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Development of E-Worksheet Based on Technological Pedagogical Content Integrated Discovery Learning to Improve Students' Critical Thinking Skills in Colloidal Materials

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Abstract. The main problem in this study is the low level of students' critical thinking skills (CTS) in chemistry learning caused by ineffective learning models that do not support CTS development. The importance of CTS has not been reflected in classroom practices. Therefore, this study aims to determine the validity, practicality, and effectiveness of a TPACK-integrated discovery learning-based E-worksheet in improving students' CTS on colloidal materials. This research uses the research and development (R&D) method with the ADDIE model, which includes five stages: analysis, design, development, implementation, and evaluation. The research subject CTS consisted of five validators and 33 students of class XII Science 1 at SMAN 1 Alalak. Data were collected using test and non-test instruments, and analyzed descriptively to determine the levels of validity, practicality, and effectiveness of the developed e-worksheet. The results show that: (1) the e-worksheet is highly valid based on content, presentation, language, and media aspect CTS; (2) it is very practical based on readability tests, student and teacher responses, and teacher ability and learning implementation observations; and (3) it is effective, as evidenced by the significant improvement of students' CTS categorized as high. In conclusion, the TPACK-integrated discovery learning-based e-worksheet is valid, practical, and effective as a teaching material in chemistry learning on colloidal materials to enhance students CTS.

Keywords: E-worksheet, CTS, discovery learning, TPACK, colloids.

Introduction

The education system emphasizes the importance of the role of teachers in preparing students to become superior and competitive graduates. One of the main competencies that need to be developed is CTS, which play a big role in supporting other skills such as creativity, problem-solving, cooperation, communication, social responsibility, and the use of media, information, and technology. CTS are the foundation that allows students to analyze, assess, and make decisions appropriately, so that they are prepared to face future challenges. Critical thinking is defined as a person's ability to control and account for his or her thought process, by trying to establish appropriate criteria and standards to assess and improve the quality of his or her thinking (Aufa et al., 2021). The ability to think critically plays a vital role in solving complex problems, as it involves in-depth understanding and analysis (Ananda et al., 2023). It helps students evaluate information objectively and form accurate conclusions. By engaging in critical thinking, students connect classroom knowledge with real-life contexts, enhancing both reasoning and conceptual understanding (Wardani et al., 2024)

Efforts to develop CTS in students have not been fully in line with the conditions that occur in the field. This low CTS is also strengthened by the findings of various research results, one of which is by (Wahyudiati, 2022) which reveals that chemistry is often referred to as the most difficult subject at all levels of education. This can be seen from the many misconceptions, difficulties in doing assignments, and lack of problem-solving skills that reduce students' cognitive achievements, CTS , and scientific attitudes.

The low CTS can also be seen from the results of observations and interviews at one of the high schools in Barito Kuala. The teacher stated that chemistry is still considered difficult by students as evidenced by low learning outcomes. Students can understand theories without being able to relate them to real life. The researcher also distributed a pre-research questionnaire to 10 students. The results of the questionnaire show the need for a learning model based on scientific activities. The learning model applied in schools has not been able to facilitate students to practice CTS. This is in line with the opinion (Khoirunnisa & Sabekti, 2020) that the choice of learning models greatly affects CTS the quality of students' critical thinking.

Efforts are made to overcome these problems by preparing a learning model that is in accordance with the situation and characteristics of students. One of the models that is considered effective for this purpose is discovery learning*.* This model is able to activate critical, logical, and analytical thinking skills through the process of searching and discovering information. This model encourages students to find their own concepts based on observation or experimental data (Prasetyo & Abduh, 2021).

Chemistry learning will look more interesting if it is collaborated with technology. Technology enables the presentation of interactive content, provides quick feedback, and monitors and stores student learning outcomes (Ningtyas & Rahayu, 2022). For this reason, teachers need to master TPACK, namely a knowledge framework that supports the effective integration of technology in learning (Zhang & Tang, 2021)(Ayuni et al., 2020). Integrating TPACK in chemistry education is essential due to the abstract and complex nature of chemical concepts, which require both effective pedagogy and technological support to enhance student understanding.(Rifa et al., 2025) TPACK combines pedagogical and technological knowledge, enabling teachers to deliver more effective and efficient instruction (Raihanah et al., 2024) One form of TPACK implementation in learning is through e-worksheet teaching materials, which are digital worksheets that utilize ICT. Unlike printed worksheet, e-worksheet is presented in electronic format and can be accessed through devices such as smartphones, making it more practical and attractive for students (Pratama et al., 2021).

