

Green Chemistry Teaching Materials Training with Coastal Area Potential to Improve Chemistry Literacy and SDGs Understanding of Chemistry Teachers

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Abstract

Chemistry learning should not only emphasize theoretical concepts but also connect learning with real environmental problems and sustainability issues. However, most teachers still use generic teaching materials that are less relevant to local potential and contextual learning needs. This community service activity aimed to improve teachers' understanding of green chemistry, contextual learning, and Sustainable Development Goal (SDG 4) through training on developing green chemistry teaching materials based on coastal local potential. The activity involved members of MGMP Kimia Tanjungpinang and applied a Participatory Action Research (PAR) approach combined with project-based activities. The implementation stages included preparation, training, mentoring, and evaluation. Data were collected using competency assessment sheets, observation sheets, product assessment rubrics, and participant response questionnaires administered before and after the activity. The results showed measurable improvements in teachers' competencies. Teachers' understanding of green chemistry concepts increased from 68.75% to 100%, the ability to develop contextual teaching materials increased from 68.75% to 100%, competence in integrating coastal local potential into chemistry learning increased from 56.25% to 87.5%, chemical literacy in learning increased from 56.25% to 87.5%, and understanding of the relationship between chemistry learning and SDG 4 increased from 50% to 87.5%. Participants also successfully developed green chemistry teaching materials based on local coastal potential that were ready for classroom use. The activity contributed to SDG 4 by strengthening teachers' professional competencies and improving the quality of contextual chemistry learning materials. These findings indicate that contextual green chemistry training effectively enhances teachers' chemical literacy, understanding of SDG 4, and competency in developing meaningful and contextual teaching materials.

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INTRODUCTION

Chemistry learning currently faces the challenge of not only conveying theoretical concepts but also linking them to real-world problems in the surrounding environment (Maulidiningsih et al., 2023). One relevant approach is the development of contextual teaching materials based on green chemistry, which not only enhance conceptual understanding but also foster students' concern for the environment and sustainable development (García-González et al., 2020). On the other hand, coastal areas, such as those in Tanjungpinang, possess a wealth of natural

resources that can be integrated into chemistry learning materials in innovative and applicable ways (Asikin & Yulita, 2019; Yulita, 2017a).

However, the reality on the ground shows that most teachers still use generic teaching materials that do not adequately represent the local context or global issues such as the Sustainable Development Goals (SDGs) (Herawati & Istiana, 2021; Jannah et al., 2019). In the context of chemistry education, the implementation of SDGs does not have to encompass all goals comprehensively, but can be focused on the goals most relevant to the learning

characteristics and needs of students, especially SDG 4 on quality education. SDG 4 emphasizes the importance of providing inclusive, quality education that can significantly improve student competency. Therefore, integrating coastal environmental issues, marine resource management, and local contexts into chemistry teaching materials can be a strategy to support the achievement of SDG 4 indicators, such as increasing scientific literacy, critical thinking skills, student learning engagement, and the relevance of learning to real life. This is both an opportunity and an urgent need, especially for MGMP Chemistry teachers in coastal areas such as Tanjungpinang City (Yulita & Amelia, 2020).

As a professional organization serving as a center for teacher competency development, the Tanjungpinang Chemistry Teachers Association (Tanjungpinang Chemistry MGMP) plays a strategic role in improving the quality of chemistry instruction in schools. However, based on initial observations and discussions with teachers, most teachers still face challenges in developing learning materials that integrate local contexts, green chemistry principles, and the Sustainable Development Goals (SDGs) into their lessons. The learning materials used generally focus on theoretical concepts and lack specific material related to real-world issues in their local environments (Sabekti et al., 2022).

Therefore, this activity focuses on improving the competency of teachers as key partners in learning development. Teachers are positioned as agents of change because the quality of learning is greatly influenced by their ability to design relevant, contextual, and meaningful learning materials. Through training on developing green chemistry learning materials based on local potential and integrated with the SDGs, it is hoped that teachers' pedagogical and professional competencies will improve, particularly in developing learning materials that are innovative, applicable, and appropriate to the characteristics of students' environments. This improvement in teacher competency is expected to result in higher-quality teaching materials and ultimately have a positive impact on the quality of learning in schools (Amelia & Yulita, 2020).

Through this training, teachers will gain insight and skills in developing teaching materials relevant to the potential of coastal areas, such as the use of shells, marine waste, or seawater pollution phenomena as contexts for chemistry learning (Yulita et al., 2023). This contextual approach is considered capable of making chemistry learning more meaningful because it connects abstract concepts with real phenomena in the students' environment. Various research results show that chemistry learning based on local context and potential can improve the quality of learning, learning motivation, critical thinking skills, and students' scientific literacy (Minata

et al., 2022). In addition, the integration of sustainability issues and local context in science learning is also reported to contribute to supporting the implementation of SDG 4 by strengthening the quality of education and developing 21st-century skills.

