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Implementing classroom action research to strengthen argumentation skills: training for chemistry educators in Mojokerto

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ABSTRACT

Improving teacher competency is more effective when supported by continuous professional development. This Community Service Program continues previous activities in 2024, which focused on training chemistry teachers to develop argumentation-based questions. Although teachers can now construct such questions, challenges remain in classroom implementation, especially in applying strategies and assessing their impact on students' argumentation skills. To address this, the program introduces Classroom Action Research (CAR) based on argumentation skills. The goal is to equip chemistry teachers with practical knowledge and skills to design and implement learning that fosters argumentation through CAR. The program includes training, group discussions, tests and questionnaires, mentoring in CAR planning, implementation practice, and reflection. Results show improved teacher understanding of argumentation structures, CAR stages, and enhanced ability to design contextual and reflective learning to develop students' argumentation skills. This program supports the sustainable development of argumentation-based learning to improve the quality of chemistry education in line with 21st-century demands. This program demonstrates an effective model for sustaining argumentation-based learning in chemistry education.

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1. INTRODUCTION

In the midst of increasingly complex societal changes, students are required not only to master knowledge but also to possess skills such as critical thinking and communication (Fikriyatii et al., 2022). These two skills are part of the global 4C competencies. Supporting both is the skill of argumentation, as the ability to construct logical opinions supported by evidence and delivered convincingly (Rusmini et al., 2025; Yusnidar et al., 2024). Although not explicitly mentioned in the 4C framework, argumentation is a concrete manifestation of quality critical thinking and communication (Roviati & Widodo, 2019). Argumentation is an essential skill for dealing with the complexity of learning in the 21st century (Muslihasari & Oktiningrum, 2023; Nazidah et al., 2022). It requires the ability to express opinions accompanied by relevant and logical evidence (Yusnidar et al., 2024). This skill serves as an entry point

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into scientific thinking through analysis, evaluation, and the assessment of information credibility (Rusmini et al., 2025).

In the context of chemistry learning, argumentation helps students analyze data, draw conclusions, and make evidence-based decisions (Osborne, 2010). Studies show that the higher a student's argumentation ability, the better their critical thinking, problem-solving, and creativity (Hasnunidah et al., 2020; Karadeniz, 2016). Unfortunately, Indonesian students' argumentation skills remain relatively low, particularly in chemistry (Yusnidar et al., 2024). In practice, the development of argumentation skills is still not aligned with curriculum expectations due to teachers' limited ability to design argumentative learning. Many teachers lack adequate pedagogical understanding to systematically build argumentative activities in the classroom (Rusmini, 2024).

In 2024, the Bachelor of Chemistry Education Study Program held a training on developing argumentation-based test items for chemistry teachers in Mojokerto. This activity showed positive results in improving teachers' understanding of how to construct indicators and argumentative questions. However, a survey of 49 members of the Chemistry MGMP showed that these skills have not been implemented consistently in classroom practice. A total of 58.1 percent of teachers experienced difficulties in designing structured argumentative activities, both in terms of pedagogy and conceptual understanding. Teachers also did not yet understand how to integrate elements of argumentation into lesson plans or learning implementation. In addition, 80.4 percent of teachers had not used Classroom Action Research as a reflective tool for improving teaching. These findings emphasize the need for practical and applicable interventions to improve the quality of argumentation-based learning.

Classroom Action Research has been proven effective as a reflective approach for teachers to systematically improve their teaching practices (Amat, 2020). Through Classroom Action Research, teachers can identify classroom problems, design data-based actions, and evaluate their impact (Fitriyah & Amin, 2021). Various training programs have been shown to empower teachers to carry out Classroom Action Research independently while producing scientific publications based on their reflections (Dinanti et al., 2021; Fitriyah & Amin, 2021). It also increases student engagement and the quality of learning activities (Amat, 2020; Jamiluddin et al., 2021). Classroom Action Research contributes to gradual and continuous improvement of education quality and supports the development of teacher professionalism (Fitriyah & Amin, 2021). It can help teachers to (1) Identify and understand specific learning problems in their classroom context; (2) Design relevant and measurable data driven solutions; and (3) Improve teaching quality through systematic cycles of planning, action, observation, and reflection (Mills et al., 2023).