E-worksheets are interactive digital learning tools designed with structured content, incorporating navigation, visuals, animations, and videos that students can access and complete online. Their electronic format allows for greater accessibility, flexibility, and interactivity, enabling students to learn anytime and revisit materials as needed (Niswah & Dewi, 2024). E-worksheet is seen as a teaching material that utilizes ICT development from printed student worksheets (Pratama et al., 2021). E-worksheet is a learning media that is systematically designed in electronic format, including animations, images, videos, and navigation that make users more interactive. E-worksheet is considered to be able to increase students' interest in learning and learning. Based on the results of the study (Vadilla, 2022) who developed e-worksheet-based discovery learning carried out to 34 students, it was obtained that the teacher's response showed a high level of feasibility and practicality. Meanwhile, the response of the students reached very decent which indicates significant attraction. In addition, the results of the research by (Prastica, 2023) also shows that the feasibility of TPACK-based chemical e-worksheet development product CTS in chemical materials is in the category of being very valid and feasible to be tested, and the results of students' responses get a very feasible category. When students show interest in learning, the achievement of learning goals will be easier to achieve through an effective communication process between teachers and students (Kurniawan et al., 2024).

Development of e-worksheet with a model discovery learning It is very important to do so because it can improve students' CTS that are still lacking. E-worksheet with this approach can also attract students' interest in learning. Through e-worksheet-based discovery learning, teachers can more easily direct learners to discover concepts through experiments or investigations (Costadena & Suniasih, 2022). If integrated with TPACK, learning will be more meaningful because TPACK emphasizes the relationship between content (learning materials), technology, and pedagogics. The interaction between these three components has the potential to create active learning that focuses on learners (Triwahyudi, 2021). Accordingly, the purpose of this reasearch is to describe the development of a discovery learning-based e-worksheet integrated with the TPACK framework to improve students CTS and increase their engagement in the learning process.

Methods

This study uses the research and development (R&D). This method aims to produce a specific product while testing the effectiveness of the product (Fikri et al., 2019). Development research is focused on the process of designing and producing product CTS that will be tested in terms of validity, practicality, and effectiveness. In general, the procedure in development research has two main objectives, namely: (1) to develop a product, and (2) to test the extent to which the product is effective in achieving the expected goals.

The research model used in the development of e-worksheet is the ADDIE model, one of the models commonly used in learning media development research to design and produce new product CTS. The ADDIE model is a systematic procedure that aims to compile or improve a product to be more effective and in accordance with learning needs (Maulana & Junianto, 2022).

The following are the stages of the ADDIE model according to (Hamidah et al., 2023) presented in Figure 1.

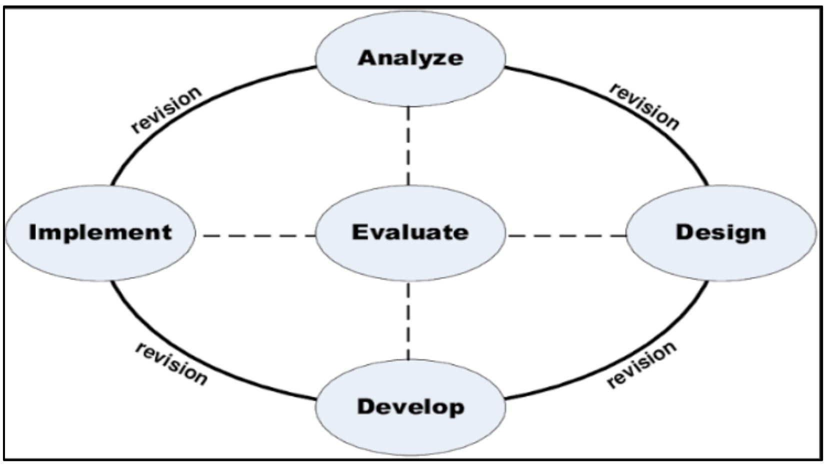

Figure 1. Model ADDIE

The five phases or stages in the ADDIE model are carried out systematically and systemically. The following are the five phases of the ADDIE model that will be carried out in this study presented in the form of Figure 2.

