JPPIPA 12 (7) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Implementation of Smartphone-Based E-Learning Modules to Enhance Understanding, Creativity, and Collaboration Among Students in Chemistry

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Received: May 06, 2026
Revised: June 18, 2026
Accepted: July 25, 2026
Published: July 31, 2026

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DOI: 10.29303/jppipa.v12i7.15940

Abstract: This study aims to test the feasibility and effectiveness of implementing smartphone-based chemistry e-modules in enhancing high school students' understanding of the material, creativity, and collaboration. The research method used is pre-experimental with a one-group pretest-posttest design. The research sample consisted of 28 tenth-grade students at SMA Negeri 1 Tinombo, selected using purposive sampling technique. Data were collected thru instruments such as material comprehension tests, creativity tests, and collaboration observation sheets. The research results show that the implemented e-module meets the validity criteria with an average of 78% and is very practical to use, with a practicality score of 84.5% for teachers and 87.78% for students. The effectiveness analysis using the N-Gain test shows an increase in material understanding of 0.71 (high category). For student creativity, the N-gain value is 0.72, and for collaboration, it is reinforced by the teacher's observation results of 87.5%. Thus, it can be concluded that the smartphone-based e-module is effective in improving the quality of chemistry learning on nanomaterial topics.

Keywords: Collaboration; Creativity; E-module; Smartphone; Understanding

Introduction

The development of information technology has driven the transformation of learning toward the use of more interactive, flexible, and easily accessible digital media for students (Gufran et al., 2020). The use of smartphone-based e-modules is one of the new innovations that allows students to learn independently anytime and anywhere. This makes learning more effective and efficient (Darlin et al., 2026). In chemistry learning, the use of smartphone-based e-modules becomes a potential alternative because it can present material in the form of text, images, videos, and animations, thereby helping students understand abstract concepts (Hidayah et al., 2026). E-modules designed for mobile devices also tend to provide ease of use, good readability, and flexibility for self-directed learning, thereby potentially increasing student engagement in learning (Farawansah et al., 2021).

Chemistry learning still faces various obstacles, particularly related to the low understanding of concepts among students due to the complex and abstract nature of the material (Nurarif et al., 2026). In addition, the creativity and collaboration skills of students also need to be improved to support 21st-century learning (Zahroh, 2020). Creativity and collaboration are important competencies needed by students to face the development of science and technology (Nursaya'bani et al., 2025).

Although all three aspects are equally important in chemistry education, the implementation of learning in schools generally still focuses more on achieving cognitive learning outcomes, while the enhancement of creativity and collaboration has not yet become the main focus in the learning process. As a result, the learning process has not yet fully developed students' competencies in a holistic manner in accordance with the

How to Cite:
Saiful, Abram, P. H., Aminah, S., Tahril, Tiwow, V. M. A., & Ratman. (2026). Implementation of Smartphone-Based E-Learning Modules to Enhance Understanding, Creativity, and Collaboration Among Students in Chemistry. *Jurnal Penelitian Pendidikan IPA*, *12*(7), 144–152. https://doi.org/10.29303/jppipa.v12i7.15940

demands of 21st-century education (S. E. Putri et al., 2024).

Based on the observation results at SMA Negeri 1 Tinombo, it was found that students still have difficulty understanding chemistry concepts, are less active in group discussion activities, and have not yet shown optimal creativity in solving learning problems. This condition indicates the need for teaching materials that can facilitate more engaging, interactive, and student-centered learning.

Moreover, although most students already have smartphones that are used in daily activities, these devices have not been optimally utilized as learning media. This condition indicates an opportunity to integrate the technology that students already possess into the learning process, thereby supporting more flexible, contextual, and competency-oriented learning (Hardika et al., 2024).

