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DEVELOPMENT OF E-LEARNING MATERIALS FOR CASE METHOD AND PROJECT-BASED CHEMISTRY CAPITA SELECTA TO IMPROVE STUDENT CHEMISTRY LEARNING OUTCOMES

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ABSTRACT

Digital technology can support active and contextual chemistry learning when it is used not only to digitize content but also to organize meaningful learning experiences. However, digital teaching materials that systematically connect case analysis with project-based application remain limited, particularly in Selected Topics in Chemistry courses. This study aimed to develop and evaluate Case Method and Project-Based Learning (PjBL) e-teaching materials in terms of validity, practicality, and effectiveness. A Research and Development design was conducted at Universitas Negeri Medan, Indonesia, with purposively selected chemistry education students and four expert validators. Data were collected using validation sheets, practicality questionnaires, learning-outcome tests, satisfaction questionnaires, and project-performance assessments, then analyzed using descriptive statistics, N-Gain, prerequisite tests, and a one-tailed *t*-test. The findings showed that the developed materials met validity and practicality criteria and produced significantly higher learning outcomes in the experimental group than in the control group. These findings suggest that integrated digital materials can connect case analysis with concept application through project activities and provide a practical framework for chemistry learning design.

Keywords: Case method, chemistry education, e-teaching materials, learning outcomes, project-based learning

INTRODUCTION

The rapid development of digital technology in the era of the Industrial Revolution 4.0 has brought significant changes in educational practices, including chemistry education in universities, through the use of various digital technologies that support more interactive and flexible learning (Tatenov et al., 2025; Wong et al., 2021). In line with the Education 4.0 paradigm, universities are required to integrate technology, innovation, and student-centered

learning approaches to develop critical thinking, communication, collaboration, creativity, and problem-solving skills needed in the 21st century world of work (Ciolacu et al., 2017; Vu Anh & Le Quoc, 2019). The shift also encourages the implementation of active learning strategies, including Case Method and Project-Based Learning (PjBL), which provide opportunities for students to engage more deeply in the learning process through problem-solving related to real-life contexts (Mogul & Shah, 2021). This requires lecturers not only to convey theoretical knowledge, but also to design learning experiences that allow students to apply knowledge through meaningful learning resources and activities.

These demands are becoming increasingly important in chemistry education because many chemical concepts are abstract, such as molecular structure, chemical bonds, and reaction mechanisms, so they are not always easy to understand through conventional learning (Hsiung, 2018; Jiménez, 2019; Kayumov et al., 2025). Students also often have difficulty visualizing phenomena at the atomic and molecular level that cannot be directly observed, which can ultimately hinder their conceptual understanding (Wu et al., 2021). Therefore, chemistry learning requires learning resources that not only present conceptual information, but also provide opportunities for students to analyze problems, connect theory with contextual phenomena, and apply concepts in authentic learning activities.

One relevant approach to meeting these needs is the Case Method. This approach provides students with the opportunity to develop critical thinking skills, analyze problems, make decisions, and discuss through the exploration of authentic cases that connect theoretical knowledge with its application in real-world situations (Head & Bays, 2010; Liao et al., 2025; C. Ma & Zhou, 2022; Obeagu & Muhammad, 2025; Ramachandran & Pillai, 2025; Seshan et al., 2021). Several studies have also shown that the implementation of the Case Method has a positive impact on students' critical thinking and problem-solving skills (Abdel-Wahed et al., 2024; Alani & Grewal, 2023; Nurita et al., 2025; Puri, 2026).

On the other hand, Project-Based Learning provides students with opportunities to actively engage in the learning process through project activities that require inquiry, creativity, self-directed learning, collaboration, and authentic problem solving (Guo et al., 2020; Zhang & Ma, 2023). Various studies have shown that PjBL can contribute to the development of students' critical thinking, problem-solving, and collaboration skills, as well as to improved learning outcomes (Chen & Jin, 2025; H. Liu et al., 2025; Mutanga, 2024; Sia & Yusof, 2024). Given these characteristics, the Case Method and PjBL serve complementary pedagogical functions. The Case Method presents contextual problems that enable students to apply

chemistry concepts in situations resembling real-world problem-solving practices (Schaber & Hobika, 2018), whereas PjBL provides opportunities for students to develop and implement solutions through project-based activities (Kurian & Beydoun, 2025).