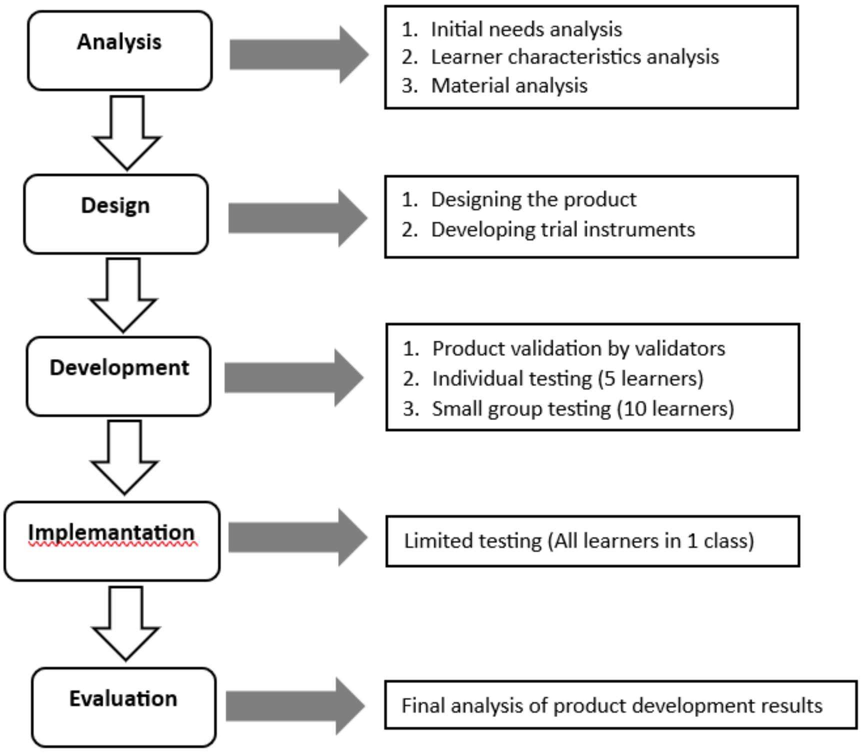

Figure 2. ADDIE development chart

This research involved two main subject CTS, namely: 1) Five validators consisting of four lecturers and one high school chemistry teacher, who provided an assessment of e-worksheet product CTS and other research instruments; 2) Students of class XII Science 1 SMAN 1 Alalak, who act as e-worksheet users, as well as provide assessments related to the use and operation of the e-worksheet developed.

In this study, the validity, practicality, and effectiveness of e-worksheet were evaluated using a combination of data collection techniques in the form of test and non-test instruments. The data obtained was analyzed descriptively to obtain a comprehensive picture. The validation results obtained can be adjusted to the assessment criteria shown in Table 1.

Table 1. Validity criteria

Percentage Interval	Validation description	Information
$85 < \rho \leq 100$	Very valid	Can be used without revision
$70 < \rho \leq 85$	Valid	Can be used with a little revision
$51 < \rho \leq 70$	Invalid	Can be used with multiple revisions
$\rho \leq 50$	Invalid	Unusable and in need of revision

(Source: Selaturrohmi & Haikal, 2024)

The analysis of practicality data was calculated based on research data obtained through readability questionnaires, student response questionnaires and teacher response questionnaires as well as observation sheets on teachers' ability to use e-worksheet and learning implementation. The criteria for assessing practicality can be seen in Table 2.

Table 2. Practicality analysis assessment criteria

Percentage Interval	Validation description	Information
$81 < x \leq 100$	Very practical	Can be used without revision
$61 < x \leq 80$	Practical	Can be used with a little revision
$41 < x \leq 60$	Quite practical	Not recommended for use
$21 < x \leq 40$	Impractical	Unusable
$x \leq 20$	Very impractical	Completely unusable

(Wahyudi, Muhammad Taufik, 2024)

The analysis of the effectiveness of e-worksheet was carried out based on data on the level of CTS of students through test instruments. The effectiveness test is carried out through pre-test and post-test with questions adjusted to the indicators to be achieved. The percentage obtained from the calculation above is then categorized into Table 3, namely the CTS assessment category.

