



RESEARCH ARTICLE

DEVELOPMENT OF A CASE METHOD-BASED CHEMISTRY LEARNING E-MODULE ON SAPONIFICATION REACTION MATERIALS THROUGH THE USE OF USED COOKING OIL INTO LIQUID SOAP TO IMPROVE COLLABORATION SKILLS

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ARTICLE INFO	ABSTRACT
Received: Mar 1 2026 Accepted: Mar 12, 2026	
Keywords: E-Module, Case Method, Saponification Reaction, Collaboration Skills	
*Corresponding Author: 1442200116@surel.untag-sby.ac.id	<i>This study aims to determine the process of making, developing, feasibility, and effectiveness of Case Method-based chemistry learning e-modules on saponification reaction materials through the use of used cooking oil into liquid soap in students' collaboration skills. This research uses the Research and Development (R&D) method. The research sample was 31 students in grade XI of SMA Negeri 1 Sentani. The results of the study show that: (1) the process of making a Case Method-based e-module includes seven steps that focus on designing to produce the initial product; (2) the development of e-modules is carried out through three main stages based on a 4D development model that is oriented towards product quality, effectiveness, and feasibility; (3) the e-module feasibility level obtained a material feasibility percentage of 93%, language 91%, and media 91%, with an overall average of 93% which is included in the very feasible category; (4) students' collaboration skills increased by 23% from Teaching Module I to II and 2.2% from Teaching Module II to III. Thus, the Case Method-based chemistry learning e-module on saponification reaction materials was stated to be very feasible and effective in improving students' collaboration skills.</i>

INTRODUCTION

Education is one of the aspects of life that has undergone significant changes as a result of the progress of modern times and the rapid development of Science and Technology (IPTEK). There are many tools and programs that are easy to learn and use as learning media through the rapid development of science and technology. The learning process has become

simpler and more efficient in the digital era through the development of technology, thus changing the way teachers and students learn to absorb and understand learning materials with a shift towards developing learning methods that are more interesting and focus on student activity (Mulyani et al., 2021). Modern learning methods that focus on student activity and develop analytical and creative skills in facing various learning challenges that are developing, one of which is *the Case Method* (Werdiningsih, 2022). *Case Method* learning or case study is a participatory and student-centered learning method in fulfilling learning outcomes based on discussions that use real cases in the surrounding environment as the main medium (Siregar et al., 2024).

Cases can be real or fictional stories that are relevant to the study material or retell events, problems, dilemmas, theoretical or contextual problems that require analysis and/or decision-making (Ministry of Education and Development, 2021). The purpose of using this method is to (1) lend reality to indirect experience, (2) focus on concrete problems, (3) develop skills in decision-making, and (4) help ensure that students see with a variety of perspectives. The stage of providing real learning experiences or designs that are relevant to the study material is expected to reduce the gap between theory and practice. This learning is characterized by a case that is presented to help students relate to the phenomenon that occurs, then through discussion activities designed based on the results of observations and students' perspectives will allow them to relate what they learn to real-world situations (Ridlo, 2023).

Real-world situations allow students to get used to communicating their ideas or ideas, develop critical thinking skills, and be creative in solving problems, thereby increasing students' enthusiasm and motivation and being able to collaborate with fellow group members so as to create a democratic atmosphere and mutual respect for the opinions of others is the main learning strategy in this century. Learning strategies designed by relating the material learned through real-world situations have become the demands of the Independent Learning Curriculum with refinement through a deep approach (*Deep Learning*) (Wosparik et al, 2024). The Independent Learning Curriculum that is enhanced with an in-depth approach (*Deep Learning*) can encourage students to relate the material to real life, think critically, and collaborate to solve real problems. This program is actually able to provide opportunities to improve students' skills in communication, critical thinking, creative thinking, and collaboration skills (4Cs: *Communication, Collaborative, Critical Thinking, Creativity*) (Andayani et al., 2022). This skill improvement is expected to be able to produce innovative, active, fun and effective learning and no longer be teacher-centered *learning but student-centered* with students as subjects in all chemistry learning (Sagala et. al., 2023).