Although the benefits of the Case Method and PjBL have been widely reported, the systematic integration of these two approaches within a single interactive electronic teaching material for chemistry learning remains limited, particularly in the Selected Topics in Chemistry course. Existing teaching materials still tend to be dominated by theoretical content and have not yet optimally integrated real-life cases, collaborative projects, multimedia learning resources, and interactive digital features. This situation highlights the need to develop teaching materials that go beyond merely digitizing content and instead organize the learning process from case analysis and concept application to project implementation and the evaluation of learning outcomes within an integrated digital learning environment.

Although the Case Method and Project-Based Learning (PjBL) have been widely implemented in chemistry education and have been shown to support conceptual understanding, problem solving, collaboration, as well as practical and research skills, these two approaches are still predominantly implemented separately (Madybekova et al., 2026; Yalçinkaya et al., 2012). PjBL has also been developed in various chemistry learning contexts, including online learning and authentic research-based projects (De Los Santos et al., 2014; Paristiowati et al., 2022). However, the integration of CBL–PjBL has also been reported to foster reasoning, hypothesis formulation and testing, contextual critical thinking, and decision-making skills (Dewi & Rahayu, 2023). Therefore, there is a need for teaching materials that integrate case analysis, concept application, and collaborative projects within a single digital learning environment.

Within this context, the present study develops interactive electronic teaching materials using EXE-Learning as a digital environment for organizing learning content, cases, project-based activities, multimedia resources, and assessments (Prasetyani et al., 2019; Rodriguez, 2022). In this study, digital technology is not positioned merely as a medium for delivering content, but rather as a learning environment that facilitates Case Method and PjBL activities within an integrated learning sequence (Asmiyunda et al., 2023). Thus, students are not only accessing the material electronically, but are directed to analyze cases, connect problems with relevant chemical concepts, and apply knowledge through project-based activities.

Different from the application of the Case Method or PjBL as a stand-alone learning activity, the teaching materials developed connect authentic cases as a starting point for problem

analysis with project activities as a means of applying concepts and developing solutions. EXeLearning is used as an electronic learning environment to organize materials, multimedia resources, interactive learning activities, and assessments in an integrated manner (Prasetyani et al., 2019), while supporting the implementation of project-based activities (Muliaman, 2021). The design is also aligned with the learning outcomes and objectives of the course so that learning and assessment activities are directed at achieving student learning outcomes.

Based on the identified gap, this study aims to (1) develop interactive electronic teaching materials based on the Case Method and Project-Based Learning for the Selected Topics in Chemistry course; (2) evaluate the validity and practicality of the developed teaching materials; and (3) examine their effectiveness in improving students' learning outcomes compared with a control group.

RESEARCH METHODS

This study employed a Research and Development (R&D) approach adapted from the Borg and Gall model to develop and evaluate interactive electronic teaching materials for the Selected Topics in Chemistry course. During the product development process, the Dick and Carey instructional design model was used to guide the formulation of learning objectives, organization of content, development of Case Method- and Project-Based Learning (PjBL)-based activities, and design of assessment components (Dick, 2015). Thus, the Borg and Gall model served as the overarching research and development framework, whereas the Dick and Carey model served as the instructional design framework for developing the teaching materials.

The research will be carried out at the Chemistry Education Study Program, Department of Chemistry, State University of Medan in 2024. Based on the adaptation of the Borg and Gall R&D framework and the instructional design of Dick and Carey, the research procedure was operationalized into 15 stages of development as presented in Figure 1. These stages include analysis of needs and curriculum, analysis of student characteristics and learning context, analysis of teaching materials that have been used, design and development of electronic teaching materials, formulation of learning outcomes and objectives, organizing materials, preparation of case- and project-based activities, expert validation, feasibility testing, product revision, product trial, implementation, evaluation, and refinement of the final product. The stages contained in the manuscript do move from needs analysis to product evaluation.

