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ENHANCING CRITICAL THINKING SKILLS THROUGH STEM PROBLEM-BASED CONTEXTUAL LEARNING: AN INTEGRATED E-MODULE EDUCATION WEBSITE WITH VIRTUAL EXPERIMENTS

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Abstract. *One of the skills needed in the 21st century is critical thinking skills that need to be developed for secondary school students. Currently, upper-secondary students' critical thinking skills are still low. To overcome the problem, website-based E-module learning media was developed using a STEM approach with a Problem-Based Contextual Learning model with virtual experiments using PhET. The aim of developing this website-based E-Module media is to improve students' thinking skills on thermochemistry learning materials. The development model is 4-D. Data collection in this study was gained from three schools representing schools in the high, medium, and low categories in Surakarta, Indonesia. In this research,216 students were involved as the subjects at the development module implementation stage. The results of expert validation of the material, language, and media modules are suitable for use with a score of 90.03% categorized as very good. In the feasibility test, the score was 87.98% categorized as very good. The score for critical thinking skills was 79.18% in the critical category. N-Gain score was 0.70 categorized as high criteria. The result of the independent sample t-test sig 0.023, Critical thinking skills were conducted using E-Module. The results are higher than conventional media and effective in improving students' critical thinking skills.*

Keywords: *problem-based contextual learning, STEM, e-module, critical thinking*

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Introduction

Learning is an important foundation in developing individuals' potential and preparing them to face all challenges in the future. The advance of technology in this digital era can change the way we learn. Therefore, learning approaches need to continue to be adapted to take advantage of technology and expand access to global knowledge. So there needs to be an appropriate balance between the use of technology and developing students' skills in the 21st century. Learning in the 21st century is focused on activities that can train students' skills by directing a learning process. In realizing the learning process for students, teachers must make efforts such as providing guidance, encouragement, direction, and good stimuli in learning (Mardhiyah et al., 2021). The learning process must be active, productive, and meaningful for students, so educators need to be able to develop learning approaches. Besides, teachers should emphasize not only knowledge and the ability to understand the learning materials but also pay attention to affective and psychomotor skills (Sj et al., 2021). In 21st-century learning, more emphasis is placed on problem-solving, with critical thinking (CT) skills. In 21st-century learning, several skills need to be developed. One of the important skills is critical thinking skills (Atabaki et al., 2015; Ennis, 2011; Wilson, 2017). Moreover, by having 21st-century competencies, students can differentiate between true and false information obtained from the environment. This capability is a basic and important competency. CT skills are very relevant to the advancement of civilization as they are considered the crucial factors foundations of economy-based knowledge so they are not only relevant for individuals (Norman et al., 2017). In the world of education, CT skills have significantly improved students' skills and become an ideal way to direct and educate children's and adolescents' minds (Paul & Elder, 2014) and make it easier for students to connect effectively and solve complex problems (Basri et al., 2019). Currently, an important goal of the education

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system in Indonesia is the teaching and application of CT learning (Radulovi´c & Stanˇci´c, 2017; Shamboul, 2022; Tiruneh et al., 2017). Teachers, researchers, and policymakers around the world now consider that CT skills need to be developed for modern society because they are important and a top priority in self-government societies (Ahern et al., 2019; Dumitru et al., 2021). The importance of CT skills is to help students achieve better results in solving problems faced in life (Hitchcock, 2021), help students have the ability to adapt to circumstances and to be intelligent (Halpern & Diane., 2021), have a good academic achievement (Ren et al., 2020). Apart from that, the principles of transformative learning are also in line with 21st-century learning, where students are expected to have CT skills and be able to collaborate and solve problems. Accordingly, the role of teachers is very much needed in this activity (Rahmawati, 2018). Apart from that, students also need to have CT skills to solve complex problems because these skills are needed when entering the world of work (Anderson et al., 2020). Currently, Indonesian students have low CT skills. This can be seen from the results of Trends in International Mathematics and Science Study in 2018 showing that Indonesian students' science scores are ranked 45th out of 50 countries (Utomo, 2018). Besides, the PISA Assessment for the last 18 years shows that Indonesia is ranked in the bottom 10, far behind many other countries since Indonesia's first participation in 2000 (Hewi & Shaleh, 2020). This shows that students' CT skills are categorized as very low. In line with research conducted by Irfana et al., (2022) at SMA N 8 Mandau showing that students have low critical thinking skills with an average score of 61.2 in chemistry. Apart from that, research conducted by Affandy (2019) found that the CT skills of students at SMA Batik 2 Surakarta are still relatively low in all indicators. From these problems, efforts are needed to improve students' CT skills. To improve critical thinking skills, an effective learning model where problem-based learning can improve critical thinking skills is needed (Park & Choi, 2015).

To improve students' thinking skills, as facilitators, teachers must choose an effective learning model because an effective learning model can create a complete, interactive, and creative learning atmosphere that can make it easier for students to master the learning materials. During the learning process, students can think more critically in responding to problems, social skills, and learning outcomes to be optimal. Therefore, the right learning process must be used so that the learning process can be successful. To overcome this problem, an appropriate learning model is needed. Problem-based learning can improve students' learning attitudes, critical thinking in decision-making, and assessment of subfield problem-solving skills (Park & Choi, 2015; Saepuloh et al., 2021). Apart from that, teachers and students can use learning media as their communication tools in the learning process. Teachers use the learning media as a technical intermediary and become a method in the learning process so that learning activities take place effectively in the classroom (Kuswanto & Radiansah, 2018). The choice of media used for learning is adjusted to the situation, conditions, and characteristics of the learning materials (Abidin, 2017). Students are considered to still have difficulty understanding chemistry learning materials. This is reinforced by around 59.7% stating difficulties in studying chemistry. One material that is considered difficult is thermochemistry. Thermochemical learning materials are abstract and difficult to understand, especially those related to concepts such as environmental systems and materials (Siagian & Yasthophi, 2021).

The development of the use of learning media in the field of education is very rapid. One of which is the use of learning media modules which have developed into electronic ones called E-Modules. According to Elvarita et al., (2020), the e-module developed includes methods, media, and assessments given to students carried out periodically and systematically to achieve the competency learning objectives that students must have with their respective levels of difficulty. Virtual experimental methods need to be supported by the use of appropriate media. Physics and Education Technology (PhET) contains visualizations of real laboratory components that can be explored in real-time, concretely, and without risk of injury (Dina, 2020). Another advantage of the module is that students can study it individually. To make it easier to access the module, it is displayed on the Google site. The advantage of using Google Sites is that it is integrated with other Google applications, such as Google Forms, YouTube, and other Google applications (Nugroho, 2021). The module requires the right learning approach to function well. Approaches are the learning methods used by teachers in learning. These learning methods, strategies, and models not only help students understand the learning material but also help teachers provide learning services in a pleasant atmosphere (Masitah & Sitepu, 2021). According to (Hidayati et al., 2019) STEM increases mastery of technology when applied to make learning media (Yusuf & Ahmad, 2020). Learning and approaches using STEM can improve students' CT skills with N-Gain results in the medium category, namely 0.37 (Retnowati, et al., 2020), and in Davidi's (2021) research, the N-Gain results were 0.45. There are three important points in STEM education: (1) eliminating barriers between scientific disciplines, (2) being able to integrate between scientific disciplines, and (3) placing learning experiences relevant to real-world problems in everyday life. The STEM approach can develop science and technology, which are important goals in 21st-century learning (Smith et al., 2022). By learning to solve

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problems related to complex real-world problems, students have experience outside and inside school. Besides, the STEM education approach can provide relevant experiences and stimulate students' thinking (Murphy et al., 2019) so that students can build relationships of relevance between STEM disciplines and problems that exist in the real world (Smith et al., 2022). Implementing active learning is essential to most integrated STEM approaches and has been shown to improve student learning outcomes (Wilson, 2017).