Table 3. CTS criteria

Critical thinking ability scale value	Category
$p > 80$	Excellent
$60 < p \leq 80$	Good
$40 < p \leq 60$	Enough
$20 < p \leq 40$	Less
$p \leq 20$	Very Less

(Source: Widoyoko, 2018).

The data from the pre-test and post-test results were then analyzed to compare the ability of students before and after the use of e-worksheet. In addition, further analysis was conducted to measure the improvement of CTS. The analysis used was the Gain normality test, which aims to determine the level of effectiveness of the e-worksheet that has been developed. The formula used to calculate the normality of gain refers to Meltzer.

$$\mathrm{N-Gain} = \frac{S_f - S_i}{I_s - S_i} \qquad (1)$$

Information:
N-gain = the value of the normality of the gain test
The = score Pre-test
Sf = score post-test
Is = maximum score

After obtaining the normalized N-gain value, the average normalized N-gain is calculated, then interpreted based on the category in Table 4.

Table 4. N-gain category

N-gain	Category
(g) < 0.3	Low
0.3 < (g) < 0.7	Keep
(g) > 0.7	Tall

(Source: Ramdhani et al., 2020)

In addition, the value of N-gain can be interpreted into the category of effectiveness level according to(Nawir et al., 2019*)*, as shown in the following Table 5.

Table 5. N-gain effectiveness interpretation criteria

N-gain value	Category
> 76	Effective
56 – 75	Quite Effective
40 – 55	Less Effective
< 40	Ineffective

Results and Discussion

This development research uses the ADDIE model which consists of five stages, namely analysis, design, development, implementation, and evaluation. Each stage produces several research outputs, including colloidal e-worksheet product CTS, data from the validity, practicality, and effectiveness test results of the e-worksheet.

Analysis

This stage of analysis is the basis for another stage because at this stage the researcher collect CTS information that can be used as material to make product CTS that include facts CTS and a series of needs in learning chemistry at SMAN 1 Alalak. The analysis stage consists of initial needs analysis, student analysis, and material analysis. Based on the results of the initial needs analysis, it shows that the learning that takes place is not interactive or only takes place in one direction. Some students are less critical and the learning resources used are still using package books.

The results of the pre-research questionnaire that had been distributed to as many as 33 students in the student analysis were obtained that 100% of students had smartphones, 70% of students did not like the methods and teaching materials used, and 90% of students needed teaching materials that contained scientific activities. Based on the results of observations, it was found that during the learning process, students were not sufficiently encouraged to develop their thinking skills. Learning focuses more on memorization and absorption of information alone, so that students tend to understand the material theoretically but are still weak in terms of applying concepts in real life.

Viewed in terms of material, almost all chemical materials are abstract including colloidal materials. If explained by the method of teaching lectures alone, then students are not able to achieve the learning goals to understand the material and its role in real-life problems. Therefore, an e-worksheet is needed that can facilitate the activeness of students to be able to develop their CTS.

Based on the results of the initial needs analysis, student analysis, and material analysis, it can be concluded that students feel that they do not understand the concepts in chemistry learning because the teaching methods and materials used have not varied, so students need a learning model that contains scientific activities and teaching materials using smartphones that can be accessed anytime and anywhere. Based on this fact, an e-worksheet based on discovery learning that is integrated with TPACK is needed so that learning is not only a process of knowledge transfer, but also can enrich knowledge by following the development of science and technology so that it is able to create CTS in students. Technology is an important factor in learning activities because it can make lessons easier to understand, fun, and interesting for students.

Design

The next stage is the design of e-worksheet, which includes the preparation of teaching materials, learning tools, and research instruments to support the process of collecting and analyzing quantitative data. The result of this stage is a colloid e-worksheet that displays texts, images, learning videos, learning activities such as practice questions, and practicums, which are published in web form with easily accessible links (Hamidah et al., 2023). Colloidal e-worksheet is prepared with additional explanations and general structure of teaching materials, including: cover, foreword, table of contents, syntax discovery learning, the implementation of TPACK, concept maps, two-part learning materials and activities, practice questions, glossaries, and bibliographies.