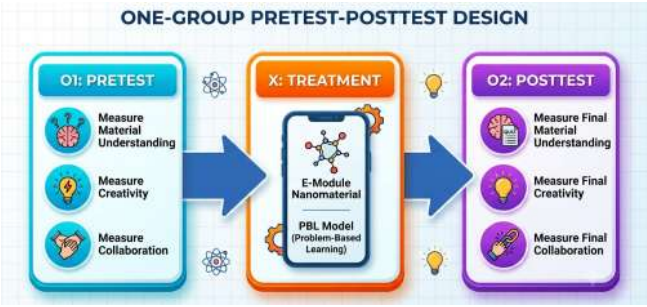
Various studies show that smartphone-based e-modules can improve students' learning outcomes and conceptual understanding (Rahayu et al., 2025). The aspects of creativity and collaboration are increasingly seen as important achievements in 21st-century learning. Digital learning environments and technology-based learning practices tend to support the development of creativity thru the fluency of ideas, flexibility of originality, and elaboration (Kholid et al., 2026). Namun demikian, sebagian besar penelitian sebelumnya hanya berfokus pada peningkatan hasil belajar atau pemahaman konsep peserta didik, sedangkan penelitian yang mengintegrasikan pengukuran pemahaman materi, kreativitas, dan kolaborasi dalam satu implementasi e-modul berbasis smartphone masih sangat terbatas. Selain itu, penelitian mengenai implementasi e-modul pada materi nanomaterial di tingkat SMA juga masih jarang dilaporkan, padahal materi tersebut memiliki karakteristik abstrak yang membutuhkan visualisasi dan penyajian pembelajaran yang interaktif (Hulu et al., 2025).

Method

This research is a quantitative study with a pre-experimental design in the form of a one-group pretest-posttest (R. D. Putri et al., 2022). The research was conducted at SMA Negeri 1 Tinombo on Class Xe students for the 2025/2026 academic year. The sample was selected using purposive sampling based on the suitability of academic characteristics and learning schedules. The systematic flow of the experiment, which includes the initial measurement procedure, intervention using the Problem-Based Learning (PBL) model, and final measurement, is presented in Figure 1. Visually, the stages of the research in Figure 1 can be described as follows:

Pretest (O1) is the initial stage of the three dependent variables, namely understanding, creativity, and collaboration, before treatment is given. Treatment (X) is the implementation of a learning intervention using smartphones on nanomaterial content by applying the Problem Based Learning (PBL) model syntax.

Posttest (O2) is the final measurement stage using an instrument equivalent to the pretest to observe changes or improvements in the variables of understanding, creativity, and collaboration of the students after the intervention is completed.



Fugure 1. The flowchart of one-group pretest-posttest research design

Data collection was conducted thru tests, questionnaires, and observations. Tests were used to measure material understanding thru pretests and posttests. Questionnaires were used to obtain data on the validity and practicality of the e-modules, while observations were used to measure students' creativity and collaboration during the learning process.

The research instruments include expert teacher and student response questionnaires, material comprehension test questions, creativity observation sheets, and collaboration observation sheets. The validity and practicality data are analyzed using percentages and interpreted based on the established categories.

The effectiveness of the e-module implementation is measured thru N-Gain analysis as a basis for determining the improvement in material understanding and student creativity after the learning process. The collaboration skills were analyzed using a descriptive approach by utilizing data from observations and questionnaires obtained during the learning activities.

Result and Discussion

Level of Practicality of Learning E-Modules

The practicality analysis in this pre-experimental study is not intended to test the validity of a new

product, but rather to determine the quality of treatment fidelity in the classroom. This aspect of practicality measures the ease of use, attractiveness, and suitability of the e-module to the learning needs of students and the smoothness of teachers in managing the learning process (W. P. Putri et al., 2026). This data is important to ensure that the improvement in students' understanding, creativity, and collaboration is truly supported by the reliability of the media used during the experiment. Measurements were conducted using two types of instruments, namely teacher response questionnaires and student response questionnaires (Ardani et al., 2026). The results of the practicality assessment by the teacher and students can be seen in Table 1 and Table 2.