The application of STEM in Asia not only focuses on expanding STEM-related subjects but also on students' interests in the 21st century including real-world problem-solving, systematic thinking skills, and higher education (Lee et al.,2020). In implementing STEM learning, it is necessary to use learning models and learning approaches (Suratno et al., 2020). Research conducted by Saraç (2018) shows that STEM education is effective in improving student learning outcomes, increasing students' motivation, attitudes, and academic learning achievements, and improving problem-solving skills. STEM research is increasingly important and has become an international research field so STEM-related research is needed globally (Li et al., 2020; Li, 2019). Contextual learning is the way teachers present their everyday life experiences in their classrooms. This aims to help students understand the learning material provided by the teacher in the learning process more easily (Aliyyah et al., 2020). The STEM approach is in line with PBL which focuses on everyday life problems that are appropriate to real-world contexts that build skills, knowledge, resources, and problem-solving practices (Savery, 2019). The four aspects of the STEM approach have a harmonious unity with the Problem-Based Learning (PBL) model because they are related to real problems so when combined they can improve CT skills (Selisne et al., 2019). This can be integrated because these two models and approaches start with problems (Syukri & Ernawati, 2020). In the implementation of PBL learning, PBL has several shortcomings including uncertainty about the right learning needs, the depth of knowledge to be achieved as well as selecting the right literature, the time required, and choosing the wrong learning needs because the teacher does not direct it well (Vanishree & Tegginamani, 2018). Therefore, the presentation of PBL learning can be overcome by integrating it with CTL because CTL learning can reduce the weaknesses of PBL, namely increasing students' ability to carry out student activities to carry out observation activities, ask questions, and propose hypotheses before carrying out investigative activities. The Contextual Teaching and Learning (CTL) approach can encourage students' critical thinking in which there is a syntax for observing problems, meaning identifying them and improving the analysis process of the problems presented but also encouraging their critical and high-level thinking (Nawas, 2018; Rahayu, 2017)"type":"article-journal","volume":"4"},"uris":["http://www.mendeley.com/documents/?uuid=7e3c8297-b84b-40ca-ac6c-cfbd9d355792"]},{"id":"ITEM-2","itemData":{"DOI":"10.1063/1.5016018","ISBN":"9780735416031","ISSN":"15517616","abstract":"Students need to be equipped with the 21st century skills/capabilities to ensure their competitiveness in the knowledge era. So, it is imperative that education at school should be changed in order to fulfill the need. However, there is not any specified approach on how to educate young students for the 21st century capabilities. Regardless the impediment for ts exist, we need to construct an innovative instruction that can develop the students' 21st century skills by incorporating the skills needed, based on contemporary theory of learning, necessary context of learning and appropriate assessment in a chemistry subject matter. This paper discuss the feasible skills to be promoted through chemistry course. Those skills/capabilities are scientific literacy, higher order thinking, communicationand collaboration and curiosity. The promoted are called the 21st century scientific literacy skills in which it emphasis on scientific literacy and embedded the other 21st century skills into the innovative chemistry instruction. The elements involve in the instruction such as inquiry and constructivist approach, nature of science, contemporary/socioscientific issues, critical thinking (higher order thinking. The CTL strategy is very important because CTL emphasizes critical thinking and can recognize teaching and learning needs. The CTL approach can motivate students to learn from each other and use an evaluation process (Hakim et al., 2023).

The integration of PBL and CTL is carried out by combining the syntax between Problem-Based Contextual Learning to be: 1) Problem-oriented; 2) Organizing students; 3) Making observations; 4) Proposing a hypothesis; 5) Carrying out investigations; 6) Development and presentation of results; 7) Analysis and evaluation. The integration between PBL and CTL (Problem-Based Contextual Learning) can improve students' critical thinking abilities (Husna et al., 2019). STEM-integrated education allows teachers to convey science, technology, engineering, and mathematics content and relate it to real situations (Sumarni & Kadarwati, 2020). A learning method known as the STEM approach blends science, technology, engineering, and math (Taşdemir, 2022) which can improve students' CT and problem-solving skills (Dogan & Kahraman, 2021) (Dogan & Kahraman, 2021) so that this approach can improve CT skills by integrating the PBL learning model and integrating CTL with STEM.

In this research, an E-module is developed which aims to overcome students' low CT skills. The developed E-Module can be accessed by students using a smartphone or laptop allowing them to learn independently and

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flexibly in terms of time and place. The developed E-Module contains several elements that are arranged based on the STEM-Problem-based contextual learning model and approach. In the arrangement, there are animations, videos, images, and interactive features such as virtual laboratories using PhET. Apart from that, the developed E-module not only has interactive content but also has problem-based challenges and exercises, formative evaluation, independent exploration, discussion, and collaboration, as well as assessment and reflection that can improve students' CT skills. Elements in the E-module that are very influential in increasing students' CT are presenting questions to solve problems. In the Problem-based contextual learning syntax, students are asked to solve problems related to their day-to-day life problems (Sugianto et al., 2013). The developed E-Module also provides students with the opportunity to hold discussions and collaborate with groups to solve problems using students' worksheets (LKPD) and carry out integrated formative assessments during the learning process (Aulia & Hardeli, 2022). The interactive content in the E-Module includes animations, videos, and simulations which are displayed attractively and can improve students' CT skills in using the E-Module (Kurniawan et al., 2018).

The results of field analysis during learning conducted on 144 students showed that 59.7% of students stated that chemistry was a difficult subject. Initial analysis of students also showed that 60% thought chemistry was abstract and, therefore, it is difficult to understand, 13% of students thought the teacher's learning material delivery was less interesting, and 10% of students said the learning media was lacking. The students' chemistry scores were 43% (fair), 30% (poor), 20% (good), and 2% (very good). Problems in learning chemistry experienced by students include abstract chemical material, difficulty in understanding formulas, uninteresting teachers' teaching strategies, abstract and complex learning materials, lack of learning media, and student visibility problems.

Based on the problems presented above, the researchers conducted research regarding the development of E-modules using the Google site. The E-Module was developed using a STEM approach with a PBL model integrated with Contextual Teaching Learning (Problem-Based Contextual Learning). The media developed is equipped with virtual experiments supported by the PHeT Colorado application included in Google Sites. This module was developed so that upper secondary students' CT skills in thermochemical materials increase.

The research questions were formulated as follows:

1. How to create a chemistry learning e-module based on STEM Problem-Based Contextual Learning supported by Google Sites and PhET Colorado applications?
2. What is the feasibility of a chemistry learning e-module based on STEM Problem-Based Contextual Learning to enhance students' capacity for critical thinking in chemistry learning material?
3. How is the effectiveness of STEM-Problem Based Contextual Learning based chemistry learning in improving students' critical thinking skills in thermochemical learning material?

Research Methodology

General Background

This research was developed using the research and development (R&D) method to create a product that was tested for efficacy after it was developed. The outcome of this research was website-based learning materials using a STEM-Problem-Based Contextual Learning methodology, which aims to incorporate STEM into the classroom and address students' deficiencies in critical thinking. The product development of this study makes use of Thiagarajan et al., (1974) 4D research model. The design of the web-based STEM E-Module platform is presented in Figure 1.

The first stage was to conduct a survey of 144 students using a questionnaire. Apart from that, a survey was also conducted on teachers using a questionnaire. The purpose of conducting a preliminary analysis is to find out the learning process that has been carried out by the teacher, to know the problems experienced, the desired module content requirements, the interest of teachers and students in STEM learning, and the availability of school facilities and infrastructure to implement electronic modules including Front-end Analysis, task analysis, learner analysis, concept analysis, and determining instructional goals.

The second stage is the process of designing website-based learning media. Currently, creating learning materials in the form of e-modules is the goal. The selection of e-module development is in accordance with the students' learning objectives, material, characteristics, and needs. Activities carried out included initial product design, planning learning objectives, compiling instruments (module validation, critical thinking, and learning implementation), and the stages of criterion-referenced test construction, media selection, format selection, and initial design.

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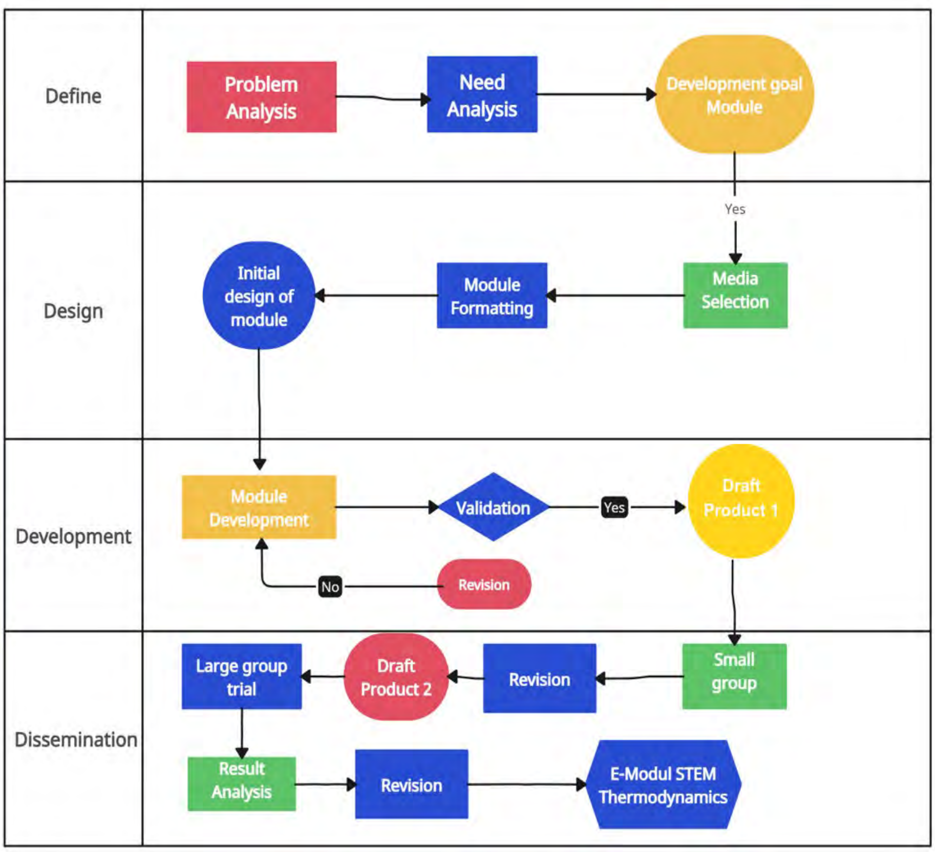
In the third stage, namely the development stage, validation was carried out by material experts, media experts, language experts, and practitioners (teachers). After all the media were valid, trials were carried out in small groups and large groups on all aspects developed including media aspects, linguistic aspects, material aspects, learning aspects and media use aspects.

