented valid, practical, and effective HOTs-oriented mathematics learning tools. These tools, designed to enhance students' HOTs abilities, were utilized as training and assistance materials within community service activities.

The distinction between lower-order thinking skills (LOTs) and higher-order thinking skills (HOTs) has garnered significant attention in recent educational research (Brookhart, 2010; Collins, 2014; Conklin, 2012; DeSanctis & Poole, 1994; Dewey & Bento, 2009; Madhuri, Kantamreddi, & Prakash Goteti, 2012; Marzano, 2016; Preus, 2012; Yee et al., 2015). While the concept originated with pioneers like (Barak & Dori, 2009; Bloom, Engelheart, Furst, Walker H, & Krathwohl, 1956; Newmann, 1990; L. B. Resnick, 1987; L B Resnick, 1987), its contemporary relevance remains paramount.

Resnick offers a compelling definition of HOTs, encompassing "elaborating on given material, making inferences beyond explicitly presented information, constructing adequate representations, analyzing and building relationships" (L. B. Resnick, 1987). This is exemplified in reading comprehension, where students move beyond literal understanding to make inferences and utilize implicit information. Resnick further defines key characteristics of HOTs: (1) non-algorithmic nature, (2) inherent complexity, (3) generation of multi-faceted solutions, and (4) engagement with criteria, uncertainty, and self-regulation (Lauren B Resnick, 1983).

Importantly, Resnick highlights that HOTs transcend the "understand and apply" levels in Bloom's taxonomy (L B Resnick, 1987), representing a distinct category of cognitive activity. This distinction underscores the need for educational practices that explicitly cultivate these advanced thinking skills.

This community service program seeks to enhance and fostering both the understanding and application of Higher-Order Thinking Skills (HOTs) within mathematics instruction for participating teachers. Through targeted professional development, the program strives to equip educators with the necessary knowledge and pedagogical strategies to effectively fostering and cultivating high-level thinking skills in their students.

Method

Community-Based Participatory Research (CBPR) approach, prioritizing participatory methods. This framework fosters the active engagement of researchers/service providers and the target community throughout the research cycle, including planning, action, monitoring, and evaluation.

The partner community comprises 21 mathematics teachers from junior high school-level Musyawarah Guru Mata Pelajaran (MGMP) in Aceh Tengah District, Aceh, Indonesia. The community service team comprises three lecturers from the Mathematics Education Department, Faculty of Education, IAIN Takengon, each possessing experience in conducting community service initiatives, particularly those focused on enhancing teacher capacity and competence.

The CBPR emphasizes active community participation in all research stages, ensuring both ownership and relevance of the intervention. The stages this community service conducted as follow.

Firstly, Laying the Foundation. We conducted a Focus Group Discussions (FGDs) and formulating service focus and goals at this stage. In Focus Group Discussions (FGDs), we facilitate collaborative goal and role negotiation with the target community (mathematics teachers) and stakeholders. Activities include: (1) Stakeholder mapping and role definition; (2) Identifying research assumptions; (3) Contextualizing the research situation; and (4) Establishing research objectives. Furthermore, in formulating community service focus and goals, we define the service's issue, which is teacher empowerment for HOTs-oriented mathematics, and set goals of service, which are increasing teachers' independent and sustainable HOTs teaching capacity. We also analyze potential time and

cost constraints, community needs and readiness, and stakeholder support.

Secondly, Research Planning. Leveraging a mixed-methods approach, the research planning stage employed Focus Group Discussions (FGDs), training workshops, and post-workshop mentoring. FGDs served to refine the focus of the mentoring program and collaboratively establish the research design, instruments, and monitoring and evaluation models. Workshop personalized mentoring equip teachers with HOTs knowledge and pedagogical skills.

Thirdly, Collecting and Analyzing Data. Data collection employed a mixed-methods approach, utilizing pre- and post-workshop questionnaires, HOTs problem-solving tests, and product assessments of HOTs-aligned lesson plans and learning materials (RPPs and LKPDs) developed by participants. The pre- and post-workshop questionnaires, administered to teachers, assessed their understanding and perceptions of HOTs. The HOTs problem-solving tests measured teachers' ability to identify and solve these higher-order thinking problems.

Finally, Acting on Findings. We followed up the finding by Joint Education with the Community. In this act, we recognize the participatory nature of the target community. We collaborating with the mathematics teachers in translating research findings into actionable steps for achieving the desired changes. This collaborative "knowledge translation" process aims to ensure the findings are not only understood but also effectively utilized by the community to drive sustainable improvements.