Table 1. Results of Teacher Response Analysis on the Practicality of E-Module Learning Implementation

Description	Score Amount	Average	Precentage %
Chemistry Teacher 1	35	3.5	87
Chemistry Teacher 2	33	3.3	82
Average total	34	3.4	84.5
Interpretation			Very practical

Table 2. Results of Student Response Analysis on the Practicality of E-Module Learning Implementation

Description	Score Amount	Average	Precentage %
Student	993	35.46	88.66
Interpretation			Very practical

The practicality of the e-module was measured thru questionnaires from teachers and students. The results of the questionnaire showed that the teachers' responses received a percentage of 84.5% and the students' responses received 88.66%, both of which fall into the very practical category. This shows that the e-module is easy to use, engaging, and capable of effectively supporting the learning process (Irawan et al., 2021).

The high percentage of ratings from teachers indicates that the e-module has a good level of practicality, making it easy to implement in the learning process. These characteristics facilitate teachers in managing the learning flow without encountering technical or instructional obstacles. On the other hand, the very high ratings from students indicate that the e-module has an interface that is easy to understand, engaging, and interactive, allowing it to be used independently and effectively (Astuti et al., 2024). This result is also in line with Aldilla (2024) which states that e-modules with a high level of practicality can facilitate the implementation of learning and support active student engagement.

The practicality of the e-module obtained in this study is suspected to be influenced by the product characteristics that can be accessed thru smartphones. The use of smartphones as a learning medium provides students with the convenience of accessing materials anytime and anywhere without being limited by space and time (Anyan et al., 2020).

Conceptually, the high level of practicality of smartphone-based e-modules supports the principles of the Technology Acceptance Model (TAM), particularly in the dimensions of perceived ease of use and perceived usefulness. The ease of access that is not limited by space and time of learning allows students to learn more independently according to their needs and learning pace. That flexibility provides students with the opportunity to revisit the visualization of abstract nanomaterial concepts before or after group discussions, thereby optimizing the process of concept comprehension (Syahri et al., 2024).

The ease of implementing this media acts as the main trigger that drives students' competence throughout the experiment. The flexible and easily accessible nature of the e-module can reduce technical barriers during the learning activities, allowing students' attention to be fully devoted to mastering the material, exploring creative ideas, and strengthening group interactions. Thus, the smooth consistency of action implementation (treatment fidelity) is closely related to the optimal increase in achievement across the three research variables (Abdilah et al., 2024).

The Effectiveness of E-Learning Modules

Results of the analysis of the effectiveness of the e-learning module on the aspect of material comprehension can be seen in Table 3.

Table 3. Results of Pretest and Posttest Understanding

Statistics	Pretest	Posttest
Total score	159	534
Average	5.68	19.39

Based on Table 3, the pretest results showed a total score of 159 with an average score of 5.68. After the learning using the smartphone-based chemistry e-module, the posttest results showed an improvement with a total score of 543 and an average score of 19.39. The difference in results between the pretest and posttest indicates an increase in students' understanding of the material after participating in the learning using the implemented e-module.

Next, the analysis of the improvement in understanding was conducted using the N-Gain test. The purpose of this test is to determine the extent of the improvement in students' understanding after using the smartphone-based chemistry e-module. The N-Gain calculation is performed by comparing the pretest and posttest scores of each student. Thus, the improvement in students' understanding can be determined. Next, the N-Gain calculation results are interpreted based on low,

medium, and high categories. This is done to determine how effective the use of e-modules is in learning. The results of the N-Gain test can be seen in Table 5.

Table 4. N-Gain Test Results of Material Understanding

Parameter	Value
Average Pretest	5.68
Average Posttest	19.39
N-gain	0.71
Category	High

Table 4 shows that the average pretest score of students was 5.68, which increased to 19.39 in the posttest, and the N-Gain calculation results indicate that a score of 0.71 falls into the high category. The results show that the use of smartphone-based chemistry e-modules is effective in improving students' abilities.

To provide a clearer picture of the improvement in student understanding, an analysis of the achievement of material comprehension on each indicator was subsequently conducted. The results are presented in Figure 2.