Chemistry is a branch of natural science that studies matter, including the composition, structure, composition, properties, and energy that accompany the change of a material (Nugraha, 2021). Chemistry learning in high school still faces several problems such as chemistry materials are often considered difficult and abstract by students and require difficult and complex learning activities. Students' lack of interest in learning chemistry is the main factor in the low achievement of their learning outcomes, students have the perception that chemistry subjects are only limited to learning (Anton et al., 2022). One of the abstract chemistry lessons, namely saponification reactions, contains an understanding of the chemical process of making soap through the hydrolysis of fats or oils with strong bases (such as NaOH or KOH) to produce soap (fatty acid salts) and glycerol. This learning includes the basic principles, mechanisms, and factors that influence reactions, as well as an analysis of the characteristics of the final product (Rindi, 2020). This material is often considered abstract by students because it is often only taught in theory and is less associated with everyday life. Therefore, it is hoped that through interactive learning and the emergence of new learning methods such as *the Case Method* by raising contextual problems in the environment around students, they will be able to solve various problems through high-quality science learning (Kurniawan et. al., 2023). One of the potential contextual cases that are close to students' lives is used cooking oil.

Used cooking oil is often household waste that pollutes the environment but can also

be reused through saponification reactions into soap. This case can be used as applicable and relevant teaching material in chemistry learning (Syafarudin et al., 2023). To bridge these problems, a solution is needed in the form of the development of a Case Method-based e-module that contains real cases of used cooking oil, problem analysis guides, soap-making experiments as one of the solutions, and reflections on learning outcomes (Kurniawan et. al., 2023). E-modules function as a substitute for the printed module in providing information as well as a source of student learning. The application of e-modules is able to encourage students to be active and facilitate them in learning. The difference between e-modules and print modules is in their physical form while the components that make up the modules remain the same. E-modules are based on technology and information so that they have advantages in terms of interactivity, which can be accompanied by various elements such as video, audio, images, animations, and other interactive features that can be accessed and repeated at any time by students, thus enriching their learning experience. In addition, the e-module makes it easier for teachers to adjust teaching materials to students' skills. The learning process becomes more flexible, not limited to the classroom environment but can also be done outside the classroom. E-modules can be accessed through various electronic devices such as laptops, computers, and *smartphones* (Rismayanti et. al., 2022).

Based on the results of observations that have been carried out at SMA Negeri 1 Sentani, chemistry learning in schools in general is still dominated by conventional approaches, where teachers become the center of learning and students tend to passively receive information. This causes low student involvement in the critical and collaborative thinking process, which is actually the main competency in the independent curriculum. One of the materials that is often taught theoretically is the saponification reaction taught to students in grade XI (two high schools). This material actually has great potential to be associated with the context of daily life, especially environmental and sustainability issues, for example the use of used cooking oil into multipurpose liquid soap. However, in practice, learning this topic is often not associated with contextual or applicative problems, making it difficult for students to understand its benefits and relevance to real life. In addition, the limitations of digital-based interactive learning media that are able to guide students to think scientifically and collaboratively are also an obstacle. Many teaching materials are still in the form of print modules that are informative, have not encouraged problem-based learning and real case studies that challenge students to think critically and collaborate. The *Case Method learning method* is present as one of the learning that is in line with the policy direction of the Independent Curriculum and learning based on *Higher Order Thinking Skills* (HOTS). Through real case studies such as the processing of used cooking oil into liquid soap, students are expected to be able to identify problems, analyze, find scientific solutions, and work together in groups to produce useful products.

The application of this method needs to be supported by an interactive e-module that is integrated with *the steps of the Case Method*, and provides multimedia features, discussion guides, reflections, and authentic assessments. The development of Case Method-based e-modules is expected to improve students' collaboration skills through learning activities that aim to; (1) applying the concept of chemical reactions in real life, (2) working together to solve practical challenges, and (3) having concern for the environment (Hasibuan et al., 2024). Based on the description above, the researcher has conducted a study entitled "Development of Case Method-Based Chemistry Learning E-Module on Saponification Reaction Material through the Use of Used Cooking Oil into Liquid Soap to Improve the Collaboration Skills of SMA Negeri 1 Sentani Students".

