



Enhancing Mathematical Conceptual Understanding through Formative Assessment with Conceptual Scaffolding

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ABSTRACT

Conceptual understanding is a fundamental aspect of mathematics learning that enables students to connect mathematical ideas and apply them in various problem-solving situations. This study aims to examine the effectiveness of formative assessment assisted by conceptual scaffolding in enhancing students' mathematical conceptual understanding. The research employed a quantitative approach using a quasi-experimental design involving junior secondary school students. Formative assessment activities were integrated into the learning process and supported by conceptual scaffolding strategies that guided students step-by-step in understanding mathematical concepts. Data were collected through conceptual understanding tests administered before and after the implementation of the learning intervention. The results indicate that the use of formative assessment combined with conceptual scaffolding significantly improves students' mathematical conceptual understanding. Students demonstrated better ability to interpret mathematical concepts, establish relationships between concepts, and apply them in solving problems. These findings suggest that integrating formative assessment with conceptual scaffolding can serve as an effective instructional strategy to support meaningful mathematics learning and improve students' conceptual comprehension.

Keywords: Mathematical, Conceptual, Learning Education

Received:	Revised:	Accepted:	Available online:
01.01.2026	01.02.2026	20.02.2026	08.03.2026

INTRODUCTION

Temperature and heat are basic subjects of science and phenomena we experience daily (I. Aykutlu, 2017). Temperature and heat are abstract materials (Nugraha et al., 2016). A weak understanding of temperature and heat causes misconceptions about both concepts (Twumasi et al., 2021). One of the difficulties students have in mastering the concepts of temperature and heat is their failure to activate concepts related to temperature and heat (AN Laili, 2021). Students do not realize that heat equals temperature, temperature equals energy, and cold is not part of heat (Sofianto et al., 2020). The research results also show that students have more than one hundred alternative concepts about temperature and heat (Bakırcı & Ensa, 2018). Students' interest in operating mathematical equations and analyzing physical quantities has decreased (Ni'mah, 2019).

Conceptual understanding can be improved by implementing learning that helps students with difficulty mastering concepts. Difficulties in mastering concepts can be identified by increasing students' ability to ask questions so that the concept mastery students receive is informative and constructive (Asmawati, 2015; D. Mulhayatiah et al., 2019). So, teachers need to know the extent of mastery of concepts received by students. Formative assessments can be used to determine the extent of student acceptance of the material. Formative assessments can motivate students to learn when given feedback on their learning (Buchholtz et al., 2018). Formative assessment feedback aims for student metacognitive development such as planning, monitoring and personal reflection (Nur'aini et al., 2020). By providing step-by-step instructions for input or assistance (scaffolding) to students, students can increase understanding which allows students to be involved in solving problems (Andersson & Palm, 2017). Scaffolding can be provided online (Setiawan et al., 2018). The use of e-scaffolding has the advantage of utilizing various multimedia, which makes it possible to meet the needs of students' different learning styles and levels of development (Ubaidah et al., 2022).

Scaffolding conceptual and formative assessments in learning, namely providing scaffolding, are only carried out individually, and teachers cannot provide direct feedback to all students simultaneously (Mardikaningsih et al., 2023). Therefore, learning strategies are needed that can overcome this problem. One is a collaboration between face-to-

face and online learning, using scaffolding and direct feedback designed into a learning application. Formative assessment assisted by conceptual scaffolding designed in the form of learning applications has several advantages. One of them is providing feedback and assistance to students more quickly (Nur'aini et al., 2020). Not many formative assessments are assisted by conceptual scaffolding on temperature and heat. The form of conceptual scaffolding provided is in the form of questions with a choice of right or wrong answers, with feedback for each right and wrong answer. Based on this description, researchers developed a formative assessment assisted by conceptual scaffolding to improve temperature and heat concepts.