The final aspect was to determine the effectiveness of the Web-based E-Module platform with the Problem-Based Contextual Learning approach. At this stage, an integrated comparison of experimental class and control class data was carried out. Pretest data and initial observations of critical thinking obtained in the design step were taken. The learning time for thermochemical material is three meetings. During the learning process, observations were made using critical thinking and the implementation of the learning by the observer. After learning was completed, a posttest was carried out. After that, an N-Gain analysis was carried out to see the increase in the results of initial and final observations of critical thinking to find out how effective the module was in enhancing students' capacity for critical thinking. In this research, the researchers reported research up to the media development stage with improvements made at each research stage.

Figure 1
Research Procedure



Participants

The research was conducted on class 11 thermochemical learning material at three schools in Solo, Central Java. The entire process was carried out during the 2023-2024 academic year. The web-based STEM-Problem Based Contextual Learning E-Module learning media development stage involved 30 students and the wide-scale testing required 108 students. The development was followed by a focus group discussion consisting of four lecturers and two teachers who are experts in the fields of media, language, content, and STEM. Assessment practitioners of 7 experimental class chemistry teachers were also used at the development stage of the STEM-Problem Based

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Contextual Learning E-Module learning media. The final stage involved 216 students who were divided into experimental classes and control classes. All students are first-semester 11th-grade students from 3 state schools in Surakarta, Central Java, Indonesia. Sample characteristics are presented in Table 1

Table 1
Characteristics and Distribution of the Sample

Variable		Control Class	Experimental Class
Range Age		16-17	16-17
Gender	Female	68	81
	Male	27	40
Total = 216		108	108

Instrument

The development of the web-based STEM - Problem-Based Contextual Learning Chemistry E-module was designed by conducting a preliminary survey on 144 students and 7 chemistry teachers. The survey with a questionnaire consisted of 6 aspects,16 indicators for students, 10 aspects for teachers, and 32 indicators regarding chemistry learning carried out by teachers.

Table 2
Research Instruments

Stage	Instrument	Subject	Time
Needs Analysis	Questionnaire	Student and Teachers	Before product development
Module Validation	Questionnaire	Experts, education practitioners, and peers	Before product try-out
Module Readability Level	Questionnaire	Students	After the learning process
Critical Thinking skills	Critical thinking questions on thermo-chemistry learning materials	Students	Before and after the learning process

There are ways students learn chemistry, student assessments of chemistry teaching-learning activities (PBM), student assessments of the materials/textbooks used by teachers, student assessments of LKPD, students' readiness to accept research products, teacher STEM questionnaire attitudes towards STEM education, STEM knowledge, the utilization of technology and science, engineering and science, science-mathematics, science-technology-engineering, and technology and science mathematics applications (Budiyono et al., 2020; Suratno et al., 2020). The module validation instrument used referred to Prastowo (2013) including media validation consisting of content quality aspects with 13 indicators and instructional quality with 8 indicators, material validation consisting of visual communication aspects with 5 indicators, and technical aspects with 4 indicators as well as language validation consisting of communicative aspects consisting of 2 items, and aspects of term accuracy consisting of 2 indicators. Then, in the application aspect of learning media, CT skills activities were carried out with five dimensions measured, including interpretation, analysis, evaluation, inference, and explanation. Observation sheet on implementation of STEM-Problem contextual learning with six learning steps consisting of problem orientation, organizing students, observation, hypothesis, investigation, and presentation of results and conclusions. The instruments used in data collection were validated by 6 teachers.

Integration E-Modul STEM -Problem-Based Contextual Learning based website

The website-based STEM-Problem Based Contextual Learning E-Module was applied to students in class XI in their first semester in the 2023-2024 academic year on thermochemistry learning materials. Thermochemical

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learning material taught included chemical reactions and enthalpy changes, types of enthalpy changes, calorimetry, and Hess's law. Learning activities included projects that students must work on. The time allocated for topics in the control and experimental classes can be seen in Table 2. Each learning activity was carried out over 1 week with an accumulation of 5 hours of lessons (1x45 minutes). Thermochemistry learning using the website-based STEM-Problem Based Contextual Learning E-Module was only taught in experimental classes. There was a discussion about how to integrate aspects of science, technology, engineering, and mathematics in chemistry learning. In presenting learning outcomes, students can present them in several forms, using PPTs, e-posters, and infographics).

Table 3

Division of Learning Time Between Experimental Classes (EC) and Control Classes (CC)

EC& CC	Topic 1 (Thermochemical reactions and enthalpy changes)	Topic 2 (Types of (enthalpy changes)	Topic 3 (Calorimetry)	Topic 4 (Hess's Law)
	Week 1	Week 2	Week 3	Week 4

EC: Experimental Class; CC: Control Class

Data Collection and Analysis

Requirements analysis data (Module Characteristics)

This stage was carried out to find out whether the module meets the characteristics that must be fulfilled as a learning medium. Descriptive analysis was carried out on the data resulting from the needs analysis. The E-module was designed according to development in accordance with the initial analysis, namely by developing a STEM-Problem--based Contextual Learning E-module, which was integrated with website-based Contextual Teaching Learning with Google Site and equipped with simulations using PhET.

E-Module development data (Module Feasibility)

The feasibility of the developed module was seen from the assessment carried out by expert validation, including language, media, and materials experts, in addition to the evaluation of chemistry instructors. Student assessments were carried out during small-scale trials and large-scale trials in terms of language, media, materials, usability, and learning. After the data was obtained, they were processed into scores which were categorized into five criteria according to Table 2. A module is said to be feasible if it is at least in the 'sufficient' category (Azwar, 2007).

Table 4

Categories of Module Feasibility Assessment Validation

Interval score	Criteria
$Mi + 1{,}5\ Sbi < X$	Very Good
$Mi + 0{,}5\ Sbi < X \leq Mi + 1{,}5\ Sbi$	Good
$Mi - 0{,}5\ Sbi < X \leq Mi + 0{,}5\ Sbi$	Medium
$Mi - 1{,}5\ Sbi < X \leq Mi - 0{,}5\ Sbi$	Low
$X \leq Mi - 1{,}5\ Sbi$	Very Low

Information :

X = Respondent's score
Mi = Ideal Mean
Sbi = Ideal standart deviation
Mi = ½ (ideal maximum score + ideal minimum score)
Sbi = 1⁄(6)(ideal maximum score - ideal minimum score)

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Feasibility was also obtained from observing the implementation of learning when the module was tested. The observation results were converted into percentages and then grouped into four categories of learning flow implementation according to Yamsari (2010) in Table 3

Score (Percent)= (Total Score)/(Maximum Score) x 100 %

Table 5
Learning Flow Implementation Criteria

No	Total Score Percentage	Implementation Criteria
1	86 – 100	Very well executed
2	71– 85	Done
3	51– 70	Less implemented
4	Less than 50	Not implemented

Field try-out data (Module Effectiveness)

Next, to find out whether the module created was successful in enhancing CT skills, posttests were utilized to evaluate the improvement of critical thinking abilities. The results of the post-test work analysis were analyzed using Normalized Gain (N-Gain). According to Hake (1999), learning is categorized into the effective category if the N-gain obtained meets the criteria:

Table 6
Category N-Gain Value

No	Interval Score	Criteria
1	< 0.7	High
2	0.7 > x > 0.3	Medium
3	< 0.3	Low

E-Module operational field test analysis

The data analyzed in the field test included critical thinking ability analysis data. The aim was to see the significance of the influence of learning using the website-based STEM Problem Based Contextual Learning E-Module, which is equipped with virtual simulations/experiments on thermochemical material. Paired sample t-test is the test that is employed if the data is normal and homogeneous. The effectiveness of the data was tested by calculating the increase in learning outcomes tested using HOTS questions with development based on measures of critical thinking abilities using the normalized gain technique.

The hypothesis of this research is:

H_o = Critical thinking skills of students who use E-Module media are the same as those classes that use conventional media

H_1 = The critical thinking skills of students who use E-Modul media are higher than students who use conventional media

In research, Ho is accepted if it has a significance value below .05 ($p < .05$).

Research Results

Define Stage

At the definition stage, data was obtained from a survey conducted on 144 students using a questionnaire. Apart from that, a survey was also carried out on 8 teachers using a questionnaire regarding learning carried out at school in Table 5. Data obtained in Table 6 were obtained.