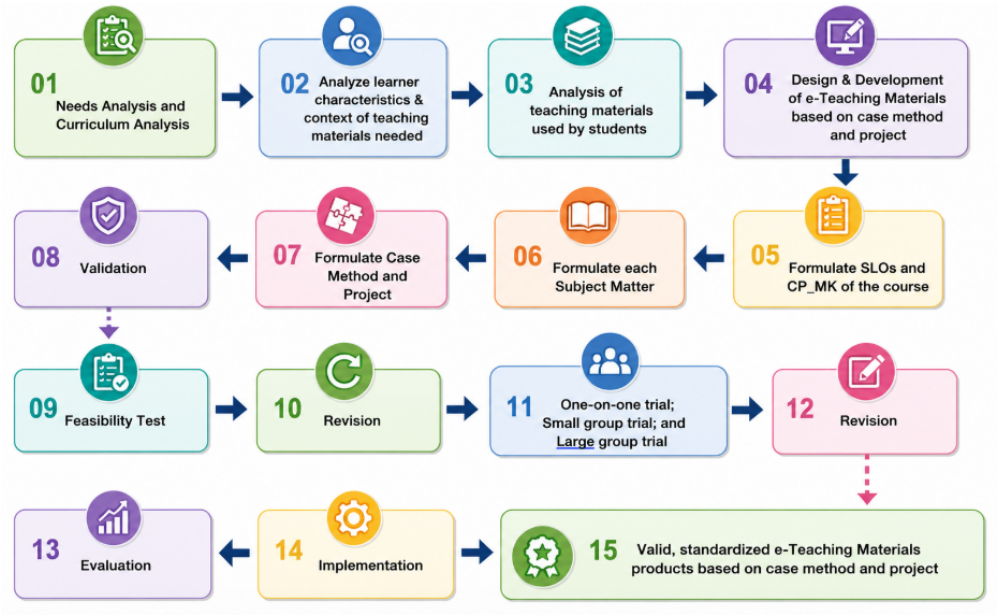


Figure 1. Research and Development Procedure Adapted from Borg and Gall and The Dick and Carey Instructional Design Model

Participants and Sampling Techniques

The research participants consisted of four expert validators and students of the Chemistry Education Study Program. The four validators represent the fields of media/information technology expertise, materials, language, and learning practices. Students are selected using purposive sampling techniques according to the needs at each stage of product development and testing. Individual evaluations involved 10 students, small group trials involved 10 students, and large group trials involved 60 students. At the effectiveness testing stage, as many as 60 students were involved in the research, consisting of 30 students in the experimental group and 30 students in the control group.

Research Instruments

The research instruments include product validation questionnaires, learning activity instruments, observation sheets, student satisfaction questionnaires, and learning outcome tests. The instruments are examined through expert judgment to evaluate the suitability of the instruments with the research objectives and aspects measured. The review process involved four validators with expertise in the fields of media/information technology, materials, language, and learning practices. Validator input is used as a basis for revising instruments before they are used in data collection.

Data Analysis

Expert validation data were analyzed descriptively using mean scores to determine the validity of the developed electronic teaching materials. Data obtained from the product trial and student responses were analyzed using the Respondent Achievement Rate (TCR) to determine the practicality of the product. Improvements in students' learning outcomes were analyzed using normalized gain (N-Gain) based on pre-test and post-test scores.

Prior to hypothesis testing, normality and homogeneity tests were conducted to ensure that the data met the assumptions required for parametric analysis. Subsequently, the hypothesis concerning differences in learning outcomes between the experimental and control groups was tested using a one-tailed independent-samples t-test (right-tailed test) at a significance level of $\alpha = 0.05$.

RESULT AND DISCUSSION

Analysis of Existing Chemistry Teaching Materials

The initial stage of development was carried out through an analysis of two chemistry teaching materials that had been used, namely Publisher A and Publisher B. Analysis was focused on four aspects, namely the feasibility of content, language, presentation, and graphics. The results of the analysis were used to identify the characteristics of the available teaching materials and determine the need for the development of electronic teaching materials. A summary of the results of the analysis is presented in Table 1.

Table 1. Results of The Analysis of Teaching Materials of Publisher A and Publisher B

Validation Aspect	Publisher A	Publisher B
Content eligibility	3.16 ± 0.08	2.88 ± 0.10
Language feasibility	3.18 ± 0.06	2.98 ± 0.14
Presentation feasibility	3.13 ± 0.07	2.86 ± 0.12
Feasibility of Graphics	2.84 ± 0.14	2.78 ± 0.13
Mean	3.08 ± 0.09	2.88 ± 0.12

As shown in Table 1, Publisher A's teaching materials obtained an overall average score of 3.08 ± 0.09, while Publisher B obtained a score of 2.88 ± 0.12. In teaching materials, the graphic aspect received the lowest score compared to other aspects. Further analysis also showed that the available teaching materials have not systematically integrated CPL and CPMK, concept maps, interactive multimedia, Case Method and PjBL activities, as well as tasks in the form of CBR, CJR, Mini Research, projects, idea engineering, and routine tasks. Based on the results of the analysis, product development is directed not only to the electronic

presentation of materials, but also to the integration of case-based and project-based learning activities in a single learning environment.

