

Validating an Innovative Guided Inquiry Learning Model for Critical Thinking in Temperature and Heat Concepts

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Abstract: This research aims to examine the validity of the development of the Guided Inquiry Learning Model based on Critical Questioning (Intersistatic) in enhancing students' critical thinking on the concept of temperature and heat. The research method used is define, design, and development. The validity of the model is evaluated through various instruments, including the content and construct validity of the learning model and the validity of instructional materials (syllabus, lesson plans, teaching materials, worksheets, and critical thinking skills tests). The research results show that the Intersistatic model obtained very valid assessments in most aspects of the evaluation. The content of the Intersistatic model received an average score of 4.29 with a percentage of 85.78%, indicating a very high level of validity. The construct assessment, with an average of 4.44 and a percentage of 88.89%, also achieved a very high level of validity. In addition, the syllabus (average 3.70, percentage 88.00%), teaching materials (average 4.61, percentage 92.22%), worksheets (average 4.26, percentage 85.19%), and critical thinking skills tests (average 4.45, percentage 89.02%) all reached a very high level of validity. The assessment of lesson plans showed good validity (average 4.24, percentage 84.73%), although it was slightly lower than other aspects. The results of this research indicate that the Guided Inquiry Learning Model based on Critical Questioning (Intersistatic) has met the criteria for good validity in various aspects of its implementation.

Keywords: Critical Thinking, Guided Inquiry, Heat, Temperature.

INTRODUCTION

Quality science education in the era of globalization is a key element in developing individuals who are competent in science and technology. One crucial aspect of science education is enhancing students' critical thinking skills (Zubaidah, 2010; Jannah et al., 2022; Affandy et al., 2019). Critical thinking is a vital cognitive skill in education, essential not only for understanding scientific concepts but also for solving everyday life problems. The low critical thinking abilities of students pose a challenge to educational efforts and the development of their learning experiences in school. Advanced-level students often exhibit low levels of critical thinking (Wilujeng et al., 2021; Setiana et al., 2020). Their inadequate reasoning abilities result from a lack of dynamism in the learning process and student learning experiences, hindering the development of critical thinking skills as expected (Nuryanti et al., 2018).

Modern education increasingly emphasizes the importance of developing critical thinking skills as a primary goal (Mardhiyah et al., 2021; Diharjo et al., 2017). The learning process plays a significant role in helping students acquire knowledge and construct critical thinking skills. The use of innovative learning models that facilitate effective learning and support the development of students' critical thinking skills is highly needed. Asyafa (2019) explains that an effective learning model is one that significantly aids students in attaining their learning goals by providing valuable information. Moreover, variation in the use of learning models can impact students' enthusiasm for learning, prevent boredom, and influence their interest and motivation in the learning process. Besides selecting existing learning models, variation in learning models can also be achieved by developing innovative learning models tailored to the characteristics, personalities, and learning styles of students.

One innovative learning model capable of facilitating student-centered learning and enabling independent knowledge construction by students is the Guided Inquiry Learning Model. David (2009) defines the Guided Inquiry Learning Model as a model based on the learning of concepts and connections between various concepts within the subject matter. Educators must be able to present real-world problems to students and guide them in discovering patterns in these problems while providing reinforcement when students understand the taught concepts. Mauk et al. (2022) state that guided inquiry has the characteristic of being a learning model in which the learning process involves problem-solving, and its main concept relates to students' knowledge formation. Students learn to construct knowledge based on what they already know.

Implementing guided inquiry learning models means that teachers provide guidance for students to conduct investigations, as mentioned by Hartono (2013). Teachers must understand and implement the principles of using the guided inquiry model to ensure that the learning process runs smoothly, resulting in enjoyable and student-oriented teaching that fosters critical thinking and active participation in the teaching and learning process. The implementation of guided inquiry learning models makes students actively engage in finding solutions to questions or problems posed by the teacher with deep guidance (Sofiani, 2011; Asmawati, 2015; Purwasih, 2015). In this model, students play a role similar to that of a scientist, where they ask questions, formulate hypotheses, conduct experiments, identify relationships between concepts, and explain their findings in line with their understanding (Maknun, 2020; Gunawan et al., 2019; Wu et al., 2006). The inquiry model is also well-suited to a constructivist approach (Suparmi, 2018; Hamdani et al., 2019), which implies that knowledge is constructed by students themselves through their own inquiry processes, allowing them to discover knowledge independently.