By considering the low implementation of argumentation and the limited use of Classroom Action Research, argumentation-based Classroom Action Research training has become highly urgent. This training can bridge the gap between teachers' knowledge of argumentation and classroom practices that support the development of students' argumentation skills. This activity aims to equip chemistry teachers in Mojokerto with the ability to design and implement Classroom Action Research that focuses on improving students' argumentation skills. Through this training, teachers will be guided to develop argumentation-based learning actions and evaluate their impact through systematic Classroom Action Research cycles. In the long term, this activity is expected to build a more reflective and contextual chemistry learning ecosystem that aligns with the demands of twenty first century education.

2. METHODS

Time and Location

This community service activity was carried out from May to October 2025. The in-person training and workshop were held on June 21, 2025 at SMAN 1 Bangsal, Mojokerto. The main activities were

conducted offline through structured training sessions, while pre training coordination, mentoring, and post training follow up were conducted online through WhatsApp groups and Zoom meetings.

Participants

The participant of this activity was chemistry teachers who are members of the MGMP in Mojokerto City and Mojokerto Regency. A total of 18 teachers participated actively in the training, coming from different schools and having varied teaching experience. The participants were selected using purposive sampling, which was based on recommendations from MGMP administrators and the teachers' commitment to take part in the entire series of activities.

Stages of Activities

The implementation method of this community service activity used an educational and participatory approach with an interactive workshop model, as applied in teacher training in the study by Duda et al. (2024). Each stage was designed to encourage active participant engagement, strengthen conceptual understanding, and provide practical skills that can be directly applied in the classroom. Stage 1 is Pre-Training which include: (1) Coordination with the Chemistry MGMP management to agree on the technical aspects of activity implementation; (2) A mini-survey to map teacher needs related to strengthening argumentation skills and implementing CAR; (3) Development of training modules containing material on argumentation in chemistry learning and CAR techniques, based on the results of the partner needs analysis (Jusuf & Sobari, 2021). Stage 2 is Training and Workshops which include: (1) The main activity was held face-to-face on June 21, 2025, at SMAN 1 Bangsal Mojokerto; (2) The material was delivered through discussions, presentations, and a question-and-answer session; (3) A practical workshop on developing argumentation-based PTK designs was also conducted; (4) Pre-test and post-test were conducted to measure understanding. Stage 3 is PTK Mentoring and Implementation which include: (1) Online mentoring was conducted twice via Zoom in July 2025; (2) Participants implemented practical work-based learning (PTK) in their respective classrooms under the guidance of instructors; (3) The practicals included application examples and direct feedback to deepen understanding (Muhsinin et al., 2019). Stage 4 is Evaluation and Reflection which include: (1) Joint reflection on the results of PTK implementation; (2) Evaluation of learning outcomes and improvement of participants' argumentation skills; (3) Preparation of activity report as feedback for future program development.

	Training & Workshop		
Distribution of Pretest at the beginning of the training session	**1st Material:** Introduction to 21st Century Skills - Argumentation Skills, Learning Strategies to Practice Argumentation **2nd Material:** Understanding the principles of PTK as an approach to improving the quality of learning and applying argumentation skills	**Workshops**: Developing an Action Plan Based on Argumentation Skills Participants presented the integration of argumentation skills into chemistry learning by developing an action plan.	**Distribution of post-test and questionnaires** at the end of the training session

Figure 1. Training design

Figure 1 shows the design of stage 2, which is the training and workshop activity. It began with a pre-test, followed by the delivery of material and a workshop on designing classroom action research based on argumentation skills, and ended with a post-test and a satisfaction questionnaire. The session used interactive presentations, question-and-answer activities, and group discussions to help participants practice the skills more effectively.

Evaluation

The evaluation of this community service activity used a mixed-methods approach, combining quantitative and qualitative methods to assess the effectiveness of the training and mentoring. The aspects evaluated included the participants' improvement in understanding argumentation skills and the stages of Classroom Action Research (CAR), the quality of participation during the training and workshop, their ability to develop argumentation-based learning tools, and their readiness to implement the training outcomes in their own classrooms.