Development

After the design stage, the next stage is development. At the development stage, the following are: (1) assessments conducted by material, media, and language experts to assess development product CTS or so-called validators; (2) the e-worksheet readability test was carried out by distributing questionnaires to students in individual trials and small group trials. Assessments by validators are carried out to obtain validity data, while readability tests are used to obtain practicality data. The readability test is carried out to determine the level of ease of reading and using the product. Students are also asked to give suggestions and comments on this e-worksheet as a reference for revision of improvements. The e-worksheet that has been developed is validated by the validator team with the aim of testing validity and feasibility before proceeding to the next stage, namely the implementation stage. The validator team consisted of 4 lecturers and 1 chemistry teacher. The validation questionnaire included 26 questions that assessed the feasibility aspect CTS of content, presentation, language, and media. The results of the e-worksheet validity test developed are presented in Table 6.

Table 6. Results of the e-worksheet validity test

Aspect CTS	Validator					Average	%
	I	II	III	IV	V		
Contents	31	31	30	31	31	30.80	96.25
Serving	20	20	18	19	20	19.40	97.00
Language	24	24	23	23	24	23.60	98.33
Media	28	28	28	26	28	27.60	98.57
Sum	103	103	99	99	103	101.4	97.50
%	99.04	99.04	95.19	95.19	99.04	97.50	Highly Valid

The average validity score of the e-worksheet developed reached 97.50%, which shows that this e-worksheet as a whole is included in the 'Very valid' category. E-worksheet is a student worksheet that is made electronically and can be used to support learning. Basically, e-worksheet is the same as worksheet, only in the form of electronic files that can be accessed through smartphones, laptops, or computers, not in the form of printed documents (Andriana et al., 2022). (Prasetyo & Abduh, 2021), in the application of the model discovery learning consists of six main steps presented in Table 7.

Table 7. Discovery learning model steps

No	Phase	Activities
1	Stimulation	Teachers start the learning process by asking questions, encouraging students to read learning resources, or doing other activities that can motivate students to think and prepare themselves to solve problems.
2	Problem Statement	Students are given the opportunity to identify various problems that are relevant to the learning material, then

No	Phase	Activities
		choose one of the problems and formulate a hypothesis as a temporary answer to the problem.
3	Data Collection	Students gather as much relevant information and data as possible to test the correctness of the hypothesis that has been formulated.
4	Data Processing	The data or information that has been collected is processed and analyzed by students, either through discussions, observations, or other methods, to obtain the meaning or conclusion of the data.
5	Verification	Students check carefully to ensure the correctness of the hypothesis based on the results of the analysis and data processing that has been carried out.
6	Generalization	Draw conclusions in the form of general principles that can be applied to various situations or similar problems, based on the results of the verification that has been carried out.

Each step in this model encourages students to actively observe, identify problems, analyze information, and draw conclusions, so as to directly train CTS in understanding the concepts learned. According to (Ennis, 2011) The indicators for each critical thinking skill criteria are outlined in Table 8.

Table 8. CTS Indicators

	Criteria for Critical Thinking	Indicator
F	Focus	(1) Students are able to identify problems well as a basis for the critical thinking process.
R	Reason(Alasan)	(2) Students are able to provide the right reasons and are supported by relevant faCTS or evidence in every step of decision-making and drawing conclusions.
I	Inference	(3) Students can draw conclusions precisely based on data.
		(4) Students choose the right reason (R) to support the conclusion made.
S	Location (Situasi)	(5) Students are able to compare the results of the conclusions obtained with the actual real situation or conditions.
C	Clarity	(6) Students use clear terms and explanations in their arguments, avoiding errors in drawing conclusions.
O	Overview	(7) Students conduct a thorough examination and review of the thought process that has been carried out, starting from the stage of problem identification to the preparation of final conclusions.

This critical thinking skill is more optimal when applying discovery learning combined with TPACK integration. Through TPACK integration, teachers not only master content and pedagogy, but are also able to utilize technology appropriately, so that the learning process becomes more interactive, interesting, and relevant to the needs of students. (Irmita & Atun, 2018) argues that TPACK is an approach based on the principle that learning is the foundation for developing knowledge, understanding the process of scientific investigation, and applying effective science teaching methods. Therefore, the implementation of e-worksheet is based on discovery learning which is integrated with TPACK is believed to be able to build a learning atmosphere that motivates students to think critically, learn independently, and hone their problem-solving skills with the support of technology.