Guided inquiry learning has been proven to be an effective approach to help students gain a deeper understanding of scientific concepts (Handayani, 2018; Sulistiyono, 2020). In guided inquiry learning models, students are given guiding questions to actively explore concepts. Additionally, the application of the guided inquiry learning model has been effective in developing students' critical thinking skills

(Nasution, 2018; Fitriyah et al., 2021; Parwati et al., 2020). The guided inquiry learning process trains students to ask critical questions that stimulate their critical thinking skills, involving deep analysis, evaluation, and reflection on the information they receive. Guided inquiry learning models with a focus on critical questions can be a promising approach for developing students' critical thinking skills in science education. Pratiwi (2021) states that science education is a subject in schools that equips students with concepts, ideas, and knowledge about the environment acquired through experience and a series of scientific processes, including preparation, investigation, and ideation. Furthermore, according to Puti et al. (2015); Yuniarti et al. (2015), science education can help students develop understanding, thinking habits, and life skills, including observation, scientific attitudes, and prediction.

One of the scientific concepts explored in science education is temperature and heat. Previous research (Rosdianti, 2021; Zayyinah et al., 2018) has shown that the concepts of temperature and heat are complex and often difficult for students to grasp. Furthermore, the implementation of the science education system should be carried out by professional teachers with supportive teaching materials. According to Susantini (2012), science teachers can effectively convey scientific knowledge to students when they have a strong grasp of the subject matter. Teaching materials are also essential as guidelines for both teachers and students. Therefore, this research aims to develop a guided inquiry learning model based on critical questioning (Intersistatic) to enhance students' critical thinking skills regarding the concepts of temperature and heat. However, before adopting the Intersistatic learning model in the context of teaching temperature and heat concepts, it is necessary to review the validity of this model. Validity is a crucial aspect in developing an effective learning model. Thus, this research specifically examines the validity of the Intersistatic learning model for enhancing students' critical thinking skills in the context of temperature and heat concepts.

METHODS

The method used in this research is the Four-D development model, which includes Define, Design, Development, and Disseminate

(Thiagarajan, 1974). The approach employed is quantitative descriptive, which will result in the development of products such as a learning model book and instructional materials, including: 1) Syllabus, 2) Lesson Implementation Plans, 3) Worksheets, 4) Teaching Materials, and 5) Critical Thinking Skills Tests on the topic of temperature and heat. However, in this article, the discussion is limited to the Development phase, particularly related to the validity of the products developed, which are the Intersistatic learning model book and its instructional materials. The instruments used for data collection in this research are instruments for the validation of the learning model book and instructional materials. The purpose of validation is to assess whether the developed learning model is suitable for implementation, suitable with improvements, or not suitable for implementation. The content validation refers to Nieveen et al. (2007) definition, which states that a learning model is considered to have good content validation if its components are grounded in strong theoretical rationale (state of the art knowledge).

The analysis of the validation results for the Intersistatic learning model and its instructional materials involves the summarizing of expert assessments, calculate the averages, and the percentage of the average expert assessments for the learning model and instructional materials using the formula (1) (Arikunto, 2010).

$$\bar{X} = \frac{\sum X}{n} \quad (1)$$

Information for X is average score, $\sum X$ is total sum of scores given by validators, and n is number of validators.

Next, determining the validity category for each criterion by matching the average validation result percentage with the validity categories established. The validity category for each criterion is determined based on the assessment criteria provided by Akbar (2013), as shown in Table 1.

Table 1. Criteria for Validity

Percentage (%)	Criteria
$85 < Va \leq 100$	Very Valid
$70 < Va \leq 84$	Valid
$49 < Va \leq 70$	Reasonably Valid
$0 < Va \leq 49$	Not Valid

The criteria used to determine that the Guided Inquiry Learning Model based on Critical Questioning (Intersistatic) has a level of validity

that is adequate when validity falls within the minimum valid category.

RESULTS AND DISCUSSION

The development of the learning model was carried out to address the issues that arose based on the observations in the Junior High Schools throughout the Batudaa district. Here is a discussion of each development stage that has been undertaken.

a. Define

In the define stage, initial and final analyses, student analyses, task analyses, concept analyses, and learning objective formulation analyses were conducted. As explained earlier in the research results, the define stage is the earliest stage in the development of teaching, where based on observations and analyses, it was concluded that the development of the Intersistatic learning model was considered necessary as one of the efforts to provide solutions to the issues that were identified.

b. Design

In the design stage, the researcher created an initial design of the Intersistatic learning model. The process of designing the Intersistatic learning model referred to the views of Joice and Weil (2000), who proposed that there are five main elements as characteristics of a good learning model. These five elements are syntax, social system, response principles, support system, and teaching and facilitating impacts. In designing the syntax of the Intersistatic learning model, the researcher first drew conclusions from several inquiry-based learning model syntaxes proposed by various experts. Then, the syntax resulting from the conclusions was connected to critical thinking triggering questions according to Paul & Elder (Filsaime et al., 2008), resulting in the syntax of the Guided Inquiry Learning Model based on Critical Questioning (Intersistatic), which includes: (1) Presenting significant problems logically; (2) Formulating hypotheses accurately; (3) Planning clear investigations; (4) Collecting relevant data; (5) Processing/analyzing data deeply and extensively; and (6) Making clear and precise conclusions.

