Improving Student's Critical Thinking Skills and Self Efficacy Through Implementation of Integrated Guided Inquiry Model with Science, Technology, Engineering and Mathematics (STEM)

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Abstract. The purpose of the study is to ascertain whether students' critical thinking abilities and sense of self-worth have increased as a result of using a guided inquiry methodology that incorporates STEM subjects (Science, Technology, Engineering, and Mathematics) (STEM). The first step in this research is the creation of chemistry learning materials for the topic of thermochemistry, including lesson plans, student books, student activity sheets, and tests of critical thinking abilities. 34 students from Senior High School 9 Surabaya's class XI science participated in the study. All learning tools that were produced were highly valid, according to the experts' evaluation. By achieving a gain value of 0.71, the science, technology, engineering, and mathematics (STEM) integrated guided inquiry learning paradigm was successful in enhancing students' critical thinking abilities (high category). The findings of the self-efficacy survey revealed an improvement in the self-efficacy scores of students in the medium group (0.46). Hence, the integrated guided inquiry learning paradigm of STEM has been successful in raising students' levels of self-efficacy and critical thinking.

Keywords: Guided inquiry learning model · STEM · critical thinking skills · self efficacy · thermochemistry

1 Introduction

In order to create a generation of thinkers who are distinct from those of the past, the extremely rapid development of science and technology demands substantial reforms in the educational system around the world, especially in Indonesia [1, 2]. As a result,

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teachers must teach kids 21st century abilities, such as cooperation, communication, critical thinking, and problem solving. These abilities must be included into educational activities in order to prepare pupils for the globalized era. The goal of the educational process is to increase students' productivity, creativity, innovation, and effectiveness [3].

The results of the TIMSS (Trends in International Mathematics and Science Studies) and PISA (Program for International Student Assessment) studies reveal that Indonesian students' thinking abilities are still subpar and require development. As many as 3% of pupils can be classified as having high-level cognitive abilities, but none of them have attained the advanced level. Moreover, 54% of children still fall into the low group for science proficiency (low level). The majority of Indonesian students only know a few basic facts and are unable to communicate or relate different science topics, let alone use complicated and abstract ideas to solve problems in the actual world [4].

One of the 21st century abilities that kids need to learn in order to be competitive in the globalization era is critical thinking. Critical thinking abilities are rational, reflective thought processes that support students' interpretation, analysis, evaluation, and inference processes. The learning process must be directed so that students actively think critically, because the concept of activity is a very important pattern in building student thinking and becomes one of the foundations of constructivist learning, namely students actively build their knowledge, not just absorbing ideas from the teacher [5]. The development of critical thinking abilities is essential for pupils' success in school and is also the primary method through which they can face and conquer future challenges. Concept mastery and critical thinking abilities are positively correlated, making it possible to enhance pupils' concept mastery by developing their critical thinking abilities [6].

The guided inquiry learning model is a teaching strategy that can help students locate a concept by using a variety of sources of knowledge and viewpoints to suggest solutions to problems, subjects, or concerns [7]. Several student abilities can be developed through the inquiry process, including critical thinking abilities like knowledge gathering, making wise decisions, and problem-solving creativity [8]. Students' critical thinking abilities can also be developed through inquiry learning [9]. Yet, not all of the difficulties presented in learning with the inquiry paradigm involve real-world situations. Students lack the necessary training to relate and apply scientific concepts to real-world problems. By including the Science, Technology, Engineering, and Mathematics (STEM) approach in the inquiry learning model, one of them can be overcome.

The STEM approach has benefits, including: 1) offering many opportunities to develop thinking skills; 2) raising interest in learning about science; and 3) The engineering component in STEM emphasizes process and product design/design and can use engineering to explore, find, and solve problems. Students can also apply the concepts they have learned to solve real-world problems. Students' motivation, creativity, critical thinking abilities, and idea mastery can all be improved by using the STEM method [10, 11].