RESEARCH METHODOLOGY

This research uses the **Research and Development (R&D)** method with a **4D model (Define, Design, Develop, Disseminate)** to develop a Case Method-based chemistry e-module on saponification reaction materials. The 4D model was chosen because it has systematic and structured steps in producing valid, practical, and innovative learning products. The research was carried out at **SMA Negeri 1 Sentani** in the even semester of the 2025/2026 school year.

The definition stage is carried out through the analysis of needs, student characteristics, material concepts, and learning objectives. The design stage includes the selection of media, format, preparation of test instruments, and the creation of an initial design of an e-module that contains real cases of the use of used cooking oil into liquid soap.

At the development stage, the e-module is validated by material, media, and language experts, then revised based on the input provided before being tested to students. The research subjects consisted of expert validators, chemistry teachers as practitioners, and students of class XI Science of SMA Negeri 1 Sentani. The sampling technique used **purposive sampling** for validators and limited trials, as well as **cluster random sampling** for field trials. The product trial was carried out in two stages, namely a trial limited to 5-10 students to find out the initial weaknesses of the product, and a broad trial on about 30 students to measure the feasibility and effectiveness of using e-modules in learning.

Research data was obtained through interviews, questionnaires, and collaboration skills observation sheets. Quantitative data was analyzed using descriptive statistics, percentages, Likert scores, **N-Gain** calculations, and statistical tests using SPSS, while qualitative data in the form of suggestions and comments were used to improve the product. The feasibility of the e-module is determined based on the results of expert validation, teacher and student responses, while its effectiveness is measured through the improvement of students' collaboration skills after using the Case Method-based e-module. Thus, this research aims to produce valid, practical, and effective e-modules as contextual chemistry teaching materials and support 21st century skills.

RESULTS AND DISCUSSION

This study developed a Case Method-based chemistry learning e-module on saponification reaction material through the use of used cooking oil into liquid soap at SMA Negeri 1 Sentani. The development began with observations and interviews that showed that chemistry learning is still dominated by conventional methods so that student collaboration has not developed optimally. The material of saponification reactions was chosen because it is closely related to daily life and environmental issues, but so far it has been taught more theoretically. The e-module is designed to connect chemical concepts with real cases through problem analysis activities, group discussions, and completion of case studies on the use of used cooking oil. The resulting product consists of an introduction, learning activities, and closing section equipped with learning videos, worksheets, pre-tests, post-tests, and evaluations. The e-module user is a student of class XI-11 of SMA Negeri 1 Sentani. In addition to product development, the validity and reliability of the test instruments were also tested on 31 students to ensure that the instruments used were able to measure collaboration skills accurately and consistently.

Table 1 Results of Testing the Validity and Reliability of Teaching Module I Test Instruments

Questions	Validity Test Results (r Calculate)	Remarks	Verdict
1	0,583	Valid and Reliable	Used
2	0,544	Valid and Reliable	Used
3	0,462	Valid and Reliable	Used
4	0,103	Invalid and Reliable	Not used
5	0,364	Valid and Reliable	Used
6	0,494	Valid and Reliable	Used
7	0,306	Invalid and Reliable	Not used
8	0,576	Valid and Reliable	Used
9	0,161	Invalid and Reliable	Not used
10	0,572	Valid and Reliable	Used
11	0,197	Invalid and Reliable	Not used
12	0,454	Valid and Reliable	Used

13	0,362	Valid and Reliable	Used
14	0,495	Valid and Reliable	Used
15	0,582	Valid and Reliable	Used

Based on Table 1, the results of testing the validity and reliability of the 15-question test instrument in learning activities in Teaching Module 1 obtained that 11 question items were valid because the calculated r value was greater than the r of the table = 0.355. The statistical reliability value of *Cronbach's Alpha* for all valid items is 0.730 so that the items in learning activity 1 are declared reliable. The validity and reliability test data is contained in appendices 10 pages 290 to 292.