Therefore, this community service activity is expected to significantly contribute to improving the capacity of chemistry teachers in Tanjungpinang and serve as a strategic step in encouraging the transformation of chemistry learning to be more contextual, relevant, and effective for students and the wider community (Kartika et al., 2017; Nazilah et al., 2018; Yulita, 2017b).

This activity aims to increase the capacity of Tanjungpinang Chemistry MGMP teachers in developing contextual green chemistry teaching materials based on the potential of coastal areas and integrated with SDGs issues. Specifically, this activity aims to:

1. Improve teachers' understanding of the concepts of green chemistry, contextual learning, and their relationship to Sustainable Development Goal (SDG 4) on quality education.
2. Improve teachers' competency in developing chemical materials that integrate local coastal potential and environmental conservation issues.
3. Improve teachers' skills in developing teaching materials that are contextual, applicable, and relevant to students' daily lives.
4. Produce green chemistry teaching materials based on local potential that are ready for use in school learning.

This activity focuses on improving teacher competency as an effort to support the achievement of SDG 4 by strengthening the quality of the learning process. By improving teachers' ability to develop quality teaching materials, it is hoped that chemistry learning in schools will become more meaningful, relevant, and able to support the continuous improvement of educational quality.

MATERIALS AND METHODS

Time and Place of Activity

This community service activity was conducted from August to December 2025 at SMAN 2 Tanjungpinang. The participants involved were members of MGMP Kimia Tanjungpinang.

Materials and Equipment

The materials used in this activity included training modules on green chemistry, Sustainable Development Goals (SDGs), contextual learning, examples of contextual chemistry teaching materials, worksheets, and evaluation instruments. The instruments used consisted of competency assessment sheets, observation sheets, participant response questionnaires, and teacher teaching

material assessment rubrics. Supporting equipment included laptops, LCD projectors, stationery, presentation media, and coastal local potential samples such as shell waste, seaweed, and seawater utilized as learning contexts.

Community Service Method

This activity adopted the Participatory Action Research (PAR) approach (Sari et al., 2025) combined with Project-Based Learning (PjBL) (Harlanu, 2024). The implementation stages consisted of preparation, training implementation, mentoring and product improvement, and evaluation-reflection stages. These stages represent the planning, action, observation, and reflection cycles in PAR while facilitating teachers to develop contextual teaching material products through project-based activities.

Preparation Stage

At this stage, coordination was carried out with the management of MGMP Kimia Tanjungpinang regarding the implementation of the activity. The team also prepared training modules, competency assessment instruments, participant questionnaires, observation sheets, and teaching material assessment rubrics. In addition, local coastal potentials relevant to chemistry learning were identified as learning contexts.

Training Implementation Stage

The training stage consisted of several sessions, namely:

- Introduction to green chemistry concepts and SDGs integration in chemistry learning;
- Identification of local coastal potential and contextual learning opportunities;
- Workshops on developing contextual green chemistry teaching materials based on coastal potential.

During this stage, participants actively discussed and developed teaching materials by integrating local environmental issues into chemistry concepts.

Mentoring and Product Improvement Stage

Participants received mentoring in revising and refining the developed teaching materials. Limited simulations of the teaching materials were also conducted to evaluate the suitability of content, contextual relevance, and integration of environmental sustainability issues. Feedback from facilitators and participants was used to improve the final products.

Evaluation and Dissemination Stage

At the final stage, participants presented the developed teaching materials and reflected on the learning process. Evaluation focused on measuring

improvements in teachers' competencies before and after the training activities (Table 1).

Table 1. Solution of dedication

Problems	Proposed	Outcomes
Teachers still use generic teaching materials and rarely integrate local coastal potential into chemistry learning	Training on contextual green chemistry teaching material development based on coastal potential	Teachers are able to develop contextual and locally relevant chemistry teaching materials
Limited teacher understanding of green chemistry and SDGs integration in learning	Workshops and discussions on green chemistry concepts and SDGs-oriented learning	Improved teacher understanding of green chemistry and SDGs
Teachers have limited skills in designing contextual teaching materials	Hands-on practice and mentoring in developing chemistry teaching materials	Improved teacher competencies in developing contextual and applicable teaching materials
Lack of sustainability-oriented chemistry teaching resources	Development of green chemistry teaching materials ready for classroom use	Availability of contextual green chemistry teaching materials for school learning

Evaluation Technique

The evaluation focused on measuring improvements in teachers' competencies before and after the training activities. Competency assessment was conducted using several indicators, namely:

- Understanding of green chemistry concepts;
- Ability to integrate coastal local potential into chemistry learning;
- Chemical literacy in contextual learning;
- Understanding of SDGs integration in chemistry learning;
- Ability to develop contextual teaching materials.