Development and Characteristics of the E-Teaching Materials

Based on the needs identified during the analysis stage, electronic teaching materials for capita selecta course were developed by integrating the Case Method and PjBL using EXE-Learning. The developed product includes program learning outcomes (CPL), course learning outcomes (CPMK), concept maps, learning content, interactive videos, HOTS-oriented assessments, as well as CBR, CJR, Mini Research, project, idea engineering, and routine task activities. The content is organized into eleven chemistry topics aligned with the course curriculum. These learning components were not integrated merely as a collection of separate features but were organized into a coherent learning sequence. The pedagogical structure of the developed teaching materials is presented in Figure 2.

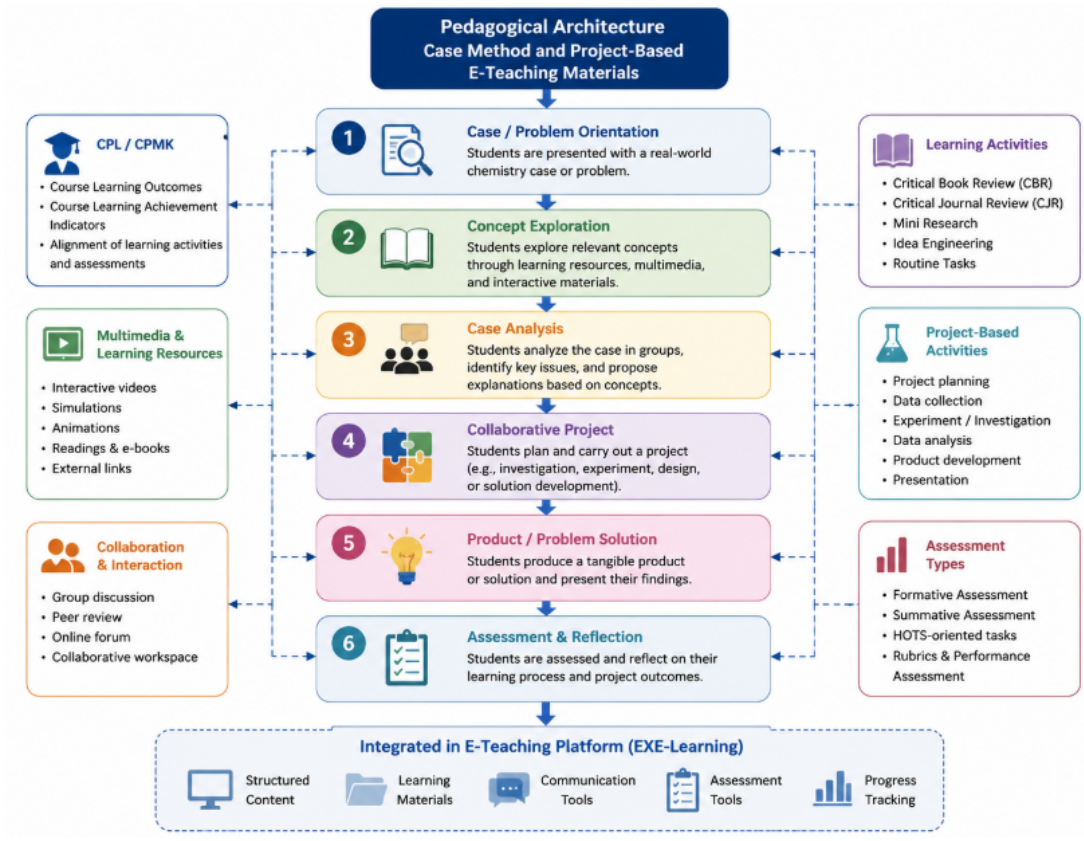


Figure 2. Pedagogical Architecture of The Developed Case Method and Project-Based E-Teaching Materials

As illustrated in Figure 2, a case or problem serves as the starting point of the learning activities. Students are then guided to explore relevant concepts and analyze the problem,

followed by project-based activities aimed at producing a product or solution. The entire process is linked to assessment and reflection. Within this structure, the Case Method primarily functions at the problem-analysis stage, whereas PjBL provides a pathway for applying concepts through project development. After the product development was completed, expert validation was conducted to determine the feasibility of the product before it was used in the student trial.

Validity of the Developed E-Teaching Materials

Validation was carried out by four validators representing the fields of media/information technology expertise, language, materials, and learning practices. The assessment covers aspects of content eligibility, language, presentation, and graphics. A summary of the validation results is presented in Table 2.