METHOD

The research was carried out using research and development methods. This research is used to discover, develop, and test a product based on systematic procedures so that the product produced has high scientific value and can be trusted. (KWB Putra, 2017). The product developed is a formative assessment that can be accessed via mobile devices or laptops to help teachers determine students' conceptual mastery of temperature and heat material—products developed in .apk and web form. Experts validated the product developed, and empirical validation was carried out using a response questionnaire regarding the learning applications of class XI MA students. The research and development method used is ADDIE. The ADDIE model has five stages: analysis, design, development, implementation, and evaluation. The development flow is presented in Figure 1

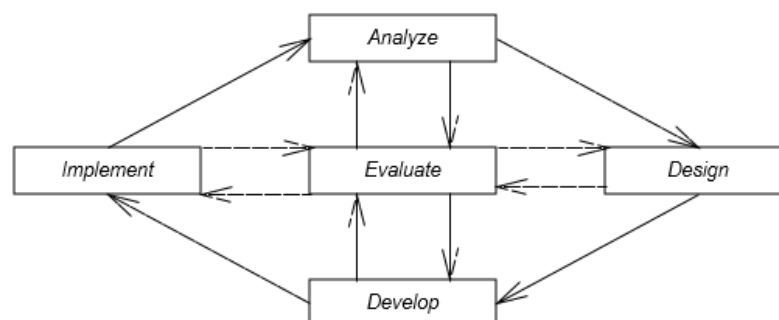


Figure 1. ADDIE Development Flow

Data was taken using validation sheets and student response questionnaires to learning applications. Research data analysis was conducted to determine learning applications' feasibility and practicality. The study was carried out using the following steps: a) We are changing the data results by filling in the checklist validation sheet into quantitative data in the form of scores using a Likert scale; b) Calculate the total score on the validation sheet and practicality using Equation 1 and Equation 2; and c) The percentage score for each aspect obtained is converted to the score interpretation criteria in Table 1 and Table 2.

$$V = \frac{x_v}{x_T} \times 100\%$$

.....(1)

Information:

V : percentage of validity

x_v : validation score obtained

x_T : total score

Table1. Interpretation of validation scores

Validation percentage	Criteria	Information
0% - 24%	Invalid	Total revision
25% - 49%	Not valid	Lots of receipts
50% - 74%	Valid	Minor revision
75% - 100%	Very valid	No revisions

$$P = \frac{x_p}{x_T} \times 100\%$$

.....(2).

Information:

P : practicality percentage

x_p : practicality score obtained

x_T : total score

Table 2 . Interpretation of Practicality Scores

Criteria	Practicality Percentage
Not practical	0% - 24%
Not practical	25% - 49%
Quite practical	50% - 74%
Practical	75% - 100%

RESULTS AND DISCUSSION

The resulting learning application is in .pptx format and converted into .apk and web form. The learning application developed is a formative assessment assisted by conceptual scaffolding. It aims to help teachers provide fast feedback and make it easier to assist (scaffold) students to complete tasks or concepts that cannot be completed independently. Formative assessment assisted by conceptual scaffolding is used to determine students' mastery of concepts in temperature and heat material. Product specifications consist of a cover page and menu display. The menu display includes three main menus: checking understanding, learning, and evaluating. Within each menu, there are several sub-menus. When working on questions on comprehension checks and evaluation questions, students will get score results directly. So that students can find out directly the results of student abilities. The menu display is presented in Figure 2. b.

Meanwhile, in the training sub-menu in the learning menu, students will work on five multiple-choice concept mastery questions, with feedback for each answer. If the answer is correct, students will get feedback on the reason for the correct answer. Meanwhile, if a student's answer is wrong, the student will get feedback that they have not been able to answer correctly. Then, students are directed to solve conceptual scaffolding problems. In each question, there are 2 to 4 conceptual scaffolding questions. Students will receive help in stages until students can answer the main questions.

The cover page of the formative assessment application assisted by conceptual scaffolding (AFSK) contains an enter button to go to the main menu. Navigation to close is at the top right—the information and instructions button is in the bottom right corner. Enlarge or reduce the

AFSK application display by clicking the screen with two hands, outward or inward. The cover page can be seen in Figure 2. A



The resulting learning application contains material to broaden students' insight and help students remember the concepts studied. The material is equipped with videos and pictures or animations to attract

students' interest and make learning concepts easier. The learning application contains questions that test students' mastery of concepts. The comprehension check menu to test students' initial concepts before learning consists of six questions about temperature and heat. Each question has a maximum processing time of three minutes. After completing all the questions, students will receive a message regarding the student's score. The understanding check display is presented in Figure 2. c. On the practice menu, five questions test students' mastery of concepts. Each answer choice is equipped with correct and wrong answer feedback.