The evaluation instruments consisted of: (1) a 20-item pre-test and post-test to measure participants' improvement in knowledge related to argumentation skills and CAR implementation (Arikunto, 2021); (2) Observation of participation during training sessions and group practice; (3) An initial survey and a partner satisfaction questionnaire; and (4) Open reflection to explore teachers' perceptions, challenges, and suggestions throughout the training stages. By applying this combination of instruments, the evaluation assessed not only the increase in participants' conceptual understanding but also the practical impact on teachers' ability to design and implement argumentation-based learning through CAR.

3. RESULTS AND DISCUSSION

Initial Surveys

The community service activity began with a survey and virtual coordination through a Zoom meeting between the implementing team and the chemistry teacher association (MGMP Kimia) in both the city and district of Mojokerto. The initial survey results are shown in Figure 2, which illustrates the relevance of CAR and argumentation skills and the teachers' experience in implementing CAR.

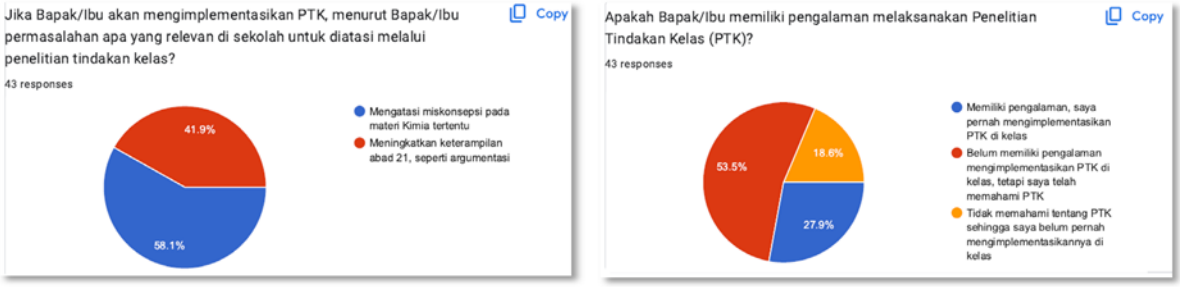

Figure 2. Initial survey results: (a) PTK relevance and argumentation; (b) PTK experience

The survey results indicate that most teachers have not yet been able to implement argumentation-based questions in the learning process. The main obstacles identified include limited understanding of strategies for applying argumentative questions in the classroom, limited ability to assess students' argumentation skills, and a lack of experience in using Classroom Action Research (CAR) as an approach to diagnose and solve learning problems. These conditions prevent argumentation-oriented learning

from being carried out optimally and from producing significant improvements in student competence. Therefore, training on implementing argumentation skills through CAR is needed.

Based on these findings, the partner and the PKM team agreed to conduct a training program on the implementation of argumentation skills based on CAR, held on 21 June 2025 at SMAN 1 Bangsal, Mojokerto.

Module Development

The development of the training module was designed to strengthen argumentation skills in the learning process and to improve teachers' ability to implement Classroom Action Research (CAR). In addition to presenting core material, the module includes participant worksheets that function as practical guides for designing CAR actions based on the development of argumentation skills. Other components included are evaluation instruments and training questionnaires to assess the effectiveness of the program.

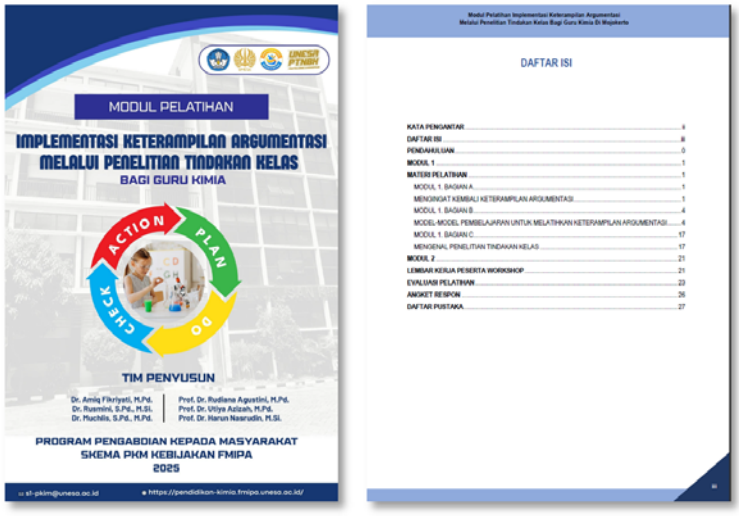

Figure 3. Training module

To complement the module, the team also prepared training support tools in the form of presentation slides and sample instruments relevant to measuring argumentation skills and implementing CAR. A visualization of the developed module is shown in Figure 3.