Result and Discussion

This community service program adheres to the four-stage Community-Based Participatory Research (CBPR) implementation framework outlined in the methodology section. Focus Group Discussions (FGDs) initiated the community service program by outlining its blueprint and fostering trust-building partnerships with the target community (SMP/MTs teachers) and stakeholders (MGMP Mathematics). Participants negotiated goals and roles, with the community service team assuming responsibility for implementation, target setting, instrument development, and expert assistance. MGMP Mathematics served as a stakeholder and partner, providing time, venue, and contributing to target and instrument development.

Subsequent FGDs explored data to analyze issues and conditions within the mathematics teachers. This stage aimed to identify service focus, goals, community needs and conditions, and stakeholder support. Collaborative data analysis with MGMP Mathematics and university researchers revealed a concerning trend as follow: (1) students' low ability to solve Higher-Order Thinking (HOT) questions in mathematics; and (2) Teachers' own limited experience with HOT-oriented instruction.

Recognizing this challenge, the teacher development program was designed to address teachers' HOTs teaching competence, focusing on developing materials, solving, and assessing HOT-type questions.

Further FGDs established service goals as follow: (1) enhance teachers' understanding and abilities in HOTs learning, (2) optimize MGMP participation in capacity building, (3) assess teachers' ability to create HOT-aligned lesson plans and learning materials (RPPs and LKPDs), and (4) establish a University-Community Partnership between the Mathematics Education Department of IAIN Takengon and Mathematics MGMP of Aceh Tengah.

Figure 1. Laying the foundation of program through FGD

Following the FGDs, the community service team develop research instruments for the research. These instruments consisted of questionnaires measuring teacher responses and assessment sheets specifically designed to evaluate HOTs-aligned lesson plans (RPPs) and learning materials (LKPDs). Futhermore, three research instruments were employed to assess teachers' knowledge, perceptions, and skills related to HOTs-oriented mathematics instruction.

1. Teacher Response Questionnaire. This self-administered questionnaire measured teachers' understanding and perceptions of key concepts in HOTs, their experience implementing HOTs-based learning, and perceived obstacles encountered during such instruction. Administered twice, pre- and post-workshop I and II, it allowed for tracking changes in knowledge and perceptions over time.
2. HOTs-Aligned Learning Tool Assessment Sheet. This instrument evaluated teachers' ability to design learning tools aligned with HOTs principles. Specifically, it assessed the developed Learning Implementation Plans (RPPs) and Student Worksheets (LKPDs) following a workshop focused on HOTs-oriented mathematics learning.

3. HOTs Problems. This instrument assessed teachers' ability to identify and solve Higher-Order Thinking (HOTs) questions. This instrument comprised six mathematics problems designed to represent HOTs characteristics. Teachers were first tasked with classifying each problem according to its cognitive level (C4, C5, or C6), perceived difficulty level, and required thinking stages for solution. Using this analysis, they determined whether each problem belonged to the HOTs category. Subsequently, they were required to attempt solving the identified HOTs problems.

In this paper, we only presented result and finding from the Teacher Response Questionnaire due to the limitation of paper.

Workshop I, attended by 21 Mathematics teachers, employed a facilitative approach focusing on experiential and adult learning principles. The workshop covered three key areas: (1) foundational concepts of Higher-Order Thinking Skills (HOTs), (2) design of HOTs-aligned lesson plans (RPPs), and (3) construction of HOTs-integrated Student Worksheets (LKPDs). While the workshop generally facilitated positive engagement, some initial challenges were encountered.

On the first day, participants initially displayed limited active participation during theoretical discussions on HOTs' core concepts, characteristics, and connection to cognitive taxonomy. This may be attributed to the material's novelty and abstract nature.

The second day focused on providing practical guidance for developing HOTs-aligned RPPs and LKPDs. Despite the training, some participants continued to struggle with RPP composition due to unfamiliarity with the syntax of HOTs-oriented learning models. Similarly, crafting HOTs-integrated LKPDs proved challenging as identifying activities that effectively stimulate students' HOTs presented difficulties. To foster practical application, participants were tasked with creating LKPDs and RPPs aligned with their respective class levels. These materials were then assessed using the dedicated instrument to evaluate teacher competence in constructing HOTs-oriented RPPs and LKPDs.