Assessments were conducted before and after the activity using competency assessment sheets, product assessment rubrics, observation sheets, and participant response questionnaires. The improvement in teacher competencies was

analyzed descriptively based on the percentage increase in each competency indicator.

RESULTS AND DISCUSSION

Preparation Stage

In the initial stages of the community service program, the implementation team coordinated with the Tanjungpinang Chemistry MGMP management, chaired by Ms. Syarifah Asyura, S.Si., M.M. This coordination activity aimed to establish a common understanding regarding the goals, objectives, and format of the training activities to be implemented. Through this meeting, the team gained an overview of the conditions for chemistry teachers in Tanjungpinang, including the challenges faced in developing contextual and environmentally-oriented teaching materials. Support from the MGMP management was a crucial step in building commitment and effective collaboration between the community service team and the participating teachers.



Fig. 1. Interview for needs analysis

Next, the team distributed a needs analysis questionnaire to chemistry teachers in the Tanjungpinang MGMP. This questionnaire was designed to identify the most relevant training needs, particularly related to understanding green chemistry concepts, chemical literacy, and the ability to integrate local potential into teaching materials (Fig. 1). The questionnaire results indicated that most teachers needed assistance in designing teaching materials that not only aligned with the curriculum but also linked chemistry concepts to real-world phenomena in the coastal areas where they taught. These findings served as the basis for developing more targeted training and module designs.

The needs questionnaire was distributed to 12 MGMP teachers. Respondents varied in terms of teaching experience: some had less than 5 years, some had 5-10 years, some had 10-20 years, and some had more than 20 years. This allowed the analysis to provide a comprehensive overview of the teachers' needs. Of the 12 chemistry teachers, 83.3%

stated they had never participated in teaching materials development training, while only 16.7% stated they had. This indicates that teachers are still lacking in developing their skills, particularly in developing teaching materials.

Furthermore, teachers already understand that integrating green chemistry is important. This is evident from the distribution of scores, which shows that 50% responded that it is important, and 50% that it is very important. Furthermore, regarding the concept of green chemistry, 100% of teachers have a fairly good understanding, with none stating they understand it very well. Regarding the use of green chemistry-based teaching materials in the classroom, 50% of teachers have used them, while the other 50% have not. Furthermore, regarding linking the potential of coastal areas (e.g., seawater, seaweed, marine ecosystems) to chemistry lessons, the majority of teachers only use them occasionally, not always or frequently.

Regarding the understanding of green chemistry concepts and the need for training in teaching material development, most teachers considered the program necessary. The needs analysis showed that 75% of teachers stated that the training was "very necessary," while the remaining 25% considered it "necessary." These findings indicate that teachers require professional development activities that support their competencies in developing contextual and sustainability-oriented chemistry teaching materials.

Furthermore, the results of the teacher needs questionnaire also showed that the types of teaching materials most needed by teachers currently are locally-based printed modules and project-based worksheets (LKPD). Furthermore, the biggest obstacles teachers face in developing teaching materials are time and lack of training.

Regarding the Sustainable Development Goals (SDGs), 50% of teachers are somewhat familiar with them, 41.7% have heard of them but don't understand them, and 8.3% have no idea at all. Because of this, some teachers sometimes link chemistry topics to SDG issues, even though they are not aware of them, as chemistry is closely related to everyday life.

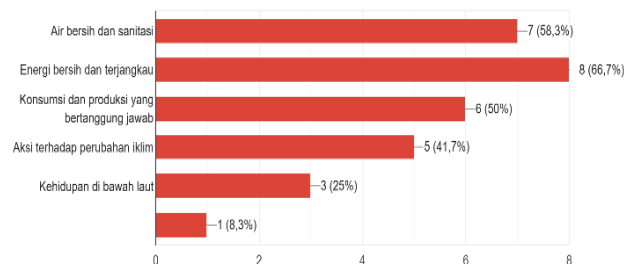


Fig. 2. SDGs topics according to teachers

The results showed that teachers considered several SDG topics relevant to chemistry learning in the classroom. The most relevant topic was clean and affordable energy, selected by 66.7% of participants, followed by clean water and sanitation at 58.3%. In addition, 50% of teachers identified responsible consumption and production as relevant to chemistry learning, while 41.7% highlighted climate action. Meanwhile, life below water was selected by 25% of participants (Fig. 2). These findings indicate that teachers tend to associate chemistry learning with environmental sustainability issues that are closely related to daily life and local environmental contexts.