Training and Workshops

The training and workshop were conducted offline through a series of activities that included material presentations, group discussions, practical exercises on designing CAR based on argumentation skills, and the administration of pre-tests and post-tests. The material provided covered an introduction to 21st-century skills, the concept of argumentation skills, instructional strategies for fostering argumentation, and the principles of Classroom Action Research (CAR) as an effort to improve learning quality. The implementation of these activities aligned with the goal of developing participants' competencies (Agus et al., 2022). The methods used included interactive lectures, collaborative discussions, practical exercises, and question-and-answer sessions, all of which complement one another

in promoting conceptual understanding, experience sharing, and participants' ability to design CAR that integrates argumentation skills.

Documentation showing the workshop presentation process and the delivery of material on argumentation is presented in Figure 4.

Figure 4. Photos of training and workshop activities: (a) Material and question and answer session; (b) Group mentoring; (c) Presentation; and (d) Group photo

The activity proceeded with active participation from all participants. Each session was designed to encourage reflection, creativity, and the strengthening of teachers' capacity as learning practitioners. The material was delivered through interactive presentations developed to facilitate both conceptual understanding and practical application. The question-and-answer sessions provided opportunities for participants to deepen their knowledge, clarify information, and share their classroom experiences. All of these learning dynamics are documented in Figure 4.

Implementation and Mentoring

Based on the results of the implementation and mentoring, 18 partner teachers were divided into four groups (4–5 teachers each) to develop argumentation-based learning materials and finalize the PTK instruments. Each group completed all stages of the activity, including preparing the lesson plan and student worksheet, designing the PTK, and revising the materials based on the mentoring process. The achievements for each success indicator are presented in Table 1.

The results show that three of the four groups successfully completed most of the success indicators, while one group did not meet all indicators, particularly in finalizing the PTK instruments and simulating the implementation of the argumentation-based learning strategy. All groups participated actively and were able to revise their materials based on mentor feedback.

Table 1. Indicators of success of implementation and mentoring

Success Indicators	Number of Groups Succeed (From 4 groups)	Percentage (%)
Preparation of argumentation-based learning tools (RPP and LKPD)	3	75
Finalization of CAR instruments (observation sheets, argumentation questions)	3	75
Suitability of CAR design to scientific procedures (planning–action–observation–reflection)	3	75
Ability to implement argumentation-based learning strategies (simulations)	2	50
Ability to revise tools based on mentor feedback	4	100
Completion of the final draft of the complete CAR (tools + instruments)	3	75
Active participation in all mentoring sessions	4	100

Evaluation (Pre-Test, Post-Test, Questionnaires, Reflections)

Pre-test and post-test

Overall, the pre-test and post-test results show an increase of 21 to 24 points across all indicators, indicating the success of this training program in developing teachers' professional competence. The training had a positive impact on improving teachers' ability to implement argumentation skills and Classroom Action Research (CAR) in their respective classes, as presented in Figure 2.