The results of testing the validity and reliability of test instruments in the learning activities of Teaching Module II are presented in Table 2 as follows:

Table 2 Results of Testing the Validity and Reliability of Teaching Module II Test Instruments

Questions	Validity Test Results (r Calculate)	Remarks	Verdict
1	0,327	Invalid and Reliable	Not used
2	0,478	Valid and Reliable	Used
3	0,352	Invalid and Reliable	Not used
4	0,261	Invalid and Reliable	Not used
5	0,452	Valid and Reliable	Used
6	0,370	Valid and Reliable	Used
7	0,177	Invalid and Reliable	Not used
8	0,569	Valid and Reliable	Used
9	0,492	Valid and Reliable	Used
10	0,592	Valid and Reliable	Used
11	0,513	Valid and Reliable	Used
12	0,507	Valid and Reliable	Used
13	0,600	Valid and Reliable	Used
14	0,084	Invalid and Reliable	Not used
15	0,409	Valid and Reliable	Used

Based on Table 2, the results of the validity and reliability test of the 15-question test instrument in the learning activities in Teaching Module II obtained that 10 question items were valid because the calculated r value is greater than the r of the table = 0.355. The statistical reliability value of *Cronbach's Alpha* for all valid items is 0.713 so that the items in learning activity 2 are declared reliable. The validity and reliability test data is contained in appendices 10 pages 293 to 294.

The results of testing the validity and reliability of test instruments in the learning activities of Teaching Module III are presented in Table 3 as follows:

Table 3 Results of Testing the Validity and Reliability of Teaching Module III Test Instruments

Questions	Validity Test Results (r Calculate)	Remarks	Verdict
1	0,615	Valid and Reliable	Used
2	0,404	Valid and Reliable	Used
3	0,376	Valid and Reliable	Used
4	0,551	Valid and Reliable	Used
5	0,211	Invalid and Reliable	Not used
6	0,467	Valid and Reliable	Used
7	0,406	Valid and Reliable	Used
8	0,346	Invalid and Reliable	Not used
9	0,299	Invalid and Reliable	Not used

10	0,260	Invalid and Reliable	Not used
11	0,359	Valid and Reliable	Used
12	0,115	Invalid and Reliable	Not used
13	0,547	Valid and Reliable	Used
14	0,522	Valid and Reliable	Used
15	0,467	Valid and Reliable	Used

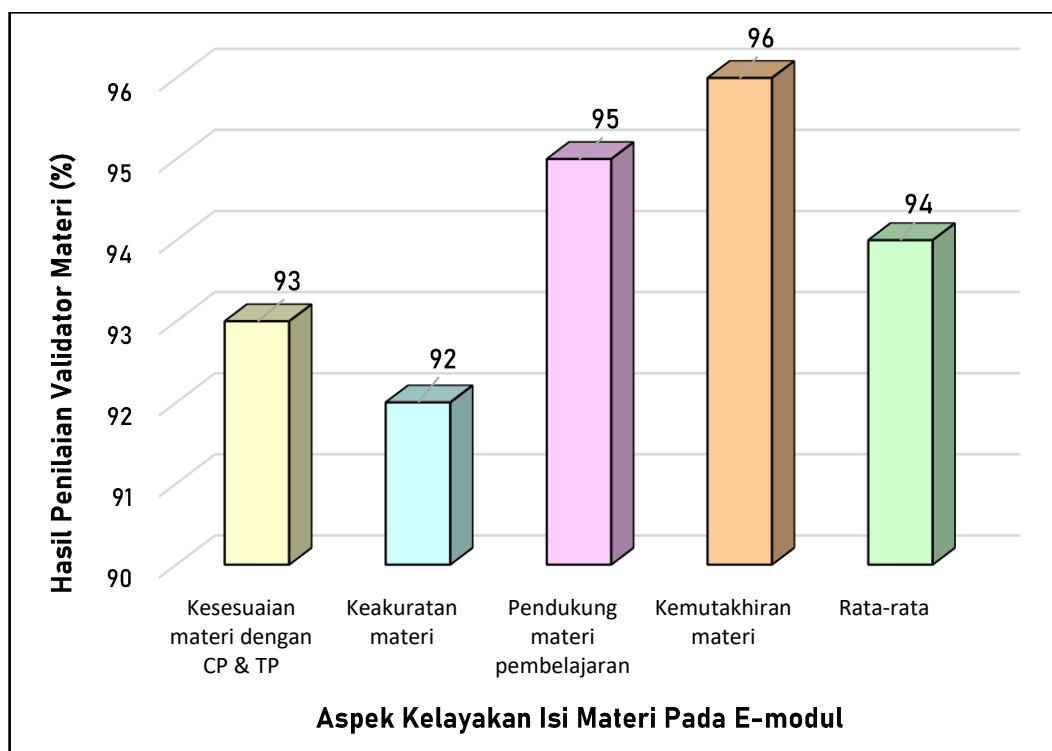
Based on Table 3, the results of testing the validity and reliability of the 15-question test instrument in learning activities in Teaching Module III obtained that 10 question items were valid because the calculated r value is greater than the table $r = 0.355$. The statistical reliability value of *Cronbach's Alpha* for all valid items is 0.714 so that the items in learning activity 3 are declared reliable. The validity and reliability test data is contained in appendices 10 pages 293 to 295.