Table 2. Results of Validation of Electronic Teaching Materials

Aspect	Expert Validation					Category
	Media	Language	Content	Practitioner	Mean	
Content eligibility	3.85	3.91	3.83	3.87	3.86	Very valid
Language feasibility	3.82	3.81	3.86	3.84	3.83	Very valid
Presentation feasibility	3.81	3.83	3.85	3.82	3.83	Very valid
Feasibility of Graphics	3.82	3.79	3.84	3.82	3.82	Very valid
Mean					3.84	Very valid

Table 2 shows that all aspects obtained a score above 3.80, with an overall average of 3.84. The feasibility of the content obtained the highest score, while the graphic aspect obtained the lowest relative score. Based on the criteria used in the study, all aspects are in the category of being very valid. To show the position of the developed product against the teaching materials analyzed in the initial stage, the scores of the four aspects are visually compared in Figure 3.

Figure 3 shows that the developed electronic teaching materials scored higher in all aspects than the teaching materials of Publisher A and Publisher B. The difference was most noticeable in the graphic aspect, with the score of the developed product being 3.82 compared to 2.84 and 2.78 in the two previous teaching materials. After meeting the validity criteria, the product proceeds to the user trial stage to evaluate its practicality at different scales.

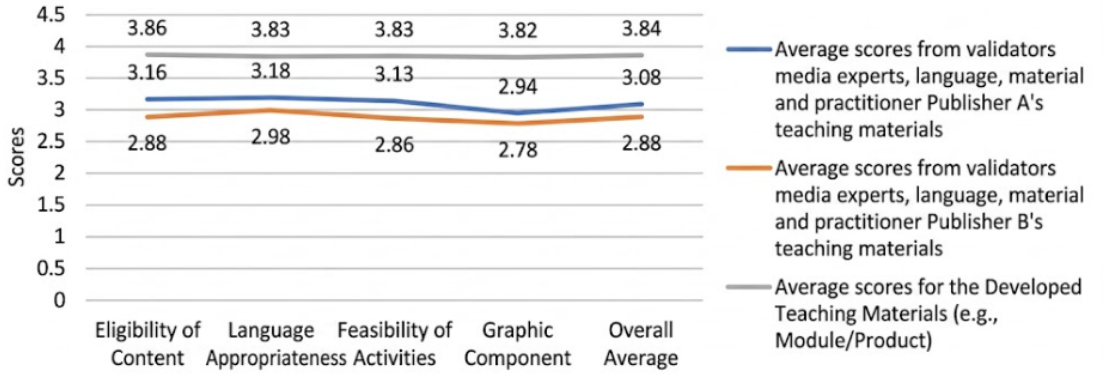


Figure 3. Comparison of Validation Scores Between Existing Teaching Materials and The Developed E-Teaching Materials

Practicality of the Developed E-Teaching Materials

The practicality of the product is evaluated in stages through individual, small group and large group evaluations. The results of the evaluation were analyzed using the Respondent Achievement Rate (TCR). A summary of the results of the three stages is presented in Table 3.

Table 3. The Practicality of Electronic Teaching Materials

Stage	n	TCR (%)	Category
Individual evaluation	10	92.00	Very high
Small-group evaluation	10	92.66	Very high
Big-group evaluation	30	93.00	Very high

As seen in Table 3, the TCR value is in the range of 92.00–93.00% and all stages are in the very high category. The score is relatively consistent when the product is used ranging from individual evaluations to larger groups. The pattern is visualized in Figure 4 to show the consistency of the product's practicality at each stage of the trial.

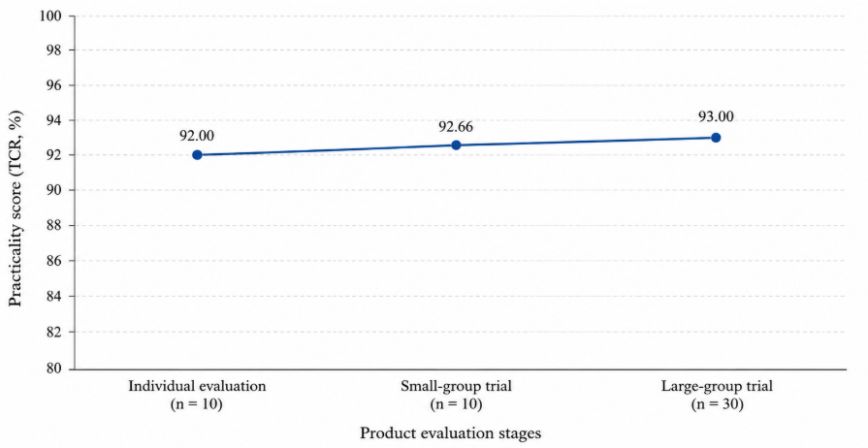


Figure 4. Practicality Scores Across Product Evaluation Stages

Figure 4 shows relatively small changes in all three stages, with the highest score obtained in the large group test of 93.00%. Although the practicality of the product shows high results, the findings have not provided evidence of changes in student learning outcomes. Therefore, the next stage of analysis is focused on the effectiveness of the product.