In the Intersistatic learning model, the social system becomes a key element that includes interactions between teachers and

students, interactions among students, and the teacher's response principles to students. This involves the active participation of students in critical questioning, giving them the freedom to express relevant opinions, and encouraging respectful discussions within groups. These response principles manifest in various indicators, such as active learning, context-dependent learning, accommodating diversity in students' backgrounds and abilities, and providing a social learning experience. Meanwhile, the support system in this learning model includes the necessary facilities, such as well-organized classroom space that is easily accessible for teachers and students, as well as providing a clean environment. Additionally, various learning resources and instructional media, including teaching materials, printed books, LCDs, laptops, worksheets, and whiteboards, are available. Learning materials such as syllabi, lesson plans, teaching materials, worksheets, and critical thinking skills tests for students are also provided. Observations indicate that this support system has met the necessary requirements. The instructional impact of this research is an improvement in students' critical thinking skills test results in the subject of science, especially in the concepts of temperature and heat. Additionally, an increase in students' learning activities and positive responses to learning in this subject were observed.

In this stage, the design of instructional materials was also carried out, referring to the K13 Curriculum, which includes syllabi, Lesson

Implementation Plans, teaching materials, Student Worksheets, and Critical Thinking Skills Tests. Specifically, in designing the critical thinking skills test, the researcher developed questions based on critical thinking skill indicators according to Ennis, which were related to high-level critical thinking questions, including analysis, evaluation, and creation. The design process at this stage resulted in the creation of the Intersistatic learning model book.

c. Development

Furthermore, in the process of developing the Intersistatic learning model, it enters the development stage, or the product design development stage. In this stage, the initial design of the Intersistatic learning model is validated by 3 expert validators. The designs validated include the learning model book and instructional materials. The validation of the learning model book consists of content validation and construct validation of the learning model, while the validation of instructional materials has components, including format suitability with the K13 Curriculum, content, readability, language, and the appearance of each unit of instructional materials in the syllabus, lesson plans, teaching materials, worksheets, and critical thinking skills tests for students. The results of the validation criteria analysis for the Intersistatic model and instructional materials are summarized in Table 2.

Table 2. Analysis of Validation Result Criteria

Types of Instruments	Average	Percentage (%)	Criteria
Content of the Intersistatic Model	4.29	85.78	Very Valid
Construct	4.44	88.89	Very Valid
Syllabus	3.70	88.00	Very Valid
Lesson Plans	4.24	84.73	Valid
Teaching Materials	4.61	92.22	Very Valid
Worksheets	4.26	85.19	Very Valid
Critical Thinking Skills Test	4.45	89.02	Very Valid

During the validation process, there were suggestions and feedback from the validators regarding the Intersistatic learning model book and instructional materials design. For the learning model book, Validator 1 suggested improving the rationality of the model to make it clearer and to clarify the role of the teacher as a facilitator and mediator. Validator 2 suggested improving the rationality of the development of the learning model, and Validator 3

recommended clarifying the development goals of the Intersistatic learning model and finding suitable supporting theories for its development.

For the construct validation of the Intersistatic learning model, Validator 1 asked that the aspects to be validated should be included in the model book, and they requested further clarification of the connection between supporting learning theories and the Intersistatic learning model. Validator 2 suggested clarifying

the teacher's behavior in guiding students to think critically, while Validator 3 asked for a more detailed explanation of the interaction between the teacher and students in the learning process, as well as the inclusion of learning resources.

In addition to providing feedback on the learning model book, the validators also gave suggestions and feedback on the instructional materials. Validator 1 recommended aligning the material presentation in the instructional materials with the K13 format and learning objectives. Validator 2 suggested aligning the material presentation with competency indicators, and Validator 3 recommended ensuring that the presentation of the temperature and heat material aligns with the learning objectives.

The design of Student Worksheets also received suggestions and feedback from the validators. Validator 1 asked that the activities be aligned with the teaching materials, Validator 2 requested further clarification of the illustrations and student tasks in the worksheets to make it easier for students, and Validator 3 requested the inclusion of space in the worksheets for students to create critical questions. Regarding the design of the critical thinking skills test for students, Validator 1 suggested that the questions be clarified in terms of cognitive domains to align them with Bloom's Revised Taxonomy. Validator 2 recommended that the questions be created using critical thinking indicators, while Validator 3 asked for the inclusion of critical thinking indicators and distractors in the questions.