Based on the needs identification results, the team then developed training modules and supporting tools that included a guide to developing locally-based teaching materials, worksheets, and examples of integrating coastal contexts into chemistry topics such as solutions, redox reactions, and environmental pollution. In addition, the team also identified local potentials in coastal areas relevant to chemistry learning, such as the phenomenon of household waste in waters, seafood processing, and environmental degradation due to human activities. These potentials were then processed into learning contexts that teachers can use to improve chemical literacy and awareness of Sustainable Development Goals (SDGs) issues (García-González et al., 2020; Zowada et al., 2021)

Training Implementation Stage

The community service program lasted 14 days, consisting of two face-to-face meetings and independent assignments between the two meetings. The first face-to-face session focused on introducing the basic concepts of green chemistry (Fig. 3 dan Fig. 4), their relationship to the SDGs, and strategies for integrating local coastal potential into chemistry learning (Fig. 5 and Fig. 6). Through this session, participants gained a solid theoretical understanding and began developing the initial framework for the teaching materials they would develop. The training was lively, with discussions and experiences shared among teachers regarding contextual learning practices in schools.

The second in-person meeting was held one week later to follow up on the results of the teachers' independent work. In this session, participants presented initial drafts of the teaching materials they had designed, including modules, student worksheets (LKPD), and digital learning media. The community service team provided input on content suitability, relevance to the local context, and alignment with green chemistry principles. Furthermore, participants were encouraged to strengthen students' chemical literacy and critical thinking skills through the learning activities they

designed. Similar to research by Kumar et al (2024) and Fahmina et al (2019) which states that teachers who have good literacy will produce students who are also literate through the learning design they develop.



Fig. 3. Opening of community service activities



Fig. 4. Green chemistry material quotes



Fig. 5. Mangrove material quote



Fig.6. Seagrass material quote

Between the two face-to-face sessions, participants completed independent tasks to refine the design of the teaching materials based on the discussions and initial feedback. The community service team continued to provide remote support through online communication to monitor progress and address any challenges. This combined offline and online model allowed for more flexibility in the training while maintaining the quality of the expected final results.

Mentoring and Trial Phase

After the training phase concluded, the activity continued to the mentoring and trial phase. In this phase, the focus was on refining the final design of the teaching materials so they were ready for implementation. The community service team provided technical and academic guidance to teachers in organizing learning components, strengthening the integration of the coastal context, and ensuring alignment between learning objectives, activities, and assessments. Intensive support was provided both in person and through online communication to provide prompt and constructive feedback.



Fig. 7. Presentation of the results of the teaching material product by the first participant



Fig. 8. Presentation of the results of the teaching material product by the second participant

The initial plan was for the teaching materials to be piloted in each teacher's classroom. However,

due to scheduling constraints, the field trial could not be implemented as planned. As an alternative, a pilot trial was conducted in front of fellow chemistry teachers. In this simulation, teachers play the roles of students to assess the clarity of the learning flow, the integration of the material, and the appropriateness of the activities outlined in the teaching materials (Fig. 7 and Fig. 8). This activity provides a platform for collaborative reflection for teachers to provide feedback and address any remaining shortcomings (Wahyuni & Haryanti, 2024).

After conducting a limited trial, the community service team provided feedback on the results of the simulation implementation. The participating teachers then revised the teaching materials based on suggestions from the team and colleagues. The final product, a refined, contextual teaching material based on the potential of coastal areas, became the main output of this phase and demonstrated the teachers' improved ability to develop innovative teaching materials oriented towards green chemistry principles.

Evaluation and Dissemination Phase

The final phase of the community service activity focused on evaluation and dissemination of the results. In this phase, each participant presented the final teaching materials they had developed to the community service team and colleagues. This presentation provided an opportunity for teachers to explain their thinking process, the local context used, and how their teaching materials supported students' achievement of chemical competencies and literacy. This activity also served as a forum for appreciating teachers' creativity and innovation in developing environmentally-based teaching materials.

This was followed by a learning reflection and activity evaluation. Through the reflection session, participants shared their experiences, challenges, and lessons learned during the training and mentoring sessions. Based on the reflection, it was identified that this activity provided new insights for teachers in connecting science to real-life contexts in coastal areas, while also raising awareness of the importance of environmentally sustainable education.