Effectiveness of the Developed e-Teaching Materials

The effectiveness of the product is analyzed through two stages. First, the improvement in learning outcomes was examined based on pre-test and post-test scores in small group and large group tests. Second, the effectiveness of the product was tested through a comparison of the learning outcomes of the experimental and control groups.

Table 4. Average N-Gain in Small and Large Group Trials

Groups	n	Mean		N-Gain	Category
		Pre-test	Post-test		
Small	10	38.00	81.50	70.80%	High / Effective
Big	30	36.67	83.50	71.25%	High / Effective

Table 4 shows the increase in scores in both stages of the trial. In the small group, the average score changed from 38.00 to 81.50, while in the large group it changed from 36.67 to 83.50. The N-Gain value is 70.80% and 71.25%, respectively. Figure 5 shows a similar pattern of increase in both small and large groups.

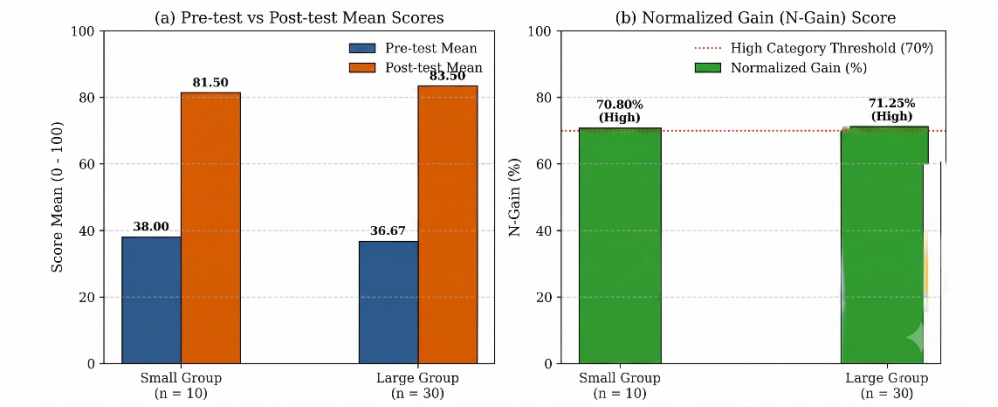


Figure 5. Comparison of Learning Outcomes Between Small Group ($n = 10$) and Large Group ($n = 30$): (a) Pre-Test and Post-Test Mean Scores, and (b) Normalized Gain (N-Gain) Percentages Indicating Highly Effective Learning Outcomes ($g > 0.70$)

Comparison of Experimental and Control Classes

Normality tests were performed to determine whether the learning outcome data in the experimental group and the control group met the normal distribution assumptions. The results of the normality testing of the two groups are presented in Table 7.

Table 5. Normality Test of Experimental and Control Class Data

Classes	χ^2 Count	χ^2 Table	Conclusion
Experiment	10.94	11.07	Normally distributed data
Control	8.87	11.07	Normally distributed data

As shown in Table 5, the calculated χ^2 values in the experimental group (10.94) and the control group (8.87) were smaller than in the χ^2 table (11.07). Based on the testing criteria used in the study, the learning outcome data of the two groups were declared to be normally distributed. With the fulfillment of the assumption of normality, the next analysis is directed to check the homogeneity of the variance of the two groups. Homogeneity tests were performed to determine whether the variance in learning outcomes of the experimental and control groups could be considered homogeneous. The test results are presented in Table 8.

Table 6. Homogeneity Test of Experimental and Control Class Data

Classes	Varians (S^2)	F-Count	F-Table	Conclusion
Experimental	0.0187	1.09	1.45	Homogeneous Data
Control	0.0172			

As seen in Table 6, the calculated F value of 1.09 is smaller than the F of the table of 1.45. Thus, based on the test criteria used, the data variance of the experimental group and the control group was declared homogeneous. The results of the normality and homogeneity test showed that the data met the assumptions used to continue testing the hypothesis using parametric tests. After the data met the assumptions of normality and homogeneity, the effectiveness of the teaching materials was tested using a right-party t-test. This test is used to determine whether the learning outcomes of students in the experimental group are higher than in the control group. The results of the hypothesis testing are presented in Table 7.