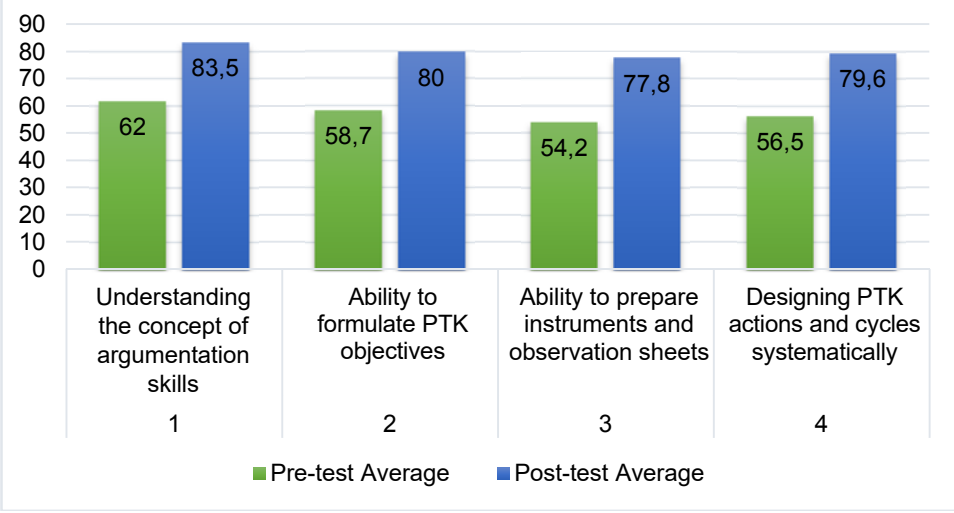

Figure 5. Pre-test and post-test results

Questionnaires

The questionnaire completed by the 18 partner teachers shows a very high level of satisfaction with the implementation of the 2025 PKM program. All respondents selected either strongly agree (SS) or agree (S) for every item evaluated, as shown in Table 2.

Table 2. Questionnaire results

Questions	Percentage (%)			
	SS	S	TS	STS
Would you like to collaborate again in the future?	66,70	33,30	0	0
Did you benefit from this training collaboration?	77,80	22,20	0	0
Did this training collaboration meet your expectations?	72,20	27,80	0	0
Did the mentoring provided by the PKM team meet your needs?	61,10	38,90	0	0
Did the PKM team serve your needs appropriately and professionally?	83,30	16,70	0	0

Based on Table 1, the plan for continued collaboration received 12 strongly agree (SS) responses (66.7 percent) and 6 agree (S) responses (33.3 percent). The program benefits aspect shows that 14 teachers (77.8 percent) selected strongly agree (SS) and 4 teachers (22.2 percent) selected agree (S). The alignment of the activities with partner expectations received 13 strongly agree (SS) responses (72.2 percent) and 5 agree (S) responses (27.8 percent). For the mentoring aspect, 11 teachers (61.1 percent) responded strongly agree (SS) and 7 teachers (38.9 percent) responded agree (S). Meanwhile, service professionalism is reflected in the 15 teachers (83.3 percent) who selected strongly agree (SS) and the 3 teachers (16.7 percent) who selected agree (S).

Training reflections

During the training activities, the partner teachers reflected on the learning experiences they gained. Based on the collected reflection notes, most participants stated that the training helped them understand the concept of argumentation skills and its application in PTK-based instruction. The teachers also noted that preparing PTK action plans became easier after participating in the practice sessions and mentoring.

Of the 18 participants who joined the training, most felt that the group discussions, PTK practice sessions, and argumentation-based learning simulations provided opportunities to share experiences and learn from their peers. Several teachers noted that this reflection process helped them identify the challenges they faced when applying argumentation skills in the classroom as well as the improvement steps they could take. Overall, the reflections show that participants actively engaged in reviewing their learning process, recognized the importance of argumentation skills in science education, and were able to plan follow-up actions for implementing PTK in their respective classrooms.

Discussion

Interpretations of results

The initial survey showed that most partner teachers from the Chemistry MGMP of Mojokerto City and Regency were not yet able to implement argumentation-based questions effectively in their teaching (Figure 2a–b). The main challenges included limited understanding of how to apply argumentative questions in the classroom, limited ability to assess students' argumentation skills, and a lack of experience in using Classroom Action Research (CAR) to diagnose and solve learning problems. These conditions indicate the need for a structured training program that integrates argumentation skill development with CAR as a reflective approach to improving teaching quality.

In response to these findings, the training module was designed to strengthen teachers' argumentation skills and improve their ability to plan and carry out CAR. The module includes core materials, participant worksheets, evaluation instruments, training questionnaires, and supporting tools such as presentation slides and sample instruments for measuring argumentation skills (Figure 3). The training was conducted offline through a series of activities, including material presentations, group discussions, CAR drafting practice, and simulations of argumentation-based learning. The activities were also supported with a pre-test and post-test to measure the effectiveness of the training (Figure 4a–d).