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Table 7
The Respondents of Needs Analysis

Number of Respondent	Gender		Age
	Male	Female	
144	58	86	16-17

Table 8
Result of Student Questionnaire Needs Analysis

No	Statement	Percentage (%)
1.	Chemistry is a difficult subject	60
2.	Chemistry learning is abstract, so it is difficult to understand	60
3.	Teachers do not use student worksheets for chemistry learning	58
4.	Teachers do not use virtual laboratories/do online simulation practices in chemistry learning	60
5.	Teachers do not use E-Module in chemistry learning	42
6.	Using visualization media will increase your understanding of chemical materials	82

Based on the results of the initial analysis of students, the results were obtained on what models or learning strategies teachers usually used in chemistry subjects, depending on the findings of surveys, namely lectures, questions and answers, and discussions. According to students, an interesting strategy is based on the results of analysis using discussions, questions and answers, and games to increase interest in learning, direct explanations, and scaffolding by the teacher. Ownership of books/teaching materials depending on the findings of surveys is not required to have a book handle. From the questionnaire, 27% of students thought their textbooks were less interesting, and 1% of students thought their textbooks were less interesting. Regarding the ownership of student workbooks (LKS), 58% of students did not have LKS. Based on this analysis, it implied that students required easy and interesting learning media in learning chemistry. Visualization media was needed because students considered chemistry to be an abstract lesson, so they needed to use visualization simulations in chemistry learning. Learning using the lecture method made students less interested, and their abilities were not maximally honed. This can be seen from the grades obtained by students in learning chemistry. So, it is very important to develop E-Modules based on Problem-Based Contextual learning with a STEM approach to improve 21st-century skills, one of which is critical thinking.

Front-end Analysis

Based on the initial needs analysis carried out on 144 students, it can be concluded that students needed easy and interesting learning media in learning chemistry. In school learning, no adequate teaching materials are available for the learning process, and in practice, the media used by teachers in learning is still conventional. The media could not accommodate all students' learning styles. Based on the initial needs analysis, it can be concluded that students needed easy and interesting learning media in learning chemistry. Media visualization was needed because students considered chemistry to be an abstract lesson, so they needed to use visualization simulations in chemistry learning. Learning using the lecture method made students less interested, and their abilities were less honed. This can be seen from the grades obtained by students in learning chemistry. The ability that students must have in the 21st century is the ability to think critically. Where these abilities can be improved by developing learning media with the Problem-Based Contextual Learning model with a STEM approach which can improve students' CT skills in learning chemistry.

Learner Analysis

At this stage, student analysis was carried out through a student needs questionnaire. Students were considered to still have difficulty understanding chemistry material. This is supported by the analysis's findings of student

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needs revealing that around 59.7% expressed difficulties in learning chemistry. One material that was considered difficult was thermochemistry. This is in line with research conducted by Toshtemirovna (2023) stating that some students had significant difficulties in mastering chemistry. This can be overcome with technology so that it can increase the strength of chemical knowledge.

Task analysis

Currently, a review of the learning objectives and minimum criteria of mastery learning was carried out. The review was then translated into several indicators that students had to achieve. The results of the initial analysis showed that the learning objectives of students were still low, as evidenced by the grades obtained by students, which were still below the criteria. This was consistent with studies carried out by (Rahmi & Azra, 2023)83.69% of SMAN 13 Padang class XI MIPA students still need to achieve the minimum completeness criteria set. It indicates that students have learning difficulties. Learning difficulties are failures to attain learning goals characterized by low learning outcomes. This study aims to determine the percentage of students who experience learning difficulties for each indicator on thermochemistry material and determine the factors that cause learning difficulties experienced by students in terms of learning methods. This research is a type of descriptive research. The sample for this research was students in class XI MIPA 6 at SMAN 13 Padang in the 2022/2023 academic year, which consisted of 34 people. The research instrument was a diagnostic test with four-tier multiple-choice questionnaires and interviews. The data analysis used is descriptive, namely analyzing and providing an understanding of the data in the form of numbers so that an overview can be given in an orderly, concise, and transparent manner. The results of this study stated that students of SMAN 13 Padang had difficulty learning thermochemistry material in the high category. The highest difficulty level is found in the sixth indicator (determining the ΔH value of the reaction through a calorimeter experiment which was conducted at 2 state schools in Padang and found that chemistry learning outcomes of 83.69% were still below the minimum criteria of mastery learning for thermochemical learning material. Apart from that, according to studies carried out by Zakiyah et al., (2018)the influence of student's\nunderstanding of stoichiometry on their learning outcomes of thermochemistry, the effects of \nremidial teaching using problem solving method in stoichiometry and in thermochemistry on \nthe students understanding of thermochemistry, and the effectiveness of both remidial \nmethods on student's learning outcomes of thermochemistry. This research used descriptive \nand quasi experimental designs. The subjects were students of year XI of SMA Negeri 2 \nPamekasan of the academic year 2014/2015. Data collecting procedure was done by a test \nmethod and tests of hypothesis were done by t-test procedures (α of 0.05 and Sirhan (2007) chemistry was a difficult material, one of which was thermochemical learning material because in thermochemical material there were abstract concepts and required mastery of mathematics and a strong memory.

Concept Analysis

After carrying out the task analysis, a concept analysis was conducted. At this stage, a concept analysis, which was used to determine the learning concepts that students need to master regarding thermochemistry learning, was carried out.

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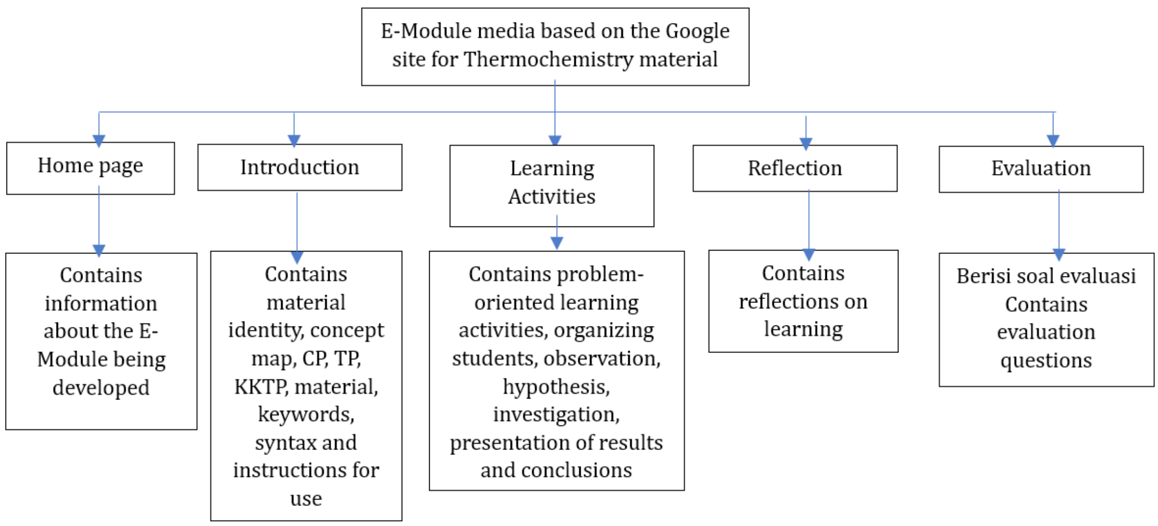
Figure 2
Arrangement of E-modules Developed



Specifying Instructional Objectives

At this stage, the learning competency objectives that students must achieve were determined. This research and development aimed to encourage, help, and facilitate students to comprehend thermochemical material correctly.

Table 9
Observation Results of Students' Initial Critical Thinking Skills

No	Representative Schools	Criteria of Critical Thinking Skills					Total Student
		Very Low	Low	Medium	High	Very High	
1	High Category	20	39	6	7	0	72
2	Medium category	34	20	12	6	0	72
3	Low Category	33	22	13	4	0	72

Table 10
Student Pretest Results

No	Representative School	Pretest Results Criteria					Total Student
		Very Low	Low	Medium	High	Very High	
1	High Category	16	34	17	5	0	72
2	Medium category	14	27	23	8	0	72
3	Low Category	21	34	14	3	0	72

The results of observations of students' important initial thinking abilities can be seen in Table 7. It is evident that the typical students from the three schools were in the uncritical category. Based on the pretest results in the three schools, it can be seen in Table 8 that the average of students in the High Category, Medium Category, and Low Category in Surakarta is not critical. This is consistent with studies implemented by Khoirunnisa & Sabekti

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(2020), which stated that the critical thinking skills of students in the city of Tanjungpinang on chemical material, namely chemical bond material, were very low. Apart from that, research conducted by Fernanda et al., (2019) on buffer solution material showed that students still experienced difficulty in making observations, making decisions, making inductions, identifying assumptions, and experiencing difficulty in finding credible learning sources, observing, and making decisions.

Design Stage

Constructing Criterion-Referenced Test

Designing instruments used for research was conducted in this stage. The E-Module product assessment instruments were in the form of student needs analysis questionnaires. Analysis was needed for teachers regarding STEM, pre-test and post-test critical thinking questions, module validation instruments, critical thinking skills activity instruments, and learning implementation observation instruments regarding Problem-Based Contextual Learning.