Also, the STEM approach is successful in honing pupils' motor abilities so they can create the products they require for daily life [12]. Students will engage in problem-solving, investigations, and other meaningful activities as part of their learning with the guided inquiry model integrated with STEM. These activities will present learning

opportunities, allow students to work independently, construct student knowledge, and result in tangible products that aid in conceptual understanding [13, 14].

Self-efficacy is a mindset that, together with critical thinking abilities, is crucial for student success in the future. Because self-efficacy is directly related to motivation, learning behavior, expectations for the future in general, and student achievement, it is included in the PISA exam [4]. Self-efficacy can affect a person's cognition, affective processes, and behavior [15]. Students' scientific attitudes about chemistry are positively impacted by self-efficacy as well. Thinking abilities, problem-solving abilities, idea mastery, and student self-efficacy can all be enhanced by inquiry learning [16]. Thus, the adoption of a guided inquiry learning methodology combined with STEM on the topic of thermochemistry in senior high school will be used in this study to examine students' critical thinking abilities and sense of self-efficacy.

2 Methods

Pre-experimental research of this kind uses a one-group pretest-posttest design [17]. It was necessary to prepare lesson plans, student books, worksheets, tests of critical thinking abilities, and self-efficacy questionnaires for the thermochemical themes included in this study. Before being used in the teaching process, all instructional materials were evaluated by three chemical education professionals. In September 2022, this study was carried out at Senior High School 9 in Surabaya. 34 science students in class XI were the study's intended audience. The learning process took place over the course of three meetings and covered the topics of exothermic and endothermic reactions, calculating the enthalpy of a reaction using a calorimeter, Hess's equation, data on formation enthalpy, and bond energy. Three methods, namely validation, test, and questionnaire, are used to collect data. Data on the applicability of learning materials on themes related to thermochemistry were obtained using the validation technique. In the meantime, data on pupils' critical thinking abilities will be gathered via test methodologies. Through the use of a self-efficacy questionnaire, information about students' self-efficacy was gathered. Using descriptive quantitative analysis, all data were examined [6]. The n-gain was used to measure how much the students' critical thinking abilities and sense of self-worth had improved [18].

3 Results and Discussion

3.1 Validity of Learning Materials

Four different types of learning resources were created for the study: lesson plans, student books, student worksheets, and tests of critical thinking abilities. Three professionals who served as validators evaluated the learning tool's validity. In Table 1, the validation findings were displayed.

The data in Table 1 showed that the four research tools developed showed validation scores above 3.25, namely 3.69 (Lesson plan), 3.63 (Student worksheet), 3.53 (Student books), and 3.60 (Critical thinking skills test) so that it was categorized as very valid [19, 20, 21]. The reliability of the validator's assessment of all research tools was greater

Table 1. The Validation results of learning materials on thermochemistry topic

Type of learning materials	Validation score			Average	Category
	V1	V2	V3		
Lesson plan	3.89	3.43	3.84	3.69	Very valid
Student worksheet	4.00	3.52	3.71	3.63	Very valid
Student's book	3.26	3.59	3.71	3.53	Very valid
Critical thinking skills test	3.25	3.75	4.00	3.60	Very valid

than 75% so that it was categorized as reliable [22]. Thus the device is suitable for use in chemistry learning activities using a guided inquiry model integrated with STEM on the thermochemistry topic at senior high school.

3.2 Student's Critical Thinking Skills

Interpretation, inference, explanation, analysis, and evaluation were measured as critical thinking indicators in the study [23]. Five essay questions make up the designed test of critical thinking aptitude. Students were subjected to the test both before and after the learning process (pre test) (post test). Also, n-gain analysis was used to examine whether students' critical thinking abilities have improved as a result of using the integrated STEM guided inquiry paradigm for learning. The information in Table 2 is based on a test of critical thinking abilities given to 34 students in class XI science at Senior High School 9 in Surabaya.

The value of n-gain for each indicator of critical thinking skills was presented in Table 3.

Table 2 demonstrated how the STEM integrated guided inquiry methodology can help students develop their critical thinking abilities, with an average pretest score of 40.5 rising to 81.3 at the end of the course. As a consequence of the n-gain analysis, the high category n-gain value is determined (0.71). This rise can be attributed to the guided inquiry model's integration of STEM and training in critical thinking skills in each of its phases.