Table 7. Results of The Right-Tailed T-Test on The Learning Outcomes of The Experimental and Control Groups

Comparison	Experimental Mean	Control Mean	t_{count}	t_{table}	α	Decision
Experimental vs. control	81.74	74.03	5.34	1.658	0.05	H_0 rejected

As shown in Table 7, the experimental group achieved a mean learning outcome score of 81.74, which was higher than the control group's mean score of 74.03. The results of the right-tailed t-test showed that the calculated t-value was greater than the critical t-value at the specified significance level. These findings indicate that, under the conditions of this study, students who used the electronic teaching materials based on the Case Method and PjBL achieved significantly higher learning outcomes than students in the control group.

DISCUSSION

Overall, the findings indicate that the electronic teaching materials integrating the Case Method and Project-Based Learning (PjBL) met the criteria for feasibility and practicality and yielded positive results when implemented in the Selected Topics in Chemistry course. These findings should be understood not merely in terms of the product's electronic format, but more importantly in relation to its pedagogical design, which organizes learning content, cases, project activities, multimedia resources, and assessments within an integrated learning sequence. Unlike the teaching materials analyzed during the initial stage, the developed product also integrates program learning outcomes (CPL) and course learning outcomes (CPMK), concept maps, CBR, CJR, Mini Research, project assignments, idea engineering, and routine tasks. Thus, the product development extends beyond the mere digitization of learning materials toward the use of technology as an environment for organizing learning activities.

The feasibility of the product in terms of content, language, presentation, and graphics shows that the integration of these various components can be realized without neglecting the basic quality of teaching materials. These findings are in line with Handayani & Adisendjaja, (2021), Pratiwi et al., (2021), Saputri et al., (2021), serta Susilaningsih et al., (2019), who place expert validation as an important stage to ensure the feasibility of teaching materials before implementation. In this study, the validation results are important because the product not only contains chemical materials, but also integrates more complex learning activities. Therefore, product quality needs to be seen as an integration between content accuracy, readability, presentation organization, display, and design of learning activities.

The consistent practicality results at various stages of the trial subsequently show that the design can be accepted and used by students when the scale of implementation is expanded. One possible explanation is the structure of the teaching materials, which provides a relatively clear sequence of activities, beginning with encountering a problem, exploring relevant concepts, analyzing cases (Gronski, 2024; M. Liu & Mu, 2022), and progressing to project-based activities (Karampour et al., 2021). This finding is consistent with Taesotikul et al., (2023), who showed that case-based learning provides students with opportunities to engage in problem solving, as well as Leonard Jr. & Cook, (2010) dan Littleton et al., (2023), who emphasized the importance of group activities and discussion in case-based learning. Nevertheless, a high level of practicality does not, by itself, demonstrate learning effectiveness. In this study, the practicality data are more appropriately interpreted as evidence that the

teaching materials were acceptable to and usable by students, whereas their impact on learning was determined through learning outcome data.

In this study, the practicality data are more appropriately interpreted as evidence that the teaching materials were acceptable to and usable by students, whereas their impact on learning was determined through learning outcome data. The pedagogical characteristics of the developed teaching materials provide a context for understanding the implementation results. Team-based project learning and the Case Method engage students in exploration, problem solving, and the collaborative completion of tasks or cases (Cahyani et al., 2023; Donoso et al., 2025; Gronski, 2024). Krupat et al., (2016) demonstrated that case-based collaborative learning is an active learning approach that integrates case analysis with group discussion and decision making. In this study, these principles were implemented by organizing cases, concept exploration, problem analysis, and project activities within the electronic teaching materials. Thus, students were provided with opportunities to engage actively in the learning process rather than merely accessing learning materials electronically.

The developed teaching materials were also designed to support conceptual understanding through structured learning activities (Dahlan & Wibisono, 2017; Kumaran & Sankar, 2013; Thobejane et al., 2026), while providing collaborative activities that create opportunities for communication and teamwork during task completion (Shieh & Hsieh, 2021). However, communication, teamwork, and scientific reasoning are positioned as potential pedagogical outcomes of the designed activities rather than as empirical findings of this study, because these constructs were not measured independently.