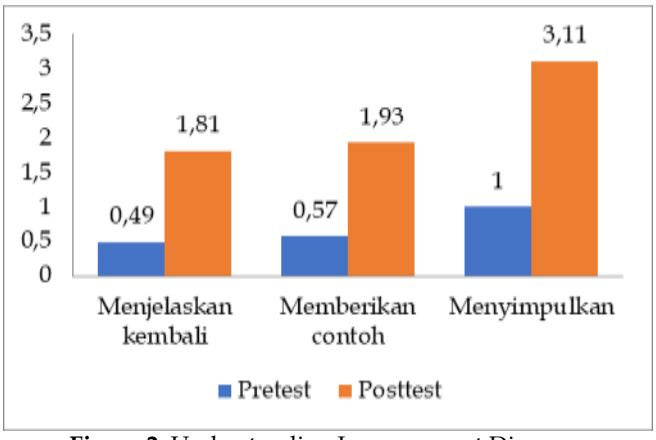


Figure 2. Understanding Improvement Diagram

Figure 2 shows the comparison of average pretest and posttest scores for each material comprehension indicator. All indicators showed improvement after learning using the smartphone-based chemistry e-module, as shown in the figure. The indicator explains that the average score increased from around 0.5 on the pretest to around 1.8 on the posttest. The indicator providing examples also increased, from around 0.6 to around 1.9. Meanwhile, the summarizing indicator showed the highest increase, with the average score rising from around 1.0 on the pretest to around 3.1 on the posttest. These results indicate that the use of smartphone-based chemistry e-modules can enhance students' understanding of the material on every indicator, with the greatest improvement occurring in the ability to conclude (Defista et al., 2024).

This result is in line with the research Raziana et al. (2025) which reported that Android-based chemistry learning media can enhance students' conceptual understanding thru the presentation of interactive and easily accessible material.

Figure 3. Documentation of e-module learning implementation

In addition to enhancing material comprehension, the use of e-modules also has a positive impact on students' creativity. Learning that utilizes digital media provides students with the opportunity to explore various ideas and solutions, thereby encouraging the development of creative thinking skills (Cahyani et al., 2020). The effectiveness of students' creativity was tested to determine the success level of implementing smartphone-based e-modules in enhancing students' creative thinking abilities after the learning activities took place. The creativity ability in this study was measured thru the results of pretest and posttest given before and after the implementation of the e-module (Rohmantika et al., 2021). The results of the pretest and posttest can be seen in Table 5.

Table 5. Pretest and Posttest Creativity Results

Statistics	Pretest	Posttest
Total Score Skor	279	483
Average	9.96	17.25

Table 6. Results of the N-Gain Creativity Test

Parameter	Value
Average Pretest	9.96
Average Posttest	17.25
N-gain	0.72
Category	High

Based on Table 5, the total score of students on the pretest was 279, with an average of 9.96. Their total score on the posttest increased to 483, with an average of 17.25. The increase in total scores and average values indicates that students' creativity skills improved after using the smartphone-based chemistry learning e-module. Next, the analysis was conducted using the N-Gain test to

determine the level of improvement that occurred. The results of the N-Gain test can be seen in Table 6.

Based on Table 6, the average pretest score of 9.96 increased to 17.25 in the posttest, and the calculations show an average N-Gain score of 0.72, indicating that this score falls into the high category according to the N-Gain interpretation criteria. These results indicate that the use of smartphone-based chemistry e-modules is effective in enhancing students' creativity, as evidenced by the improvement in learning outcomes from before to after the instruction. To provide a clearer picture of the improvement in student creativity, an analysis of the achievement of material understanding on each indicator was subsequently conducted. The results are presented in Figure 4.