Media Selection

The advantage of the module was that students were able to study it individually. To make it easier to access the module, it was displayed on the Google site. The advantage of using Google Sites is that it is integrated with other Google applications, Google Forms, YouTube, and other Google applications (Nugroho, 2021).

Format Selection

The appearance and content design in developing E-Module learning media included several home menus, introductions, learning activities, reflection, and evaluation. Each menu in this application had its own function. More detailed contents of this research and development product can be seen in the following chart in Figure 2.

Initial Design

The design stage was the stage of designing and preparing the E-Module media that was created. The media menu page contained 5 menus consisting of the home menu, introduction, learning activities, reflection, and evaluation. The activity menu contained 4 main topics related to Thermochemistry and enthalpy changes, Types of enthalpy changes, Calorimetry, and Hess's Law.

Table 11
Electronic Module Design

No	Module Section	Explanation of Module Section
1	Home page	This section contains the title, UNS logo, module target subject, module compiler, and module compiler agency.
2	Material Identity	This section contains subjects, class/semester, main material, sub-main material, and time allocation.
3	Concept maps	This section contains an illustration of a chart that connects one concept to another concept in thermochemical material.
4	Learning Outcomes	Learning outcomes (CP) are competencies that students must be able to achieve in the learning process.
5	Learning objectives	Learning objectives are students' achievements in the competency aspect which includes knowledge, attitudes, and skills that students can acquire during learning activities.
6	KKTP	KKTP is a series of criteria or indicators that show the level of students' ability to achieve a certain competency in the learning objectives that have been set.
7	Material	This section contains scientific material regarding thermochemistry.
8	Keywords	Keywords are words or phrases that stand out in the title, header, subject, abstract, or text, as well as content notes.

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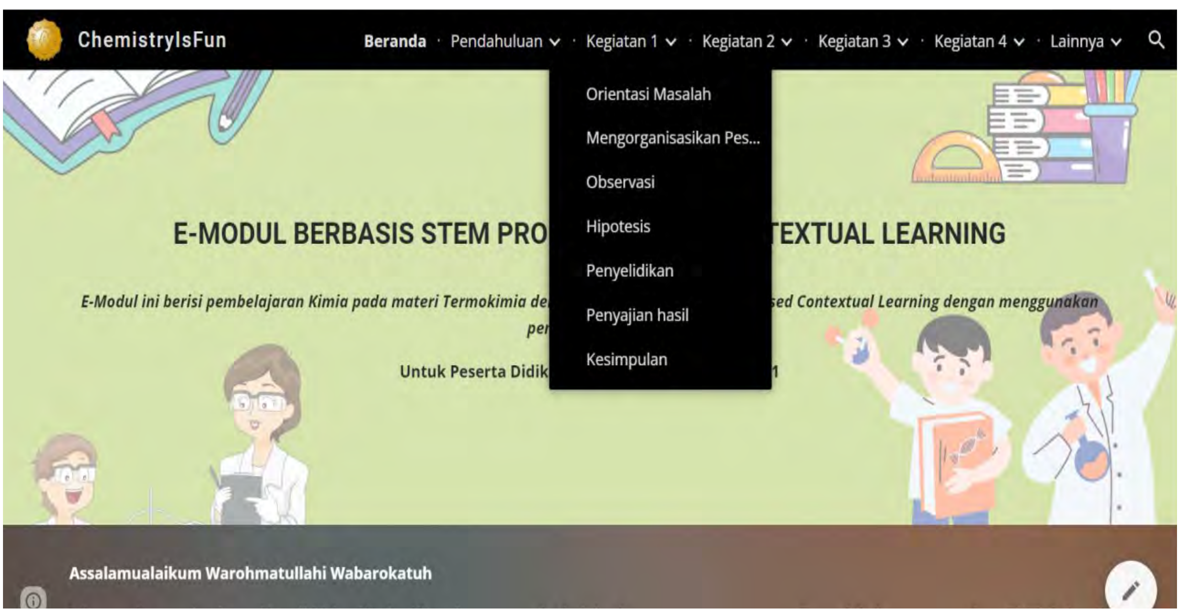
No	Module Section	Explanation of Module Section
9	Learning Syntax	This section contains an explanation of the learning flow according to the problem-based contextual learning syntax, which contains STEM components.
10	Problem Orientation Section	This section conveys learning objectives, explains the logistics required (convey problem orientation), and presents problems related to everyday life
11	Part of Organizing Students	Motivating students
12	Observation Section	This section forms groups and helps organize tasks in each group and presents problems related to everyday life
13	Hypothesis Section	This section guides students in creating hypotheses
14	Investigation Section	This section guides students in creating hypotheses
15	Results Presentation Section	This section guides students in collecting data or information, compiling data, and analyzing them.
16	Conclusion section	This section invites students to make presentations
17	Reflection	Together with the students, teachers draw conclusions and reflections.
18	Evaluation	This section contains 2 types of HOTS for each activity
19	Assessment Guidelines	This section contains HOTS questions
20	Glossary	This section contains scoring guidelines for learning activities

Figure 3
Main Menu Display E-Modul



Development Stage

The module's first step in the development process was to validate the product created with language experts, media experts, and learning material experts. This research used two media experts consisting of two lecturers, material experts consisting of two lecturers, and language experts consisting of two experts. Practitioner research was conducted by seven teachers representing state and private schools.

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Expert's Validation

Table 12
Result of Expert Validation

No	Expert's	Indicators	Score (%)	Criteria	Feasibility
1	Material	Suitability of content, accuracy of content, completeness of content, systematic presentation, student motivation	89.28	Very Good	Worth to use
2	Media	Neatness, accuracy, readability, navigation, and convenience	87.50	Very Good	Worth to use
3	Language	Communicative language and accuracy of sentence construction	93.33	Very Good	Worth to use

Table 10 results indicated that the E-module's validation by media, language, and content specialists revealed the material produced was good in terms of content and based on the problem-based contextual learning model, it was necessary to add additional learning objectives and learning outcomes. Media experts stated that the product was developed well, but a sub-menu on the homepage regarding learning outcomes and learning elements needed to be created. The words in the subtitles needed to be simpler, and the arrangement of images and videos in the activities needed to be rearranged. Linguists needed to make improvements regarding the writing of instructions for learning syntax so that it became more communicative for users. The module can be used in learning after improvements have been made. This is in line with research by Yulianto et al., (2009) which stated that for the learning media to be chosen appropriately, it is important to be mindful of objectivity, effectiveness, and efficiency in the use of learning media, where the objectives were formulated in the teaching materials to be delivered and make it simpler for learners. The input provided by experts was revised, and the product was then used for try-out.

Table 13
Feasibility of Chemistry E-Module

No	Aspects of Research Results	Average (%)	Category	Feasibility
1	Teacher's assessment	95.38	Very good	Worth to use
2	Small group try-out	84.91	Very good	Worth to use
3	Large group try-out	83.66	Very good	Worth to use

Based on Table 13, it can be seen that all aspects of the development of the STEM-Problem Based Contextual Learning E-module developed by researchers on thermochemical material had met the product development criteria.

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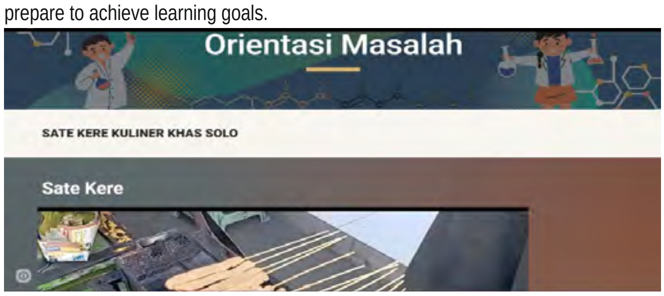
Table 14
The Result of Module Development

No	Module Section	Module Section Screnshoot and STEM Components on the Module
1	Problem Orientation	Science At the problem orientation stage, students can observe the phenomena presented by viewing the videos presented, the images provided, and reading the descriptions provided on the E-module page. Students use their critical thinking skills to process analysis results. Interpretation of existing phenomena to ensure students have an idea of what students must prepare to achieve learning goals. 
2	Organizing Students (-)	
3	Observation (Science)	Science Students observe the phenomena presented. The observation process is carried out based on problem discourse or after students see the display in the form of provided pictures, articles, or videos. Based on these observations, students are expected to be able to identify existing problems and formulate problems (ask questions) related to observations of the learning material carried out. 
4	Hypothesis (Science)	Science It is expected that students can analyze and estimate answers or temporary solutions to the problem formulations they have made and connect them with previous knowledge through observations. 