The question display with correct answer feedback is presented in Figure 2.d. Strengthening the concept after answering correctly is presented in Figure 2.e. Answer options that the student does not choose will not appear after the student answers. This ensures that students have mastered the concept and avoid working on it by guessing the answer. Conceptual scaffolding questions will appear after students get the results that the student's answer is wrong, as presented in Figure 2. f. Scaffolding questions will be given in stages so students can understand the concepts. The conceptual scaffolding question display is presented in Figure 2. h. Concept reinforcement is not only given when students answer correctly but also incorrectly, as in Figure 2. g.

Media validation is divided into four aspects: product suitability with formative assessments, layout, language appropriateness, and product use. These four aspects have received an in-depth evaluation of each part of the learning media. The validation data was then analyzed using percentages and obtained a percentage value of 89.25%, including very valid criteria. Apart from that, several parts need to be improved and adjusted according to suggestions and comments from validators. A recapitulation of product validation results and suggestions and comments by validators are presented in Table 3 and Table 4.

Table 3 Recapitulation of Product Validation Results by Validators

Rated aspect	Assessment aspect	Assessment aspect		Average	Percentage (%)	Criteria
		V1	V2			
Product conformity with formative assessment		4	3.71	3,855	96,375	Very valid
Layout		3.25	3	3,125	78,125	Very valid

Rated aspect	Assessment aspect		Average	Percentage (%)	Criteria
	V1	V2			
Language eligibility	3.57	3.28	3,425	85,625	Very valid
Product use	4	3.75	3,875	96,875	Very valid
Average feasibility value			3.57	89.25	Very valid

Information :

V1 : Validator 1

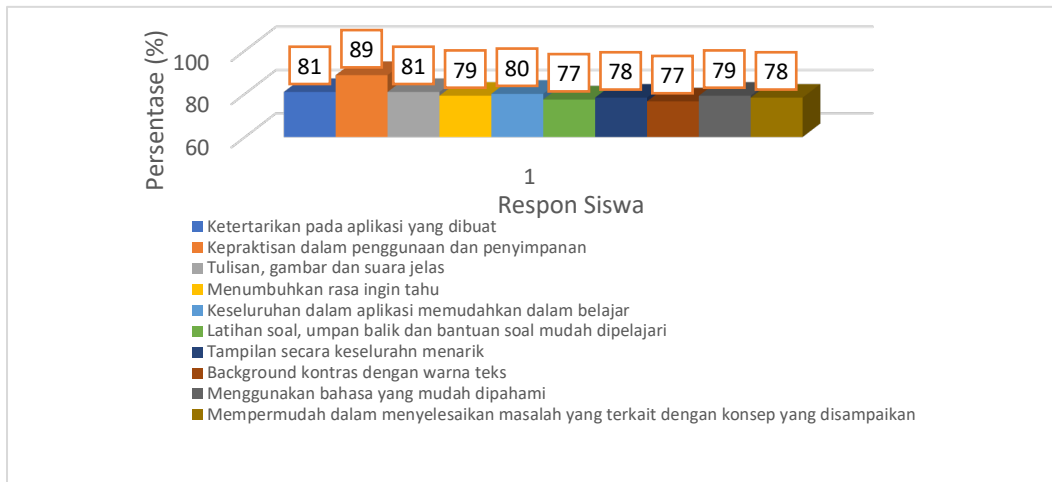
V2 : Validator 2

Table 4 Recapitulation of Suggestions and Comments by Validators

Validator	Suggestions and Comments
V1	<p>There needs to be adjustments to the background of the product so that it does not seem too busy (distracting from the writing/material)</p> <p>The typeface needs to be more modern</p> <p>Images and animations can be improved to make them better</p> <p>Several sentences need to be revised</p> <p>The use of language needs improvement by Indonesian language rules</p>
V2	<p>Backgrounds the front page needs to be adjusted so that the title is clearer</p> <p>There needs to be a difference between pretest and posttest questions with practice questions with feedback and scaffolding so that students do not appear to memorize answers to pretest and posttest questions.</p> <p>Please adjust the question indicators used in practice questions and scaffolding questions to the questions to be tested (pretest questions and posttest questions)</p> <p>Several buttons do not work</p> <p>Visually, it is good</p>

A limited trial was conducted using a response questionnaire from AFSK application users. The test subjects were 23 class XI MA students taking the even semester. The average percentage of student response

results is 80%. The results of the limited trial are presented in Graph 1. The trial results show a very positive response from users