After receiving feedback from the validators, the researcher revised the design based on their suggestions and feedback. The revised design of the learning model book and instructional materials was then revalidated by the validators until it was declared valid and suitable for use. The final analysis of the validation of the Intersistatic learning model book and instructional materials was deemed valid according to Akbar (2013) criteria. The validation results met the criteria of being "very valid" for both content and construct validation of the learning model book, making it suitable for the next development phase.

In terms of the validation of instructional materials, the results indicated that the syllabus and lesson plans were valid according to Akbar (2013) criteria, which consider validation results acceptable if they meet the minimum criteria for

validity. Meanwhile, the validation results for teaching materials, worksheets, and critical thinking skills tests were categorized as "very valid" according to Akbar (2013) criteria, making them suitable for the next phase.

The Guided Inquiry-Based Critical Questioning (Intersistatic) learning model in the concept of temperature and heat aims to enhance students' critical thinking skills alongside a profound understanding of scientific concepts. In this paper, the focus is on the validation of the Intersistatic learning model as a part of the development process of an effective learning model to improve critical thinking skills in students in the context of temperature and heat.

Firstly, the validation of the Intersistatic learning model aims to assess the quality of the model in nurturing critical questioning skills in students. The model should be capable of motivating students to formulate deep and critical questions regarding the concepts of temperature and heat. Thus, the model can help develop critical thinking skills in students, as critical thinking often begins with formulating relevant questions. The validation of this model is supported by several previous studies highlighting the effectiveness of guided inquiry-based learning in enhancing students' critical thinking skills. Previous research (Firiyah et al., 2021; Musliman et al., 2022; Iman et al., 2017; Kurniawati et al., 2019) has shown that guided inquiry-based learning can motivate students to think more deeply and critically about the learned scientific concepts.

Secondly, the validation of this model aims to understand its impact on students' conceptual understanding of temperature and heat. Intersistatic-based learning allows students to actively explore scientific concepts, resulting in students who follow this model having a deeper and more comprehensive understanding of temperature and heat concepts compared to students in conventional learning. Intersistatic-based learning effectively improves students' understanding of temperature and heat concepts. Students who follow the Intersistatic model tend to have a deeper and more comprehensive understanding of these concepts (Asmawaty, 2015; Saminan et al., 2016).

Thirdly, the validation of the Intersistatic learning model examines the teacher-student interaction aspect in the learning process. This model is designed to encourage teachers to act as facilitators who provide a critical discussion

learning process. Teachers do not merely provide direct answers but rather motivate students to find their answers through questioning and exploration. This creates a more collaborative and interactive learning environment. Previous research by Adiputra (2017), Nurhayati et al. (2019), and Nurraaksa et al. (2023) observed that teachers shifted from being information providers to facilitators who encourage students to formulate questions, seek answers, and actively participate in class discussions. This creates a more collaborative, student-centered learning environment that fosters meaningful learning.

Fourthly, the validation of the Intersistatic model is related to student engagement in the learning process. This model encourages students to be active in asking questions and seeking answers to those questions. This increases student participation in the learning process and helps develop their critical thinking skills. Students who are active in using scientific questions during learning can construct their knowledge as a meaningful knowledge acquisition process (Widiada et al., 2013; Nursit, 2015; Nasar et al., 2020). Therefore, the use of scientific questions in the learning process needs to be trained for students to develop a critical thinking mindset based on scientific principles.

In summary, the validation of the Guided Inquiry-Based Critical Questioning (Intersistatic) learning model aims to produce a valid and effective learning model for enhancing students' critical thinking skills in the context of temperature and heat. The validation of this model is supported by its ability to stimulate critical questioning, improve the understanding of scientific concepts, change the role of the teacher, and actively engage students in the learning process. After going through the validation process by experts, the Intersistatic learning model has proven to be valid in terms of its construction and content. Therefore, the Intersistatic learning model can be one of the innovative learning model alternatives to enhance the quality of science education and train students' critical thinking skills.

CONCLUSION

This research has examined the validity of the Guided Inquiry-Based Critical Questioning (Intersistatic) Learning Model in the context of developing students' critical thinking skills in the

concept of temperature and heat. The validity assessment of the model was conducted on various aspects, including the content and construction of the Intersistatic model, the syllabus, lesson plans, teaching materials, worksheets, and critical thinking skills tests. Overall, the results indicate that the Guided Inquiry-Based Critical Questioning (Intersistatic) Learning Model is a valid instructional model for enhancing students' critical thinking skills in the context of temperature and heat. Therefore, the Intersistatic model has the potential to improve the quality of science education, particularly by facilitating the enhancement of students' critical thinking skills in science learning.

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