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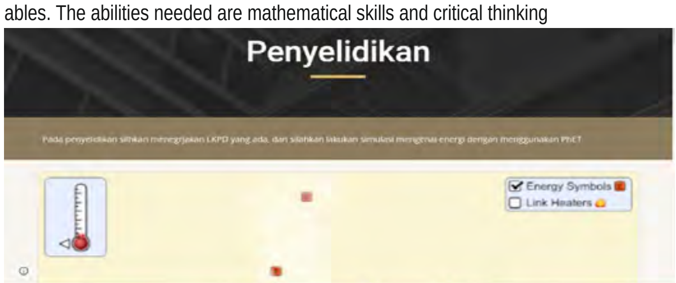
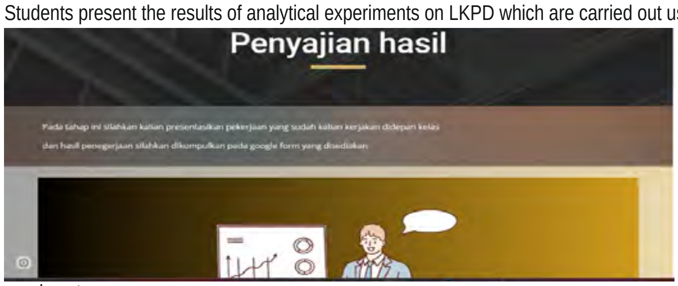
5	Investigation (Engineering, Science, Mathematics)	Science Students can collect information by doing practicums, studying literature, or opening websites on the internet. It is anticipated that students are ultimately able to find answers to the problems they have formulated and able to determine whether or not the hypothesis formulated is true. Students conduct experiments using procedures prepared using the PhET Colorado application Manipulation Students conduct analysis, design experiments, and develop procedures for conducting experiments. Mathematics Students carry out experimental analysis on thermochemical material which aims to obtain relationships between variables. The abilities needed are mathematical skills and critical thinking 
6	Presentation of results (Science)	Science Students present the results of analytical experiments on LKPD which are carried out using language and constructing  good sentences
7	Conclusion (-)	
8	Evaluation (Science, Mathematics)	Science Students can analyze the problems/questions presented and provide appropriate solutions or answers according to the understanding they gain during the learning process. Mathematics Students can solve the questions given by carrying out analysis coherently and correctly. 

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Disseminate Stage

a) Final criteria of critical thinking skills

Table 15.
Final Criteria for Critical Thinking Skill Level

No	Representative School	Critical Thinking Criteria					Total	Mean (%)	Criteria
		Very Critical	Critical	Medium	Low	Very Low			
1	High Category	38	30	4	0	0	72	79,73	Critical
2	Medium category	23	37	12	0	0	72	77,56	Critical
3	Low Category	42	28	2	0	0	72	80,19	Critical

b) Descriptive Statistical of Pre-Test and Post-Test Critical Thinking Skill

Table 16
Descriptive Statistical of Pre-Test and Post-Test for Critical Thinking Skills

No	Representative School	Group	Pre-test				Post-test			*N*-Gain
			N	Range	$\bar{X}$	*SD*	Range	$\bar{X}$	*SD*	
1	High Category	Experiment	36	64	44.556	14.619	22	85.222	5.329	0.70
		Control	36	58	46.416	15.329	24	76.805	5.721	
2	Medium category	Experiment	36	73	49.861	17.053	26	81.861	6.512	0.69
		Control	36	58	54.889	15.555	32	75.500	6.954	
3	Low Category	Experiment	36	60	46.138	13.983	32	75.333	6.811	0.67
		Control	36	60	45.694	12.363	36	72.555	10.728	

Table 16 shows a summary of the results of the descriptive statistical analysis which reveals that the post-test average of the CT skills of the students in the experimental class was greater than the control class's average. The standard deviation of CT skills in learning using the STEM Problem Based Contextual Learning E-Module was smaller than the standard deviation of the control class. Based on the findings of the research, implementing the E-Module STEM-Problem-based contextual learning media could enhance students' CT skills using an average of 79.16% in the three school categories from low, medium, and high categories in the critical category. Apart from that, it was also supported by the highest average N-Gain results in high-category schools, meaning that CT skills using E-Module media were higher when compared to students who made use of traditional media. The N-Gain score for students' CT skills was 0.69 based on the calculated data, including at a high level (Hake, 1999). This was consistent with a study by (Lestari et al., 2018), indicating that the application of E-Modules could provide meaningful learning experiences for students, so using the STEM approach and problem-based contextual learning could improve students' CT skills. The STEM approach can be applied to classroom learning in various forms of activities, including as models, teaching materials, or Student Worksheets (LKPD) (Cruz et al., 2021; English, 2017; Lestari et al., 2018). The PBL learning model can increase student activity during learning and improve students' critical thinking skills (Yulia & Salirawati, 2023)

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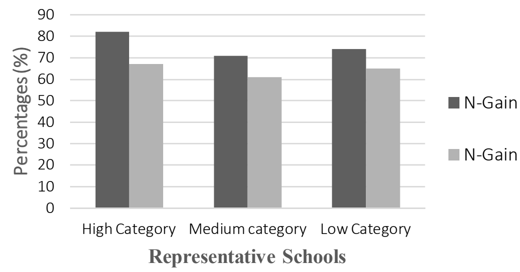
Figure 4
Pretest-Posttest N-Gain Value Criteria



The results of the pretest and post-test research were used to determine CT skills. It is evident that students in the experimental class had better CT skills than those in the control group. These results showed that integrating the E-Module based on the STEM-Problem Based Contextual Learning website can be achieved to improve students' CT skills in chemistry learning.

Table 17
Results of Critical Thinking Skills Analysis

No	Test	Test Type	Significance	Decision	Conclusion
1	Normality	Shapiro-Wilk	N-Gain Exp = .265 N-Gain Control= .103	*Ho* accepted	Normally Distributed Data
2	Homogeneity	Levene's Test	.135	*Ho* accepted	The variance of the chemistry pretest and posttest N-Gain data for students in the experimental class and control class was homogeneous
3	Difference between Experimental N-Gain and Control N-Gain results	Independent Sample T-Test	.023	*Ho* was rejected	These results state that the critical thinking skills of students who use E-Module media are higher than students who use conventional media.

Tests for normality, homogeneity, and paired sample t-tests were conducted in this research by using the SPSS 22 software. In the normality test, because the sample consisted of less than 50 participants, the Shapiro-Wilk test was used. In normality testing, the significance value (p) obtained for the experimental N-Gain was .265, and for the control N-Gain, the significance value (p) was obtained at .103 with a significance value greater than .05, indicating that the students' CT skills data were assumed to be normal. After that, homogeneity was tested using Levene's test. The result was a significance value of .135 (p>.05), indicating homogenous data. An independent sample t-test was carried out to look for differences in students' CT skills before and after the treatment administration using the E-Module problem-based contextual learning. The result was a significance of .023 ($p < .05$), demonstrating that there was an obvious difference in the students' CT skills. Enhancing students' CT skills with the media developed using the STEM-Problem-based contextual learning approach using learning syntax started from problem orientation to a natural phenomenon that was commonly experienced in everyday life. Next, organizing students to form groups according to their respective learning styles. Then students made observations by making observations, discussing problem identification, and formulating problems from the problems presented so that students can develop CT skills by identifying problems. The next step was carrying out the hypothesis stage by finding possible alternative answers. Next, an investigation was carried out to find a solution to the problem. At the investigation stage, students could complete the project given on the LKPD used to sharpen students' thinking at the design stage. In the final stage, students presented their results and concluded. This was in line with research by Budiyono et al., (2020) who conducted the same research with the STEM E-Module to provide an increase in CT skills. In the research, learning activity was carried out in the classroom by providing e-modules for discussion. In the experimental stage, it was carried out virtually using the virtual laboratory application simulation.

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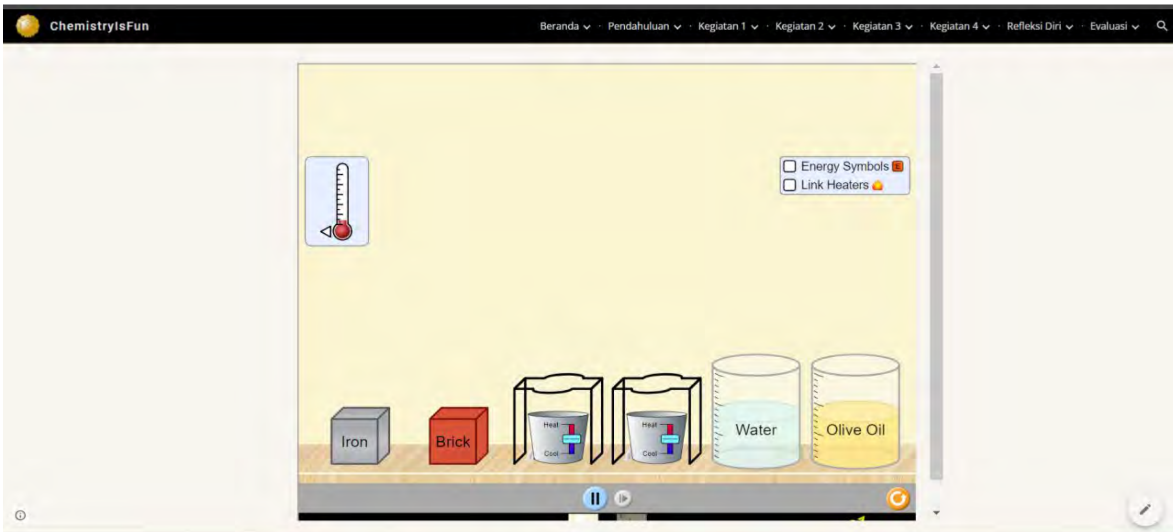
Figure 5
Virtual Laboratory on E-module