The results of the feasibility test of the Case Method-based chemistry learning e-module on saponification reaction material through the use of used cooking oil into liquid soap were carried out through a validation process by lecturers of the Master of Science Education Study Program, Cenderawasih University Jayapura. This validation aims to assess the feasibility of e-modules from the aspects of material, language, and media before being used in learning in schools. The assessment uses three categories, namely suitable for use without revision, suitable for use with revision, and not suitable for use so that it requires a thorough revision. Specifically in material validation, the assessment includes aspects of content feasibility which include the suitability of learning outcomes and objectives, accuracy, up-to-date, and supporting learning materials, as well as aspects of presentation feasibility which include presentation techniques, presentation support, learning presentation, and completeness of material presentation. This validation is carried out to ensure that the e-modules developed meet quality standards and are suitable for use as a learning medium in improving student collaboration.

Table 4 Results of the Material Validator Assessment in the E-Module

Table 1: Results of the Material Validator Assessment in the E-Module					
Yes	Aspects	Percentage Score			Average
		Validator I	Validator II	Validator III	
Eligibility Aspects of Content					
1	Material suitability with CP & TP	93%	100%	87%	93%
2	Material accuracy	89%	94%	94%	92%
3	Supporting learning materials	89%	100%	97%	95%
4	Material updates	100%	100%	87%	96%
Average		93%	99%	91%	94%
Aspects of Presentation Eligibility					
1	Presentation technique	90%	90%	100%	93%
2	Material presentation support	89%	100%	94%	94%
3	Presentation of learning	100%	80%	90%	90%
4	Completeness in presentation	80%	100%	100%	93%
Average		90%	93%	96%	93%
Average percentage of aspects I & II		91%	96%	94%	93%
Average overall percentage		93%			

Criteria	Highly Worth It
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The results of the validation of the Case Method-based chemistry learning e-module on saponification reaction material showed a very high level of feasibility. In terms of material, the average percentage of content feasibility reached 94% and the feasibility of presentation was 93%, resulting in an overall average of 93% with a very feasible category. The aspect that obtained the highest score was the up-to-date of the material (96%), while the lowest score was found in the accuracy of the material (92%). These results show that the content, presentation, and relationship of the material with learning outcomes are appropriate so that the e-module can be used in learning with several revisions according to the validator's suggestions.

From the language aspect, the e-module obtained an average percentage of 91% with a very decent category. The assessment includes straightforward, communicative, interactive dialogical aspects, suitability with student development, collapse of the mindset, and the use of symbols and terms. The highest score was obtained in the use of symbols, terms, and icons (93%), while the lowest score was found in the straightforward aspect (89%). These results show that the language used in the e-module is easy to understand, communicative, and in accordance with the characteristics of students.