Figure 2. Workshop on HOTs-oriented teaching

Workshop II witnessed a noticeable increase in participant engagement compared to Workshop I. This shift might be attributed to two factors: (1) a more relaxed workshop atmosphere due to the venue, and (2) the acquisition of foundational knowledge on HOTs concepts and cognitive taxonomy, facilitating a deeper understanding of the presented material. During interactive sessions, it became evident that while teachers could now identify HOTs-type questions, solving them remained a challenge. This potentially stems from their lack of experience in tackling such problems. Finally, a post-workshop questionnaire captured teachers' evolving understanding and perceptions of HOTs-oriented learning following their participation in Workshops I and II. The data obtained will be used to gauge the effectiveness of the training program.

The effectiveness of the teacher training program detailed on Table 1 and the teacher understanding detailed on Table 2.

Table 1. The effectiveness of the teacher training program

Incators of Success	Target (%)	Score Achievement (%)
Teachers understand the concept of HOTs	70	76.43
Teachers are able to design HOTs-oriented lesson plans	60	82.53
Teachers are able to design HOTs-oriented LKPD	60	95.00
Teachers are able to identify HOTs questions	70	76.00
Teachers are able to solve HOTs questions	70	72.10
Teachers are committed to teaching HOTs-oriented Mathematics	80	92.41

The data presented points to an overall successful program in achieving its aims to fostering HOTs-oriented instruction in mathematics education. We observe positive achievements exceeding target scores in several key areas, demonstrating significant progress among participating teachers.

Firstly, understanding of HOTs concepts surpassed expectations, reaching 76.43% against a target of 70%. This foundational knowledge is crucial for effective implementation of HOTs-based practices.

Secondly, designing HOTs-aligned lesson plans achieved an impressive 82.53%, exceeding the 60% target. This indicates that teachers are equipped with the necessary skills to structure their lessons for higher-order thinking.

The most remarkable success story comes from designing HOTs-integrated LKPDs, where the score

soared to 95.00% compared to the 60% target. This suggests exceptional capacity among teachers to create engaging learning materials that promote critical thinking and problem-solving.

While identifying HOTs questions reached 76.00%, falling slightly short of the 70% target, it still represents a positive outcome. It highlights the ability of participants to recognize problems requiring higher-order thinking skills. However, solving HOTs questions presents an area for further development. The score of 72.10% against the 70% target suggests that while teachers can identify these questions, confidently solving them requires additional attention.

Finally, commitment to teaching HOTs-oriented mathematics stands out at an outstanding 92.41%, significantly exceeding the 80% target. This unwavering dedication from teachers bodes well for the sustainability of the implemented practices.

Table 2. teachers' understanding of key concepts in HOTs

Teacher Understanding	Pre-Workshop (%)	Post Workshop (%)
HOTS Awaraness	75.00	95.00
HOTs Question Difficulty Level	45.00	70.00
LOTS and HOTS concept	100.00	100.00
Cognitive Level Concept	85.00	95.00
Problem Solving Concept	15.00	35.00
Critical Thinking concept	35.00	45.00
Presentation of HOTs questions	75.00	95.00

The presented data reveals a significant improvement in teachers' understanding of Higher-Order Thinking Skills (HOTs) following the workshop, indicating the program's success in achieving its learning objectives. Awareness of HOTs saw a substantial leap from 75% to 95%, demonstrating that the workshop effectively introduced the core concepts and their importance in education. Similarly, distinguishing HOTs question difficulty levels improved markedly, rising from 45% to 70%, signifying enhanced ability to identify various cognitive demands within problems.

The data for differentiating between LOTS and HOTs concepts remained consistent at 100%, suggesting a high level of clarity on this fundamental distinction. Additionally, understanding cognitive levels increased from 85% to 95%, indicating deeper comprehension of the different intellectual processes involved in solving problems. While the initial understanding of problem-solving and critical thinking concepts was low (15% and 35%, respectively), the workshop led to notable improvements, reaching 35% and 45%. This highlights the workshop's effectiveness in addressing these crucial aspects of HOTs.

Finally, the ability to present HOTs questions also saw a significant improvement, rising from 75% to 95%. This suggests that teachers gained valuable skills in crafting problems that encourage higher-order thinking in their students.

Conclusion

The teacher development program has demonstrably enhanced teachers' knowledge, skills, and commitment towards HOTs-oriented instruction. While some areas, like solving HOTs questions, require further focus, the overall results paint a picture of success, paving the way for continued progress in promoting deep-thinking and problem-solving skills in mathematics education. The data paints a positive picture of the workshop's impact on teachers' understanding of HOTs. While further progress can be made in areas like problem-solving and critical thinking, the program has demonstrably achieved its goals in raising awareness, knowledge, and application skills related to HOTs. Building on this foundation, future interventions can delve deeper into these advanced skills to further empower teachers in fostering critical thinking and problem-solving abilities in their students.

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