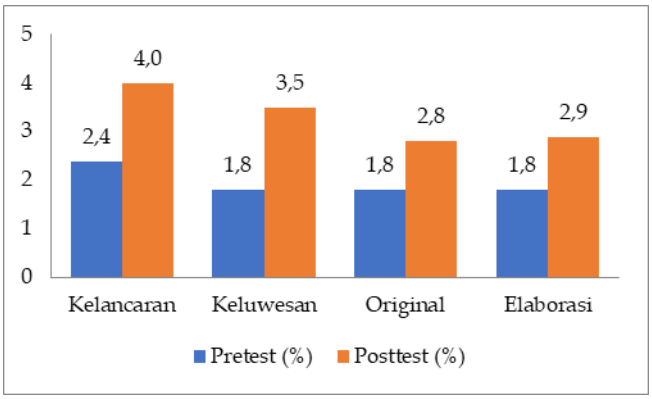


Figure 4. Creativity enhancement diagram

Based on the graph of student creativity measurement results, there is an increase in the average scores across all creativity indicators after the implementation of learning using smartphone-based chemistry e-modules. On the fluency indicator, the average score increased from 2.4 in the pre-test to 4.0 in the post-test. The flexibility indicator saw an increase from 1.8 to 3.5. Improvement was also observed in the originality indicator, which rose from 1.6 to 2.8. Meanwhile, the elaboration indicator increased from 1.8 in the pre-test to 2.9 in the post-test. The results indicate that students' creativity skills have developed in every measured aspect. The increase that occurred indicates that students are becoming more capable of generating diverse ideas, presenting more unique concepts, and developing answers in greater detail after participating in the learning process. In general, the data indicates a positive change in the students' creativity levels after the use of smartphone-based chemistry e-modules (Kumfardiah et al., 2025).

The increase in students' creativity also occurs because smartphone-based e-modules present learning activities that provide opportunities for students to explore various ideas, express opinions independently, and develop concepts thru the presentation of material and interactive activities (Suardana et al., 2024). The flexibility of using e-modules also allows students to access materials anytime according to their needs, giving them more time to think, try various alternative solutions, and develop ideas in more detail. These conditions contribute to the development of creative thinking skills, as evidenced by the improvement in aspects of fluency, flexibility, originality, and elaboration (S. E. Putri et al., 2024).

Figure 5. Documentation of e-module learning implementation

In terms of collaboration, the use of smartphone-based e-modules can support interaction and cooperation among students during the learning process (Sidiq et al., 2020). The high level of collaboration achieved indicates that e-module-assisted learning can facilitate group discussions, communication, and task completion (Triwoelandari et al., 2023). Thus, smartphone-based learning e-modules not only contribute to improving learning outcomes but also support the development of 21st-century skills such as creativity and collaboration (Ramadhan et al., 2025).

The results of measuring student collaboration were obtained thru a collaboration questionnaire given before and after the use of a smartphone-based e-module. Description of the pretest and posttest results of student collaboration is presented in Figure 6.

Figure 6 shows that all indicators of students' collaboration skills demonstrate consistent and significant improvement from the Pre-test stage to the Post-test stage. At the initial condition (Pre-test), the five measured aspects—active contribution, work productivity, responsibility, flexibility and compromise, and mutual respect—were in the sufficient category with an average score range between 2.6 to 2.67 on a scale of 4. After the implementation of the learning intervention, students' learning outcomes in the Post-test sharply increased to the very good category with an average score reaching 3.7, where the mutual respect indicator recorded the highest value of 3.75. The uniform increase in each indicator indicates that the

implementation of the learning model used in the classroom has proven to be effective and capable of facilitating the comprehensive development of students' collaboration skills.

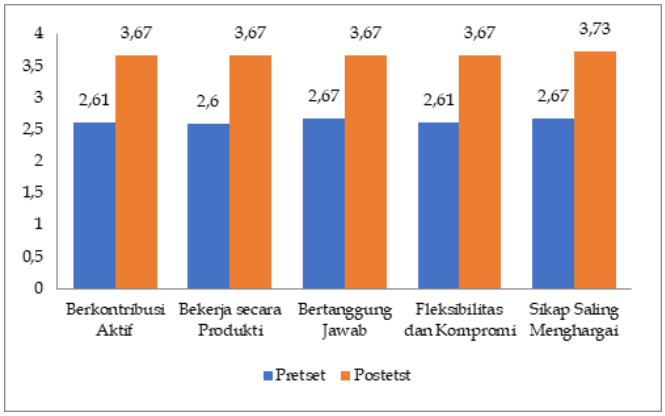


Figure 6. Collaboration improvement diagram

The results show that students can collaborate better after the learning process than before. This improvement indicates that students can participate and cooperate during the learning process thru smartphone-based chemistry e-modules.