Based on the implementation and mentoring activities, 18 teachers were divided into four groups (4–5 teachers each). Three of the four groups successfully completed most of the success indicators, including the development of argumentation-based learning tools, the finalization of CAR instruments, the alignment of their CAR designs with scientific procedures, and the completion of a full final CAR draft. One group did not meet all indicators, particularly in finalizing the CAR instruments and simulating the application of argumentation-based learning strategies (Table 1). All participants showed active engagement and were able to revise their materials based on the feedback provided during mentoring.

The pre-test and post-test results presented in Figure 5 show an average increase of 21–24 points across all competency indicators, including understanding the concept of argumentation skills, formulating CAR objectives, preparing instruments and observation sheets, and planning CAR actions and cycles. This indicates that the training successfully improved the teachers' conceptual understanding and technical skills in designing and implementing CAR based on argumentation skills.

The evaluation of the partner survey showed a high level of satisfaction, with most teachers selecting strongly agree or agree across all aspects, including interest in establishing further collaboration, program benefits, activity alignment, mentoring, and the professionalism of the PKM team (Table 2). The training reflections further reinforced the quantitative findings, showing that teachers became increasingly aware of the importance of argumentation skills, were able to plan follow-up CAR actions, and gained confidence in integrating reflective, CAR-based learning into their classrooms. Participants noted that the discussion sessions, hands-on practice, and simulations provided collaborative learning experiences that helped them identify challenges, develop improvement strategies, and build readiness and motivation to enhance their professional competencies.

Overall, these findings indicate that the PKM training and mentoring successfully enhanced the chemistry teachers' capacities, in terms of concepts, technicalities, and affective. The teachers not only gained theoretical understanding of argumentation skills and CAR, but were also able to apply this knowledge in classroom practice that is more reflective, problem-based, and argumentation-driven. This intervention highlights the importance of collaborative and reflective approaches in teacher professional development, while also strengthening the MGMP network as a space for sharing best practices and pedagogical innovation.

Comparison with previous studies

Findings from the training and workshop activities show consistency with previous research on the effectiveness of Classroom Action Research (CAR) and teacher professional development programs. Several studies emphasize that CAR can improve teachers' pedagogical competence, enhance the quality of teaching and learning processes, and strengthen teachers' skills in systematically designing and implementing instructional actions (Amat, 2020; Dinanti et al., 2021). The PKM training results show that teachers who previously struggled to prepare CAR proposals, observation instruments, and reports

are now more prepared and have a clearer framework. This aligns with Fitriyah and Amin (2021), who highlight the importance of structured CAR training to increase teachers' awareness of the need for reflection in instructional practice.

This activity also created a collaborative space that encouraged the exchange of experiences and innovative ideas among teachers, reinforcing the role of MGMP as a professional forum for enhancing pedagogical competence and teacher professionalism. From a socio-pedagogical perspective, the activity strengthened the network between universities and educational practitioner communities, while providing access to best practices and competency updates.

In the context of chemistry learning, the argumentation skills emphasized in the training have been shown to play an important role in encouraging students to think critically, analyze data, construct evidence-based arguments, draw logical conclusions, and make scientific decisions systematically (Akhdinirwanto et al., 2020; Darmawansah et al., 2025; Epriliyani & Deta, 2024; Osborne, 2010; Yusnidar et al., 2024). The PKM findings confirm the relevance of this literature, showing that interventions integrating the strengthening of argumentation skills through CAR can build teachers' reflective competence while supporting more effective action-based and problem-solving-oriented learning in the classroom.

In addition, participants' suggestions regarding the need for follow-up in the form of a collaborative forum highlight the importance of program continuity for building a reflective learning ecosystem. The implementation of CAR accompanied online through WhatsApp and Zoom was designed to ensure the sustained development of students' argumentation skills, not merely as a short-term outcome of the training. Thus, this PKM activity not only enhanced the individual abilities of teachers but also strengthened the capacity of the chemistry teacher community to design learning that is more argumentative, reflective, and problem-based, in line with previous research findings on the effectiveness of CAR interventions and teacher professional development.

Implications

Based on the results of the training, workshop, CAR implementation, and participant reflections, this PKM program has several important implications for the professional development of chemistry teachers and teaching practices in secondary schools.