Phase 1: Initiation. At this stage, students are given phenomena that contain problems in everyday life related to thermochemistry topics. Students are asked to examine and interpret these phenomena to find the formulation of the problem to be solved through scientific investigation. Therefore, through the initiation stage, students are trained in

Table 2. The results of critical thinking skills test of students of class XI science Senior High School 9 Surabaya

Number of students	Average score of pre test	Average score of post test	n-gain	Category
34	40.5	81.3	0.71	High

Table 3. N-gain value of critical thinking skills indicator

No.	Critical thinking skills indicator	Average score of pre test	Average score of post test	n-gain	Category
1	Interpretation	38.24	92.65	0.85	High
2	Analysis	31.62	78.68	0.71	High
3	Inference	31.62	69.85	0.59	Medium
4	Explanation	34.56	92.65	0.89	High
5	Evaluation	37.50	72.79	0.60	Medium

critical thinking skills for interpretation indicators [23]. Phenomena that contain scientific problems are a manifestation of the science component in STEM [12]. Through the use of everyday phenomena, it will be able to arouse student motivation in the learning process so that according to information process theory it will affect the storage of information in long-term memory thereby increasing mastery of concepts and critical thinking skills [24, 25].

Phase 2: Selection. The selection stage is carried out after students are able to formulate problems related to thermochemistry. At this stage, students in groups are encouraged to discuss seeking information from a variety of accurate sources, both from textbooks or other sources, including the internet in order to formulate temporary answers to problems (hypotheses). Through these activities students will also be motivated to carry out further processes, namely scientific investigations to solve problems [7, 25]. The indicators of critical thinking skills that are trained at this stage are interpretation and analysis because students are required to be able to interpret and analyze sources of information in order to find temporary answers to problems [23]. The process of finding accurate scientific information to formulate hypotheses and research variables is a manifestation of the science component of STEM which is studied at the selection stage [12].

Phase 3: Formulation. At the formulation stage, the teacher guides students to formulate hypotheses to answer the problems that have been formulated based on the results of a study of information that has been collected from various sources. In addition, students are also asked to determine research variables that will be solved through scientific investigation. The process of formulating hypotheses and determining research variables is a manifestation of the science component in STEM [12]. In this third stage, indicators of critical thinking skills that are trained include interpretation, analysis and inference. Students are required to carry out these three indicators to formulate hypotheses and determine scientific investigation variables [23].

Phase 4: Collection. At this stage students carry out experiments within the framework of scientific investigation to test the truth of the hypotheses that have been formulated related to the topic of thermochemistry. All STEM components are applied at this stage both science, technology, engineering and mathematics [12]. Through experimental activities students are trained in critical thinking skills for indicators of interpretation, analysis, inference and evaluation [23]. It makes students more actively participate to gain mastery of the concept. In addition, students will gain experience that is useful

for proving the correctness of concepts. Scientific investigation activities carried out in groups allow for scaffolding from students with higher abilities to students with less abilities thereby increasing their potential ability to master the thermochemical concepts being studied [24, 25].

As students create equipment for exothermic and endothermic reactions, such as ice gel products manufactured from baby diapers, a simple thermos, a simple calorimeter constructed of styrofoam, and an emergency bottle lighter, science, technology, engineering, and mathematics are used.

Phase 5: Presentation. At this stage, students are required to present the results of scientific investigations that have been carried out. Reports on the results of scientific investigations are a manifestation of the science component in STEM [12]. In the presentation stage students are trained to apply indicators of critical thinking in explanation, interpretation, analysis, inference and evaluation [23]. Such skills are needed to know and obtain the necessary factors to make reasonable conclusions. It is applied when research results are concluded through scientific investigation and the results are communicated in front of the class [26].