To measure the impact of the activity, the community service team also evaluated participants' understanding of green chemistry concepts (Mitarlis et al., 2023), SDG integration (García-González et al., 2020), and the development of contextual teaching materials (Mubarak et al., 2022).

Table 2 shows that the training activities succeeded in improving teachers' competencies in several assessed aspects related to green chemistry, SDGs integration, and contextual teaching material development. The results indicate that teachers'

Table 2. Evaluation of increased participant understanding of the concept of green chemistry, SDGs integration, and development of contextual teaching materials

No	Aspect	Before	After	Upgrade
1	Understanding the concept of green chemistry	68,75	100	31.25% increase
2	Utilizing coastal potential	56,25	87,5	31.25% increase
3	Chemical literacy in learning	56,25	87,5	31.25% increase
4	Relationship to SDGs issues	50	87,5	37,5% increase
5	Development of contextual teaching materials	68,75	100	31.25% increase

Table 3. Changes resulting from the community service activities

Initial Condition	Intervention	Condition Change
Teachers still used generic teaching materials and had limited understanding of green chemistry concepts	Training on green chemistry concepts and contextual learning	Teachers' understanding of green chemistry increased from 68.75% to 100%
Teachers had limited ability to integrate coastal local potential into chemistry learning	Workshops and discussions on the utilization of coastal local potential in chemistry learning	Teachers' competency in utilizing coastal potential increased from 56.25% to 87.5%
Teachers had not optimally integrated chemical literacy into classroom learning	Mentoring and practice in developing contextual chemistry teaching materials	Teachers' chemical literacy competency in learning increased from 56.25% to 87.5%
Teachers had limited understanding of the relationship between chemistry learning and SDGs	Training and discussion on SDG integration in chemistry learning	Teachers' understanding of SDGs integration increased from 50% to 87.5%
Teachers had limited skills in developing contextual teaching materials	Project-based workshops and product mentoring	Teachers' competency in developing contextual teaching materials increased from 68.75% to 100%, and green chemistry teaching materials based on coastal local potential were successfully produced

understanding of green chemistry concepts increased from 68.75% before the training to 100% after the training, representing an improvement of 31.25%. Similarly, teachers' competency in developing contextual teaching materials also increased from 68.75% to 100%. The ability to utilize coastal potential in chemistry learning improved from 56.25% to 87.5%, while chemical literacy in learning increased from 56.25% to 87.5%, both showing an increase of 31.25%. The highest improvement was found in teachers' understanding of the relationship between chemistry learning and SDGs, which increased from 50% to 87.5%, with an increase of 37.5%. Overall, the training activities resulted in an average improvement of 32.5% in teachers' competencies. These findings indicate that the participatory training and mentoring activities effectively strengthened teachers' understanding and skills in developing contextual and sustainability-oriented chemistry teaching materials

Table 3 shows the changes resulting from the community service activities conducted for chemistry teachers. The training and mentoring activities

successfully improved teachers' competencies in several aspects, including understanding of green chemistry concepts, integration of coastal local potential, chemical literacy in learning, understanding of SDGs, and development of contextual teaching materials. The results indicate that the activities not only increased teachers' theoretical understanding but also strengthened their practical skills in developing contextual and sustainability-oriented chemistry teaching materials. In addition, the program successfully produced green chemistry teaching materials based on coastal local potential that are ready to be implemented in classroom learning. As with the community service carried out by Astuti & Fitriyani (2018), this activity also has an impact on increasing the competence of teachers as objects of community service.

CONCLUSION

The community service activity conducted with members of MGMP Kimia Tanjungpinang successfully improved teachers' understanding of green chemistry concepts, contextual learning, and their

relationship to Sustainable Development Goal (SDG 4) on quality education. Through training activities involving discussions, exploration of coastal local potential, and teaching material development practices, teachers gained broader insights into integrating environmental sustainability issues into chemistry learning.

The activity also enhanced teachers' competencies and skills in developing chemistry teaching materials that integrate local coastal potential and environmental conservation issues. Teachers were able to design contextual and applicable teaching materials by utilizing local resources such as shell waste, seaweed, and marine environmental phenomena as learning contexts relevant to students' daily lives. In addition, the program successfully produced green chemistry teaching materials based on local potential that are ready to be implemented in school learning.

Overall, the training contributed positively to strengthening teachers' professional competencies in designing more meaningful, contextual, and sustainability-oriented chemistry learning. However, this activity was limited to evaluating teachers' competencies and the products developed during the training. Therefore, further activities are recommended to focus on classroom implementation and evaluation of the effectiveness of the developed teaching materials in improving learning quality.

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