The program highlights the need for structured training that integrates the strengthening of argumentation skills with the implementation of Classroom Action Research (CAR). The increase in pre-test and post-test scores, the successful implementation of learning tools, and the positive feedback from partner teachers indicate that collaborative approaches and hands-on practice are effective in building teachers' conceptual, technical, and affective competencies.

The training provides practical guidelines that can be directly applied in the classroom, including lesson plans, worksheets, observation instruments, and argumentation-based questions. This allows teachers not only to understand the theory but also to systematically apply argumentation-based learning strategies. This implies that the development of modules and supporting materials must be accompanied by continuous mentoring so that the transfer of learning from the workshop to classroom practice can be maximized.

The PKM program encourages the formation of a reflective and collaborative learning ecosystem among teacher communities. Group discussions, joint practice sessions, and reflection forums enable teachers to exchange experiences, solve CAR implementation issues, and develop pedagogical innovations. In the long term, an active and collaborative teacher community will improve the quality of teaching in schools, strengthen MGMP networks as professional spaces, and support ongoing capacity development.

The results of the training reinforce the importance of evidence-based interventions that emphasize 21st-century skills, such as argumentation, critical thinking, and problem solving in the context of chemistry learning. Argumentation-based CAR not only improves teacher competence but also has the potential to enhance students' ability to analyze data, construct scientific arguments, and make decisions systematically. Thus, the implications of this program extend beyond improving teacher competence and contribute to the quality of both learning processes and outcomes for students.

Overall, these PKM findings show that structured, collaborative, and practice-oriented teacher professional development programs make a significant contribution to strengthening pedagogical capacity, professionalism, and teacher effectiveness in managing argumentative, reflective, and problem-based chemistry learning.

Impact and sustainability

The PKM program had a positive impact on teachers and student learning. Teachers showed improvements in conceptual and technical competencies, as well as increased motivation in implementing argumentation skills through CAR, as reflected in the pre-test and post-test results, the implementation of learning tools, and participant reflections. The impact on students emerged through chemistry learning that was more argumentative, reflective, and evidence-based.

The sustainability of the program was strengthened through online mentoring, collaborative teacher forums, and learning modules and materials that have been submitted for intellectual property rights, allowing them to be reused and officially utilized. Through this mechanism, pedagogical innovations based on CAR and argumentation skills can continue to be implemented, fostering a sustainable reflective learning ecosystem in secondary schools.

4. CONCLUSION AND RECOMMENDATIONS

This PKM activity aims to equip chemistry teachers in Mojokerto with skills in designing and implementing argumentation-based learning through Classroom Action Research (CAR). The results show that the teachers experienced improvements in their conceptual understanding of the structure of argumentation skills, the stages of CAR, and their technical ability to develop contextual and reflective learning materials. Of the 18 partner teachers, most successfully completed the preparation of lesson plans, student worksheets, and CAR instruments, and were able to revise these materials based on mentor feedback. The questionnaire evaluation indicates a very high level of satisfaction and teacher readiness to continue implementing CAR in their respective classes, confirming that this program is effective in enhancing teachers' professional competence and supporting the ongoing development of argumentation-based learning.

Based on the findings and evaluation of the PKM implementation, several recommendations are proposed to improve the program's effectiveness and sustainability: (1) Partner program continuity. Partner teachers are advised to establish a regular collaborative forum to share best practices, discuss challenges in implementing CAR, and monitor the development of students' argumentation skills. Online mentoring through WhatsApp or Zoom should also be continued to ensure that CAR implementation proceeds consistently in each school; (2) Program development. Similar programs should emphasize a combination of theoretical training, hands-on practice, and ongoing mentoring. Providing ready-to-use modules, learning materials, and CAR instruments has proven effective in enhancing teachers' competencies. Collaborative and reflective approaches should be the main focus so that participants can learn from peers' experiences and build a sustainable learning ecosystem; (3) Activity limitations. The

limitations of this activity include the small number of participants (18 teachers) and the short duration of mentoring, resulting in one group not fully achieving all success indicators. Therefore, it is recommended that future implementations increase the number of participants and extend the mentoring period so that all teachers have optimal opportunities to finalize materials and implement CAR comprehensively.

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