Phase 6: Assessment. In the last stage of the guided inquiry model that is integrated with STEM, the teacher gives students the opportunity to evaluate the learning activities that have been carried out so that information on the achievement of the goals can be obtained. At this stage students are trained indicators of critical thinking skills namely interpretation, analysis, inference, explanation and evaluation [23]. The STEM component integrated at the assessment stage is science. Several questions given by the teacher at this stage will be able to deepen students' understanding of concepts and critical thinking skills [24, 25].

According to the justification provided, using the STEM-integrated guided inquiry learning paradigm to teach students about thermochemistry has a positive impact on their ability to think critically. It can increase student motivation throughout the learning process, resulting in better test results for students' critical thinking abilities [26]. It is feasible to produce pupils with higher-order thinking through preparation such as through critical questions, questions with language, and in-depth concept development [23]. The process of developing critical thinking skills in children is gradual and involves preparation.

The results of students' critical thinking skills can also be linked to constructive theory. It is explained that cognitive development is a process when students form a meaningful system and an active interpretation of reality through their experiences and interactions. By using critical thinking skills, students can form long-term memory related to the material being studied so that students can achieve learning achievement [24, 27].

Based on the data in Table 3, all indicators of critical thinking skills showed an increased value of n-gain in the moderate and high category. Indicator of interpretation, analysis and explanation showed n-gain value in high category. While indicators of inference and evaluation showed n-gain value in the medium category. The explanation indicator had the highest n-gain value (0.89), while the lowest n-gain was shown by the evaluation indicator.

3.3 The Student's Self Efficacy

In the study, measures of students' self-efficacy were made before and after the adoption of teaching using the STEM-integrated guided inquiry learning methodology on the subject of thermochemistry in the classroom, in addition to their critical thinking abilities. 20 statements make up the self-efficacy questionnaire, which was developed using four indicators—mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states—to measure self-efficacy [28]. The information in Table 4 was obtained from the answers to a self-efficacy questionnaire completed by 34 students in class XI at IPA SMAN 9 Surabaya.

N-gain value for each self-efficacy indicator was presented in Table 5.

Based on the data in Table 4, learning chemistry on the thermochemistry topic using the guided inquiry model integrated STEM could increase students' self-efficacy from the average score before learning 0.51 to 0.73 after the learning process. From the results of the n-gain analysis, the n-gain value was obtained in the medium category (0.46). All indicators of self-efficacy have increased with the value of n-gain in the moderate category. The vicarious experiences indicator showed the lowest n-gain value (0.36), while the physiological and affective states indicator showed the highest n-gain value. The increase in student self-efficacy has an impact on improving students' critical thinking skills because a person's self-efficacy can affect cognition, motivation, affective processes and ultimately the person's behavior [15, 29, 30]. In addition, self-efficacy also has a direct positive influence on students' scientific attitudes towards chemistry which will have an impact on their critical thinking [16]. The high value of n-gain indicators of physiological and affective states indicates that the chemistry lesson on thermochemistry

Table 4. The results of self efficacy questionnaire for students of class XI science Senior High School 9 Surabaya

Number of students	Average score before learning process	Average score after learning process	n-gain	Category
34	0.51	0.73	0.46	Medium

Table 5. N-gain value of self efficacy indicator

No.	Indicator of self efficacy	Average score before learning process	Average score after learning process	n-gain	Category
1	Mastery experiences	0.56	0.76	0.45	Medium
2	Vicarious experiences	0.61	0.75	0.36	Medium
3	Verbal persuasion	0.42	0.69	0.47	Medium
4	Physiological and affective states	0.45	0.73	0.51	Medium

topic being implemented is able to make students enjoy and not stressed during the learning process. It will increase motivation and have an impact on student's mastery of concepts and critical thinking skills [24, 25, 28].

4 Conclusion

The guided inquiry learning model integrated with STEM is effective for improving students' critical thinking skills and self-efficacy on the subject matter of thermochemistry. The application of the learning model is proven to be able to produce n-gain values in the high category (0.71) for critical thinking skills, while for self-efficacy, the n-gain value in the medium category (0.46) is obtained. Increasing students' self-efficacy has supported the improvement of students' critical thinking skills.

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