Media validation also showed excellent results with an average percentage of 91%. The aspects assessed include the size of the e-module, cover design, and content design. The content design received the highest score of 94%, followed by the cover design at 92%, while the size of the e-module received a score of 87%. Overall, the validator stated that the visual display, layout, typography, and illustrations in the e-module have met the media feasibility criteria so as to support the learning process effectively.

A small-scale trial involving five students of grade XI showed a very positive response to the e-module with an average percentage of 91%. The language aspect obtained the highest score (93%), followed by the aspect of interest (91%) and material (90%). In addition, the response of chemistry teachers was also very good with an average percentage of 97%, which shows that the e-module is considered relevant, easy to use, and in accordance with learning needs. These results indicate that the product is well received by users both from students and teachers.

The application of e-modules has been proven to be able to improve students' collaboration skills. All indicators have increased from Teaching Module I to Teaching Module III, with an average *n-Gain* value of 0.651 which is in the medium category. Meanwhile,

collaboration skills also improved across all indicators, such as active participation, communication, cooperation, decision-making, and responsibility. These findings show that the use of Case Method-based e-modules not only improves cognitive learning outcomes, but also significantly develops students' critical thinking skills and social skills.

This research focuses on the development of a Case Method-based chemistry learning e-module on saponification reaction material through the use of used cooking oil into liquid soap to increase the collaboration of SMA Negeri 1 Sentani students. The development of the e-module began with a needs analysis through classroom observation and chemistry teacher interviews. The results of the analysis show that chemistry learning is still dominated by conventional methods so that students find it difficult to relate chemistry concepts to real problems in their environment. In addition, the limitations of interactive digital teaching materials cause students to be less involved in critical and collaborative thinking activities. Therefore, the e-module is designed to connect the concept of saponification reaction with environmental issues in the form of processing used cooking oil into liquid soap. Development is carried out systematically through needs analysis, determination of learning objectives, selection of materials, preparation of learning activities, media development, evaluation, as well as trials and revisions to suit the needs of 21st century learning.

The preparation of the e-module follows the principles of teaching material development which refers to the Independent Curriculum and the 4D (Define, Design, Develop, Disseminate) development model. At the design stage, the saponification reaction material is associated with real case studies that are close to the student's life. The structure of the e-module includes covers, material maps, learning objectives, case-based materials, learning videos, student worksheets, formative tests, glossaries, and evaluations. Each learning activity is designed using a *Case Method* approach that directs students to identify problems, gather information, discuss, formulate solutions, present results, and reflect. The use of interactive media such as videos and animations is intended to increase student engagement in learning. The e-module was developed using Canva and converted into a digital *flipbook* so that it can be accessed through various devices such as smartphones, laptops, and classroom LCDs to support flexible and independent learning.

The development stage is carried out through expert validation, product revision, and limited and extensive trials. Validation involves material, language, and media experts to assess the feasibility of the content, presentation, language, and visual appearance of the e-module. After receiving feedback from validators, the product is revised to improve the quality of the material and design. A limited trial was conducted on five students to identify technical constraints, measure readability, and obtain initial feedback. Furthermore, a wide-ranging trial was conducted on 31 grade XI students to measure the effectiveness, practicality, and feasibility of using e-modules in learning. The final stage of development is planned through digital dissemination using online platforms, social media, and Learning Management System (LMS). However, this study is still focusing on the initial feasibility and effectiveness testing stages so that the widespread dissemination has not been fully implemented.

The validation results show that the e-module has a very high level of feasibility. In terms of material, the feasibility of the content obtained an average score of 94% and the feasibility of presentation 93%, so that the overall average reached 93% with the category of very feasible. The material is considered to be in accordance with learning outcomes, scientifically accurate, supported by relevant learning examples and activities, and follows the latest scientific developments. In terms of presentation, the e-module is systematically arranged and equipped with various components that make it easier for students to understand concepts. The high validation score indicates that the e-module is able to support case-based learning effectively. The preparation of structured materials also makes it easier for teachers to manage discussions so that the learning process becomes more meaningful and contextual for students.