After validation, the next step is a readability test which is carried out through an individual readability test (5 people) and a small group readability test (as many as 10 people). The results of the readability test assessment on individual tests can be seen in Table 9.

Table 9. Results of individual test assessments based on aspect CTS

Aspect CTS	Rating (%)	Category
Serving	82.50	Very Practical
Language	77.50	Practical
Material	78.23	Practical
Average	80.00	Practical

Based on Table 9, the average score of the individual readability test is 80.00% with the category "Practical". The results of the small group trial are shown in Table 10.

Table 10. Results of small group trials based on aspect CTS

Aspect CTS	Rating (%)	Category
Serving	83.13	Very Practical
Language	86.25	Very Practical
Material	82.50	Very Practical
Average	83.61	Very Practical

Based on Table 10, the average score of the results of the small group trial showed a figure of 83.61% in the category of "Very Practical". Readability tests are indispensable because they are effective in predicting the level of difficulty in a text in a quick and simple way (Handayani et al., 2021). This colloidal e-worksheet is very useful for students in understanding the material because in addition to text, it is also equipped with real images, animations, audio, and video links on its display which can increase students' interest in learning (Andriana et al., 2022).

Implementation

The next stage after the development process is the implementation stage, which is to use colloidal e-worksheet in chemistry learning activities that can be accessed directly by students and teachers. The implementation stage consists of a limited group readability test, student response test, teacher response test, learning implementation test, and teacher ability test using e-worksheet. The limited group readability test, just like the individual and small group readability test, is to find out the extent to which the e-worksheet is easy to understand and use by students. The student response test is useful to find out students' responses or perceptions of the appearance, content, and ease of use of e-worksheet. The teacher response test was carried out to find out the teacher's opinion regarding the practicality, suitability of content, and ease of implementation of e-worksheet in learning. The learning feasibility test is to see the extent to which learning can run according to the design that has been made using e-worksheet based on observer assessments. Meanwhile, the teacher's ability test uses e-worksheet, which is to measure the extent to which teachers can operate and utilize E-worksheet as a learning medium based on observer assessment. The assessment of the practicality of the e-worksheet was developed using an instrument in the form of a questionnaire. All tests at this implementation stage aim to obtain data that illustrates the level of practicality of e-worksheet in the learning process before it is used more widely. Based on the explanation of the practicality component above, the recapitulation of the practicality of e-worksheet as a whole is presented in Table 11.

Table 11. Recapitulation of the results of the practicality test

Component	Rating (%)	Information
E-worksheet Readability	81.81	Very Practical
Student Responses	87.88	Very Practical
Teacher's Response	95.00	Very Practical
Implementation of Learning	93.23	Very Practical
Teachers' Ability to Use E-worksheet	93.06	Very Practical
Average	90.20	Very Practical

Based on Table 11, it shows that all components of the practicality assessment are in the "Very Practical" category with an average of 90.20%. The practicality test is one of the criteria in assessing research instruments. E-worksheet is considered to have a high level of practicality if it is easy to use and useful and e-worksheet is declared practical if observers, teachers, and students agree that the e-worksheet is suitable for use in the field and the level of implementation is included in the good category. The practicality test aims to find out the views and assessments of observers, teachers, and students regarding the implementation and usefulness of e-worksheet in learning (Siahaan et al., 2022).

The next test after the practicality test is the effectiveness test. The effectiveness test was conducted to analyze the extent to which colloidal e-worksheet is effective in improving CTS through implementation in the field. The e-worksheet that is being tested is an e-worksheet that has been declared valid and practical (Putra et al., 2023). Testing the effectiveness of e-worksheet using one-group pretest-posttest. The research instrument was in the form of a CTS test in the form of 6 essay questions. This instrument is compiled based on indicators of critical thinking skills, namely focus, reason, inference, situasion, clarity, and overview. This test was attended by as many as 33 students of class XII Science 1 SMAN 1 Alalak. The obtained values were then analyzed using the test N-gain. Test N-gain It was carried out to find out whether or not there was a difference in students' test scores between the pretest and posttest. Test results N-gain for CTS are presented in Table 12.