Evidence from the learning outcomes indicates that students who used the electronic teaching materials based on the Case Method and PjBL achieved better outcomes than those in the control group. This finding is also consistent with the pattern of improvement in learning outcomes observed during the product trial stage. From a pedagogical perspective, these results may be explained by the connection between problem analysis and concept application embedded in the design of the teaching materials. Cases provide a context that requires students to identify problems and determine the relevant chemistry concepts (Donoso et al., 2025; Gronski, 2024), whereas project activities provide opportunities to apply this knowledge in completing tasks or developing products (Hakim et al., 2016; Kahl, 2015; Khambuo et al., 2024). Thus, the learning process is not solely oriented toward the acquisition of information but also encourages students to actively use their knowledge through the stages of case analysis, concept exploration, problem analysis, and the application of knowledge in project activities.

This explanation is consistent with Littleton et al., (2023) dan Taesotikul et al., (2023), who showed that case-based learning can support the application of knowledge and students' engagement in problem solving. In this study, this process was extended through PjBL, so that case analysis did not end with discussion or the identification of solutions but was followed by activities that required students to apply concepts through projects. Thus, the pedagogical value of the product does not primarily derive from the use of EXE-Learning as a technology, but rather from how the digital environment connects the analytical function of the Case Method with the applicative function of PjBL. This represents one of the main contributions of the developed teaching material design.

Students' positive responses and strong performance during the project activities provide supporting evidence for the implementation of the design. Students' responses may be associated with the contextual and activity-oriented characteristics of the learning process, as students interacted not only with conceptual content but also with cases and tasks that required their active involvement in learning. This interpretation is consistent with Alani et al., (2025), Gade & Chari, (2013), Ma et al., (2016), serta Yoo & Park, (2015, 2014), who showed that case-based learning provides students with opportunities to analyze problems, communicate ideas, and apply knowledge in complex situations.

Students' performance in the mini research and instructional video projects also provides a complementary perspective to the cognitive test results. These activities positioned students as active participants who were required to prepare, carry out, and produce project outputs, rather than merely as recipients of information. This is consistent wit Rajiah, (2018, 2024), Steenkamp & Brink, (2024), and Zhu, (2026), who showed that collaborative learning environments provide opportunities for interaction, discussion, and the sharing of responsibilities in completing activities. Studies by Baeten et al., (2013), Bennett, (2010), Nurita et al., (2025), and Robinson et al., (2019) also showed that the use of authentic cases can support motivation and the application of theoretical knowledge to complex problems.

These findings can be understood in the context of the characteristics of case- and project-based learning, which provide students with opportunities to actively engage in completing learning tasks. Previous studies have shown that case-based learning can enhance students' engagement in analyzing and applying knowledge to contextual problems (Alani et al., 2025; Gade & Chari, 2013; X. Ma et al., 2016; Yoo & Park, 2015b, 2014). Meanwhile, project-based activities provide students with opportunities to organize and carry out tasks leading to the production of a learning product.

Overall, the findings indicate that the contribution of the developed teaching materials lies not only in their technical feasibility or electronic format, but also in the systematic integration of case analysis and project activities within a single learning environment. These findings imply that the digitalization of chemistry teaching materials should go beyond simply transferring printed materials into an electronic format. Technology can be used to construct a pedagogical sequence that connects authentic problems, concept exploration, analysis, knowledge application, projects, and assessment. In the context of the Capita Selecta course, this design provides an alternative learning approach that connects conceptual understanding with application-oriented activities, while also providing evidence that the product can be used practically and can support students' learning outcomes.

CONCLUSION

This study developed electronic teaching materials based on the Case Method and Project-Based Learning (PjBL) for the Capita Selecta in Chemistry course, integrating learning content, cases, project activities, multimedia, and assessment within a single learning environment. The developed product met the validity criteria in terms of content, language, presentation, and graphics and demonstrated consistently high levels of practicality across the various trial stages. The use of the teaching materials also resulted in improved learning outcomes during the trial stages and significantly higher learning achievement in the experimental group than in the control group. In addition, students' satisfaction responses and performance during project activities provided supporting evidence regarding the acceptance and implementation of the product. These findings indicate that the main contribution of the developed teaching materials lies in the organization of the Case Method and PjBL within a coherent learning sequence that connects case analysis with concept application through project activities.

The findings should be considered in light of several limitations. The implementation was conducted within a single course context using a purposively selected sample, thereby limiting the generalizability of the results. Effectiveness was primarily evaluated based on cognitive learning outcomes, while other competencies that may potentially be facilitated by case- and project-based learning were not directly measured. In addition, this study did not provide evidence of instrument reliability. Future research should involve more diverse samples and contexts, employ instruments with established validity and reliability, and directly measure competencies such as problem solving, communication, collaboration, and scientific reasoning.

Longitudinal studies and more rigorous experimental designs are also needed to examine the consistency and sustainability of the effectiveness of the teaching materials.

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