Virtual experimental methods need to be supported by using appropriate media. Physics and Education Technology (PhET) contains visualizations of real laboratory components that can be explored in real-time, concretely, and without risk of injury (Dina, 2020). The E-module developed is equipped with virtual experiments in each learning activity using PhET to significantly improve students' thinking skills, and there are differences in learning independence (Kartimi et al., 2022; Ramadan et al., 2020). Through virtual experiments, students can not only observe physical phenomena visually but also improve skills, spark questions, critical thinking, and further research. By developing E-modules, students can improve their ability to think analytically and critically about the learning materials they are studying. These results indicate that PhET simulations in modeling and implementation classes are effectively used in terms of improving students' CT skills toward minimum competency standards

Discussion

Based on the research results and explanations from the research results and e-module development process carried out, the following results were obtained:

Module characteristics

a. This research develops an E-Module using the Problem-Based Contextual Learning model with STEM

The development of the E-Module in this research used a 4D model to improve students' low CT skills because these skills are very important for 21st-century learning, so they need to be improved in chemistry learning, especially thermochemical material. Media development was carried out by following current technological developments. Currently, we have entered the digital era, so in the world of education, it is necessary to adapt to advances and developments in technology, where technology has the potential to create new learning spaces that are needed to facilitate the learning process in the classroom. According to research by Faisal et al., (2020), in the current era, students find it easier to learn by utilizing technology and are more interested in digital teaching materials, which can later be accessed easily by students using electronic devices such as smartphones.

b. Teaching modules can be used online via smartphone and laptop

The learning media developed is media that can be used for theory and practice. Planning and designing learning media that can be used as a tool for practical activities in the learning process with this E-module facility is more practical. The E-module developed can provide facilities for students to study independently. Students can access e-modules anywhere and anytime using a smartphone (Basuki, 2022). The use of information computer and technology (ICT)in the learning process can reform education in all aspects (Ishaq et al., 2020), is capable of offering an energetic environment for teaching and learning facilities (Shatri, 2020), and can replace the traditional learning process with more modern tools and facilities(Motamedi, 2019; Singh, 2016).

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c. The module developed is made in electronic form based on the Google site.

Google Sites is an application for creating website-based E-modules. Google Sites is an application that can be used to create the most interesting web-based media. The Google site itself was created in March 2008. Users can easily, swiftly, and simply design website displays with the help of the Google site. Google Sites can support learning by using several available features such as Google Docs, sheets, forms, calendars, awesome tables, etc. The Google Site has advantages, such as it is easy to operate and simple to maintain. The application of the site does not require a complicated high-level programming language because it is very simple (Riza et al., 2022). Apart from that, another advantage is that the Google Site is free and easy to use. Besides, it provides a large capacity of 100 MB online storage with sites stored securely on Google. The Google site has also been integrated with Google-based applications such as Google Meet, Google Classroom, Google Form, Google Spreadsheet, Google Docs, Google Slides, and others (Bhagaskara et al., 2020). Another advantage that the Google site has is that it can be accessed by Windows, Linux, Android, etc. Google Sites media was developed to help students develop the ability to master concepts and think critically through direct experience because they not only listen to explanations from teachers but students also carry out other activities such as observing videos and pictures, and carrying out simulations (Ciung et al., 2022).

d. The module developed is equipped with virtual trials or experiments

The e-Module developed is equipped with virtual experiments using PhET Colorado which can be carried out easily online, can save time and money, and can reduce the risk of injury. By using PhET Colorado, students can carry out virtual experimental simulations, which can be used to obtain exact data (formula data, not real data) and have the advantage of easy operation (Defianti et al., 2021). The use of PhET Colorado cannot completely replace real practicum because by using virtual experiments, students conduct and carry out experiments without seeing them directly. Aspects of measurement skills and attitudes cannot be observed directly, so they cannot apply data uncertainty due to the data obtained are exact data with the same results. Therefore, it is necessary to use approaches, class situations, concepts, and objectives that students must master.

e. The module supports student activities in achieving indicators of students' critical thinking skills.

Students' CT skills can be seen from the pretest results and initial observation results of students from the three schools (high category schools, medium category schools, and high category schools) representing Surakarta City, Central Java, Indonesia. Based on the pretest results in Table 8, it can be seen that the average of students at three schools representing Surakarta City, Central Java, Indonesia is in the non-critical category. The E-Module developed contains activities that can support student activities that contain indicators of students' critical thinking to be achieved. CT skills are not inherent in students since birth, so they need to be trained in the learning process to improve these skills.

Module eligibility

In testing the feasibility of the E-Module which was developed, validation by material, language, and media experts was conducted and resulted in very good criteria so that the module was suitable for use. Then the teacher was assessed from three aspects, namely material, media, and language, showing very good criteria so that the E-Module is suitable for use. Apart from that, for feasibility, try-out was also carried out in small groups on five aspects, namely media, material, language, learning, and use, showing that the E-Module met the criteria very well so that the module was suitable for use. Furthermore, large group tryouts were carried out on five aspects, namely media, language, materials, language, learning, and use of modules, showing that the results were suitable for use.

Module effectiveness

Students' CT skills from the three schools were tested after the developed module was applied to learning. The results showed an improvement compared to learning before using the E-module. An independent t-test was carried out to determine the increase in CT skills after implementing STEM-based E-Module contextual learning on chemistry material. The results obtained were a t-test of 0.025 where the significance showed results that were smaller than 0.05. meaning that Ho was rejected. Thus, students' CT skills when using the E-Module are higher when compared to students who used conventional media.

Analysis of aspects of students' critical thinking skills

1. Interpretation

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In the interpretation aspect, schools in the medium category showed an average of 81.5% which was in the very critical category, schools in the low category had an average of 80.58% which was in the critical category, and schools in the high category had a score of 79.42% with the critical category, so this showed that in identifying observations and categorizing phenomena, students can explain phenomena based on previous experience and students can identify problems from the phenomena given in each learning activity on thermochemical material. This was in line with research conducted by Pertiwi (2018) revealing that students who had interpretation skills or the ability to understand the problems they faced well could directly be proportional to students' critical thinking skills.

2. Analysis

In the analytical aspect, schools in the medium category and schools in the low category had an average of 78.67% in the critical category. Schools in the high category had an average of 80.89% in the critical category, and schools with a total of seven indicators had an average of 80.14% in the critical category. This means that students can find creative and innovative ideas and find solutions to solve problems presented in learning, detecting arguments or ideas. Apart from that, it also shows that students can design problem formulations through observation and have the ability to design temporary answers to problems given during the learning process in class. Apart from that, students can also solve problems in the LKPD by answering the questions in the LKPD. Besides, students can conclude the relationship between the results they obtain by answering the questions given in the LKPD by analyzing the results from the investigations. This is in line with research conducted by Pertiwi (2018) revealing factors that can later influence the analyzing aspect, including students' ability to answer questions given on the LKS according to the concept and given examples of contextual use of technology. In addition, students can also introduce the concept and provide related materials. Identifying concepts can improve students' CT skills. In believing something or before doing something, students must carry out a rational process (Listya et al., 2019).

3. Evaluation

In the evaluation aspect, there are two indicators, schools in the high category show an average of 79.12%, meaning that they are in the critical category. Schools in the low category have an average result of 78.63%, meaning that they are in the critical category. Schools in the high category have an average of 80.37% included in the critical category. The scores obtained by the three schools show that students can consider the arguments used in solving a problem related to the results of the analysis, and students can use the right strategy to complete the problem formulation completely and correctly related to the results of the analysis. In line with research conducted by Benyamin et al., (2021) regarding accuracy in solving a problem, efforts to improve students' CT skills by using STEM-based E-modules in classroom learning activities can improve aspects of student evaluation. The E-module developed based on problem-based STEM learning can be accessed using a smartphone as an effort to improve students' CT skills in aspects of student evaluation. During presentations, students learn how to formulate ideas and provide explanations for them. During presentations in groups, students are required to be able to deepen and develop innovations and ideas in unique ways (Kartimi et al., 2021; Yustina et al., 2022)

4. Inference

In the inference aspect, where there are three indicators tested on three schools, schools in the medium category get an average of 78.16%, which indicates the critical category. Schools in the high category get an average of 79.83%, which indicates that the school is included in the critical category. Schools in the low category obtained an average score of 77.33%, which shows that students' CT skills are in the critical category. The average results in the three schools show that students have skills in drawing alternative conclusions, concluding correctly, and providing explanations accompanied by supporting evidence during the learning process. This is shown by the KKTP that students have passed so that learning using media can run well seen from the average obtained by students. The inference prioritizes students' ability to make inferences from the information acquired and guides students to think critically(Pritananda, 2017).