Table 12. N-gain results

Test	Average	*N-gain*	Category
Pre-test	27.05	0.82	Tall
post-test	87.05		

Based on the results in Table 13, it is known that the average Pretest score is 27.05 and the average Posttest score is 87.05. Value N-gain of 0.82 with the category included in the high category. Thus, it can be concluded that e-worksheet is based on dicsovery learning on colloid materials that are developed and effective in improving CTS with increased grades in the high category.

During the pre-test, all students received a score with an average of 27.05. Low CTS' are caused by unsystematic student answer factors, misidentifying questions, misconceptions, and a tendency to rely on memorization rather than comprehension. According to (Iriani et al., 2024), the basic thinking skill of a high-level thinking skill is analytical ability (C4). Because of their low analytical skills, learners need to learn things that can help them become more proficient in this area, including the problem-based learning paradigm. The learning process is also a factor in this low CTS. These factors include the use of a dominant learning model of lectures, questions that are less familiar to students, problem-solving strategies that do not make students understand, and the teacher's limited understanding of material that is only sourced from textbooks.

The results of the post-test conducted after treatment showed a significant increase in CTS in all students, with an average of 87.05 in the high category. This increase is due to the treatment carried out in the study, namely the use of e-worksheet-based diecovery learning integrated TPACK which trains students to be able to improve their CTS in the learning process. E-worksheet-based discovery learning TPACK integrated encourages students to be more active in discovering concepts through exploration activities, analyzing problems, and connecting them with technology and real-life contexts. The process allows students not only to passively receive information, but also to be trained to think critically, solve problems, and draw conclusions independently so that their CTS improve significantly. This is in line with research (Wardani & Jatmiko, 2021) which shows that TPACK-based teaching materials can optimize learning and improve students' CTS. (Adenolira, N. B., & Amir, 2023) It also revealed that students tend to be more enthusiastic and enjoy learning if the teaching materials are packaged attractively through a combination of materials, images, videos, and supporting visual designs.

Type discovery learning It is also able to have a good influence on oral communication, writing, and CTS. This is strengthened by the statement that if the results of the effectiveness test obtain a percentage of both small-scale and large-scale tests, it can be categorized as effective (Yulanda et al., 2023). The use of e-worksheet has also been proven to be able to increase students' focus and interest in the learning process. This interest plays an important role in achieving learning goals, especially through the creation of effective communication between teachers and students (Kurniawan et al., 2024). In addition, according to Ilmy et al. (2022), the implementation of e-worksheet can also encourage active involvement of students in understanding the material. This active engagement provides a hands-on learning experience, which ultimately contributes to the improvement of learners CTS.

Evaluation

The final stage of this research is evaluation, which was conducted continuously throughout all stages of development to ensure the quality of the e-worksheet. The evaluation analyzed data on validity, practicality, and effectiveness. Validation results from five experts showed an average score of 97.50% (very valid), indicating strong content and presentation quality (Andriana et al., 2022; Selaturrohmi & Haikal, 2024). The practicality score reached 90.20% (very practical) based on student and teacher responses, proving that the e-worksheet is easy to use and supports learning activities (Siahaan et al., 2022). The effectiveness test using pre-test and post-test data produced an N-gain of 0.82 (high category), showing a significant improvement in students' CTS (Putra et al., 2023; Yulanda et al., 2023). Overall, the evaluation results confirm that the TPACK-integrated discovery learning e-worksheet is valid, practical, and effective in improving students CTS (Wardani & Jatmiko, 2021).

Conclusion

Based on the results and discussion of this development research, it can be concluded that the e-worksheet, designed to improve students' CTS in colloid materials using a discovery learning approach integrated with TPACK, was declared very valid, as evidenced by the high scores in content, presentation, language, and media, achieving 97.50%. The e-worksheet was also considered very practical, based on the assessment of several components, including the readability questionnaire, student response questionnaire, teacher response questionnaire, observation of the teacher's ability to use the e-worksheet, and observation of learning implementation, with a total score of 90.20%.

Furthermore, this e-worksheet has been proven effective in enhancing students' CTS, as demonstrated by the improvement in CTA categorized as effective, with a score of 82%.

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