The language and media aspects also received excellent ratings. Language validation resulted in an average of 91%, showing that the use of language in e-modules is straightforward, communicative, interactive, according to student development, and uses

scientific terms and symbols appropriately. Meanwhile, media validation obtained an average score of 91%, with the cover design and content indicators getting the highest scores. Attractive visual display, systematic layout, and the use of illustrations and learning videos are considered to be able to increase students' learning comfort. In addition, student response to the e-module reached an average of 91%, while the teacher's response reached 97%. Students find the e-module interesting, easy to understand, and helps to understand chemistry material, while teachers consider the e-module to be very helpful in delivering material and managing learning. Overall, the e-module feasibility value reaches around 92-93% and is categorized as very suitable for use.

The use of Case Method-based e-modules has been proven to be able to improve students' collaboration skills. Learning is carried out through three teaching modules that focus on case analysis of used cooking oil waste, liquid soap making practicum, as well as interpretation of results and reflection on their benefits. In Module I, most of the students are still passive and not used to working together in groups, so collaboration skills are still at the initial level. After participating in the practicum in Module II, the students' involvement in group discussions increased significantly as the students began to become accustomed to case-based learning and practicum activities. In Module III, students have been able to actively participate, communicate well, work together, make decisions together, and show responsibility in groups. All indicators of collaboration skills increased from Teaching Module I to Teaching Module III, with the largest increase occurring between Module I and Module II by 23%. An average n-Gain value of 0.651 indicates an improvement in collaboration skills in the medium category.

The e-module successfully develops students' collaboration skills. At the beginning of the lesson, most of the students are still passive and not used to discussing in groups. However, when entering the practicum and case analysis stages, student engagement increases significantly. Indicators of active participation, communication, cooperation, decision-making, and responsibility showed an increase from Module I to Module III. The largest increase occurred between Module I and Module II with an average of 23%, mainly as students began to adapt to case-based learning and practicum activities. In the later stages, the improvement tends to be smaller because collaboration skills are already at a more stable level. These results show that learning that integrates group discussions, experiments, and reflection is able to build a better culture of cooperation in the chemistry learning process.

Overall, the development of a Case Method-based chemistry learning e-module on saponification reaction material through the use of used cooking oil into liquid soap has proven to be feasible and effective for use in learning. E-modules not only meet the feasibility standards of materials, language, media, and get positive responses from teachers and students, but are also able to increase collaboration as an important competency in the 21st century. The use of real cases related to the management of used cooking oil waste makes learning more contextual and meaningful. Students not only understand the concept of chemistry theoretically, but are also able to relate it to solutions to environmental problems around them. Thus, this e-module has the potential to be an alternative to innovative teaching materials that supports the implementation of the Independent Curriculum and strengthens real-life experience-based learning in schools.

CONCLUSION

How to make a Case Method-based chemistry learning e-module on saponification reaction material through the use of used cooking oil into liquid soap includes 7 (Seven) steps that focus on the design process and the results of the initial product (finished product). The development of a Case Method-based chemistry learning e-module on saponification reaction material that is very relevant by being able to relate chemistry concepts to real life and the addition of interactive learning videos is carried out through 3 main stages based on the 4D development model and oriented towards product quality, effectiveness, and feasibility.

The Case Method-based chemistry e-module obtained a feasibility assessment from 93%

material validators, 91% language validators, 91% media validators, 91% student responses and teacher responses obtained the highest score of 97%. The average score of the overall e-module feasibility aspect is 92.60%, is in the category of very feasible and can be used as one of the effective teaching materials to support the learning process.

The results of the evaluation of the collaboration skills of students in grades XI-11 of SMA Negeri 1 Sentani on each indicator showed an increase from Teaching Module I to Teaching Module II by an average of 23%. Teaching Module II to Teaching Module III on each indicator is relatively smaller, which is 2.2%.

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