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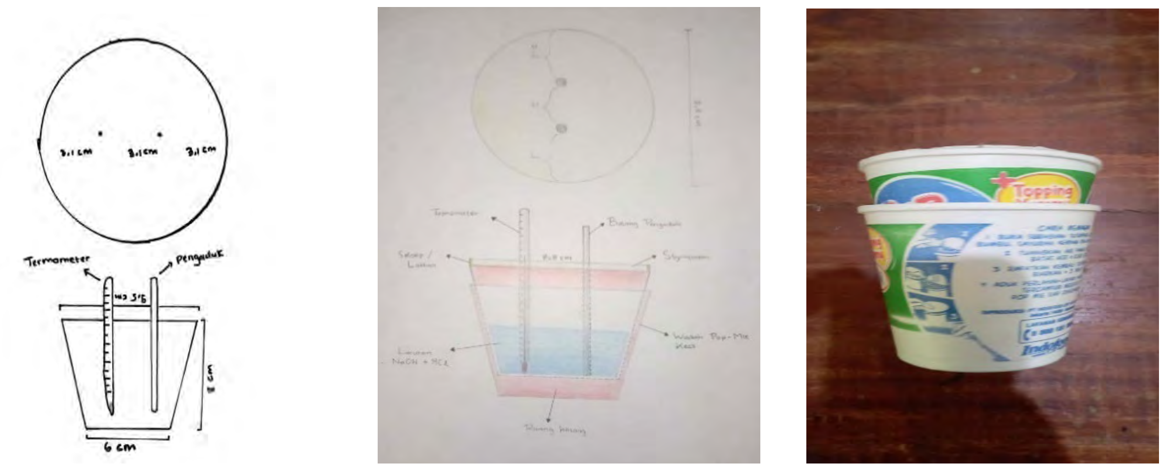
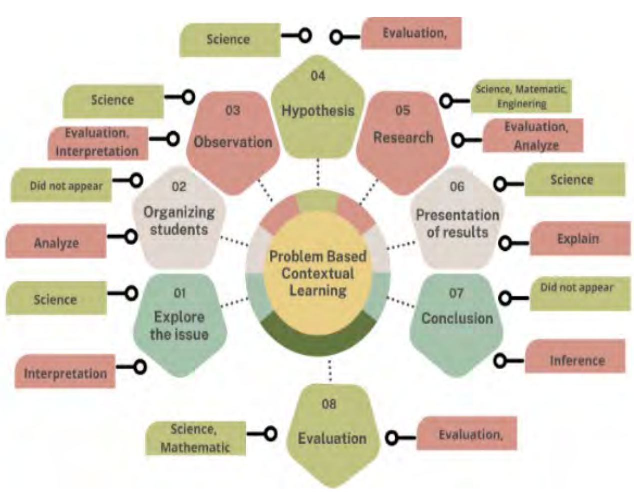
Figure 6
Picture of The Stages of Investigative Activities in The Third Activity (A) Sketch of A Simple Calorimeter Tool Designed by Students and Its Dimensions (B) Results of The Calorimeter Tool Made by Students in Groups According to The Sketch Made



(a) (b)

Based on Figure 4, which is one of the third learning activities at the investigation stage, students carry out a bomb calorimeter simulation using a virtual laboratory, then students sketch a simple calorimeter from used materials found around them. After that, they design a simple calorimeter according to the plan or sketch that has been made. The results obtained using a simple calorimeter tool that has been designed are then compared with the data obtained using a standard calorimeter and then analyzed. At this stage, the STEM component that emerges is science students who can gather information by doing practical work, studying literature, or opening websites on the internet. The hope is that students can do this and ultimately find answers to the problems they have formulated and be able to determine whether the hypothesis formulated is true or not. Students carry out experiments using the PhET Colorado application based on the work steps on the LKPD. In the mathematics component, students can use their CT skills to analyze the experimental results obtained and then connect between variables mathematically. In the engineering component, students carry out analysis and design experiments and develop work procedures for conducting experiments as a way to solve a given problem. The critical thinking ability that is developed is the ability to evaluate using problem-solving strategies. Students analyze procedures that have been designed and carry out experiments. After that, students carry out data processing and then interpret the data results.

Figure 7
The Relationship Between Problem-Based Contextual Learning and STEM Learning Models to Improve Critical Thinking Skills. The Red Color Shows Critical Thinking Skills, While the Green Color Indicates a STEM Approach.



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The research combines STEM-Problem-Based Contextual Learning with critical thinking skills, and the relationship between the two is as follows.

Learning Syntax	STEM components	Critical Thinking Skills	Learning Activities
Problem Orientation	Science	Interpretation (understanding and identifying problems)	This activity is carried out so that students have an idea of what will be done and what must be prepared to achieve the learning objectives and have confidence that they can complete and achieve the expected learning objectives.
Organizing students		Analysis (Identifying relationships between statements, questions and concepts by creating models)	The stage of organizing students aims to ensure that learning activities can run smoothly and under control. Educators guide students to form study groups. At this stage, problems related to the real world are also given according to the material to be studied.
Observation	Science	Evaluation (Using problem solving strategies)	To make observations at the observation stage. The observation process is carried out based on the problem discourse or after students see the display in the form of a power point or video that has been provided. Based on these observations, students are expected to be able to identify existing problems and formulate them in the form of questions
Hypothesis	Science	Evaluation (Using problem solving strategies)	Hypothesis stage, at this stage, students are expected to be able to estimate answers or temporary solutions from the problem formulation they have made, through observations they have made and relate them to the knowledge they have previously
Investigation	Mathematics Science Technology Engineering	Evaluation (Using problem solving strategies)	Next, students will search for the truth of their temporary answers at the investigation stage. Students can do practicums, study literature, or open websites on the internet. It is hoped that students will ultimately be able to find answers to the problems they have formulated and be able to determine whether the hypothesis they have formulated is true or not.
Presentation of results	Science	Explanation (states the results and basic arguments)	Students are asked to communicate the results of their findings so that they can be known by other groups
Conclusion and evaluation	Science Mathematics	Inference (making conclusions correctly)	Next, in the final stage, namely the conclusion, educators and students together draw conclusions from the results of the presentations that have been made by each group and evaluate the learning process that has been carried out so that the next learning activity will be better.

In the STEM approach, there are four important components, including science, technology, engineering, and mathematics (Decoito, 2016; Falloon et al., 2020; Firman, 2016). The STEM approach can be applied to classroom learning in various forms of activities, including as models, teaching materials, or Student Worksheets (LKPD) (Cruz et al., 2021; English, 2017; Lestari et al., 2018). The application of transdisciplinary STEM learning methods can create learning in schools with a collaborative atmosphere that respects sacrifice, initiative, and responsibility and can contribute to increasing conceptual understanding, student motivation, and inspiration for students' critical thinking from students (Shidiq, 2020; Shidiq et al., 2022; Susanti, E., & Fatmawati, 2023)during the COVID-19 pandemic, students and teachers could not access laboratories. Thus, innovative pedagogical approaches are required to meet these challenges. The current study, therefore, examines the use of contemporary hybrid laboratory pedagogy to construct a simple spectrophotometer by implementing Science, Technology, Engineering, and Mathematics (STEM. Activities with a STEM approach designed for learning through less study can actively increase students' understanding of the learning material, make learning meaningful, and create a happy atmosphere throughout the process of learning (Martynenko et al.,2023; Nursyahidah et al., 2023). By implementing learning with integrated digital media, STEM in learning has the advantage of developing elements of the conceptual knowledge of the students and can improve students' literacy skills effectively (Asrizal et al, 2023). So, the improvement of class XI students' CT skills through the implementation of the STEM approach in digital learning materials, such as the STEM problem-based contextual learning approach in website-based e-module learning materials, is very effective on thermochemical materials.

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Conclusions and Implications

In this research, digital learning media is developed in the form of an E-Module STEM-Problem Based Contextual Learning, displayed electronically on the Google site application. The E-module developed is equipped with integrated experiments with the PhET Colorado application. Learning media is designed to fulfill the four STEM components in each learning syntax. The advantage of the E-Module STEM-Problem Based Contextual Learning package on the website is that it helps students understand chemistry learning materials more easily. Based on the feasibility test carried out in the research, the module is suitable for use for learning thermodynamics in terms of the material, media, and language aspects. Feasibility try-out with an average of small-scale try-out results in a score of 84.91% in the category of very good and usable. Large-scale try-outs yield an average score of 84.06% in the very good category, making it appropriate for educational use. With an average N-Gain value of 0.70 with strong criteria, the effectiveness test indicates that the module has been successful in enhancing students' critical thinking skills in thermochemistry courses. The use of chemistry E-module on thermochemical materials ranging from low to high improved critical thinking skills, based on the research and development findings. Therefore, educators can utilize this E-module as an alternative when selecting instructional materials to help students develop their critical thinking skills.

Declaration of Interest

The authors declare no conflict of interest.

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