Figure 7. Documentation of e-learning module implementation

The improvement indicates that the e-module not only serves as a medium for delivering material but also as a means that facilitates interaction among students during the learning process. The structured presentation of material, learning activities that require group discussions, and the joint completion of tasks provide each group member with the opportunity to exchange information, express opinions, and agree on solutions to the given problems. The process encourages the development of skills such as contributing, being responsible, compromising, and respecting others' opinions as the main components of collaboration skills. This result is in line with (Nurussalamah et al., 2025) which shows that the use of digital teaching materials designed for group activities can enhance students' collaboration skills thru discussion and joint task completion.

The results of the student collaboration questionnaire are reinforced by teacher observation data during the learning process. Observations are conducted to directly observe students' collaborative behaviors, such as group contributions, task responsibilities, ability to compromise, and attitude of respecting peers' opinions (Desmaliza et al., 2025). Thus, the observation data is used as a support to verify the obtained questionnaire results (Sahid et al., 2024). The results of the observation of students' collaboration skills can be seen in Table 7.

Table 7. Teacher Observation Results

Observed Aspects	Score
Students actively participate in group discussions.	3
Students express ideas or opinions.	3
Students listen to their friends' opinions well.	4
Students help friends who are experiencing difficulties.	4
Students carry out tasks according to group assignments.	4
Students do not dominate group work.	3
Students cooperate in completing tasks.	3
Students maintain good communication within the group.	4
Amount	28
Precentage	87.5%

Based on the teacher's observations during the learning process using smartphone-based chemistry e-modules, it appears that student collaboration is progressing quite well. Students have started to actively contribute to group discussions, although there are still some students who are not yet fully engaged.

In terms of mutual respect, students show positive interactions by listening to each other's opinions within the group. Meanwhile, in terms of responsibility, some students have performed their tasks well, but there are still those who are inconsistent in completing group assignments.

Additionally, in terms of flexibility and compromise, students are already quite capable of accepting differing opinions within the group. In general, the observation results show that learning with e-modules has a positive impact on student collaboration, although improvements are still needed in several aspects.

Conclusion

Based on the research results, it can be concluded that the use of smartphone-based chemistry learning e-modules has proven to be practical and effective in supporting the learning process. E-modules provide a

more flexible learning experience and are capable of enhancing students' understanding of the material, creativity, and collaboration thru structured material presentation, interactive learning features, and learning activities that encourage active student engagement. Thus, smartphone-based chemistry learning e-modules have the potential to become an effective alternative learning media to support the development of students' competencies and can be applied to a wider range of subjects and educational levels thru further research. It is recommended that smartphone-based chemistry learning e-modules be applied to other chemistry subjects and tested on a larger sample to obtain more comprehensive results.

Acknowledgments
The author expresses the deepest gratitude to all parties who have provided support, assistance, and contributions throughout the implementation and completion of this research, especially to the supervising lecturer who has consistently offered guidance, direction, input, and motivation during the preparation of this scientific work. The author also hopes that the research results on the implementation of smartphone-based learning e-modules can provide benefits for the development of chemistry education, particularly in enhancing students' conceptual understanding, creativity, and collaboration, and can serve as a useful reference for educators and researchers in developing technology-based learning innovations in the future.

Author Contributions
Conceptualization, S, PHA, and SA; methodology, S, PHA, and SA; validation, T, VMAT, R; formal analysis, S; investigation, S.; data curation, S.; writing—original draft preparation, S.; writing—review and editing, S, PHA, and SA; All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The author declares no conflict of interest.

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