Graph 1 Respons for users

The development of formative assessment products assisted by conceptual scaffolding was done with several revisions after expert validation. Some revisions include adjusting the product background, using more interesting sentences, pictures, and animations, and adjusting practice questions with scaffolding questions. For more details, some of the revisions can be seen in Table 4. The product was tested on students in .apk or web form. Students can choose any of the given application formats. Adapting scaffolding questions to practice questions is intended to harmonize the concepts that will be given. Giving scaffolding questions in stages aims to help focus students' thinking because it simplifies complex concepts. Apart from that, the information obtained during assistance helps students solve the problems given. Providing assistance and feedback given by teachers creates cognitive conflict for students. So, the cognitive process occurs when students integrate this new information with their initial knowledge and reorganize it into a coherent cognitive structure to form a new conceptual understanding of the temperature and heat material they study (Altmeyer et al., 2020).

Based on expert validation carried out by lecturers and user responses with predetermined criteria, it can be said that the learning application is feasible, valid and practical to use to determine students' mastery of concepts in temperature and heat material. Based on the analysis that has been carried out, the valid percentage for product

conformity with the formative assessment is 89.25%. The revised product was then tested on 23 respondents. Based on the analysis of the use of formative assessment media assisted by conceptual scaffolding to increase mastery of concepts in practical temperature and heat material, with an average percentage of student response results of 80%. Even though the learning application developed is practical, based on the respondent's response questionnaire in the form of a quasi-open questionnaire, several things were taken into consideration in the learning application created.

Criticisms and suggestions include that the website has problems, the display is not clear, and several parts do not appear, so improvements are needed so that the website can be used properly. The font is used to be clearer and bigger, and the background is busy, so the writing is not visible. Use in the form of a web that requires a stable and strong internet network creates display problems that users receive. However, the majority of respondents who use applications in .apk format do not experience difficulties in use. Most respondents said they liked and were interested in the AFSK application. When respondents work on practice questions and get wrong answers, they are interested and motivated to work on conceptual scaffolding questions until they can answer the main question.

CONCLUSION

Conceptual scaffolding-assisted formative assessment is an application or learning media with material presentation equipped with a menu in the form of questions to check students' initial abilities, temperature and heat material, a menu in the form of practice questions with feedback and assistance (scaffold) for completing practice questions, a virtual laboratory for material form of heat form and evaluation menu. The practice and scaffolding questions are in the form of multiple-choice concept questions that can be used to determine students' mastery of concepts in temperature and heat material and explore students' weaknesses and difficulties in temperature and heat material. Learning applications motivate students to study the material well.

Based on quantitative data analysis through assessing the number of scores converted into score interpretation criteria, the validation and practicality test results showed that the conceptual scaffolding-assisted

formative assessment was valid (89%) and practical (80%) to be applied in teaching physics on temperature and heat materials with suggested revisions. Research and development should be carried out with several trials and revisions, not just once so that the learning applications used are really good and appropriate to the students' conditions and no serious obstacles related to media use are found. Limited trials must also include students and teachers so that they can provide a broad picture of the learning application being developed. Learning applications should contain more varied and interesting animations or images or be 3D animations developed in a web form that is easy to access and run

REFERENCES

- A N Laili, S. M. (2021). Ragam kesulitan Siswa SMA dalam Menguasai Suhu dan Kalor. *Jurnal Riset Pendidikan Fisika*, 20-26.
- Altmeyer, K. K. (2020). The Use of Augmented Reality to Foster Conceptual Knowledge Acquisition in STEM Laboratory Courses—Theoretical Background and Empirical Results. *British Journal of Educational Technology*, 51(3), 611-628.
- Andersson, C. &. (2017). Characteristics of Improved Formative Assessment Practice. *Education Inquiry*, 8(2), 104 - 122. <https://doi.org/10.1080/20004508.2016.1275185>.
- Asmawati, E. Y. (2015). Lembar Kerja Siswa (LKS) Menggunakan Model Guided Inquiry untuk Meningkatkan Keterampilan Berpikir Kritis dan Penguasaan Konsep Siswa. *J. Pendidik. Fis*, vol. 3, no. 1, pp. 1–16.
- Bakırcı, H. a. (2018). The Effect of Common Knowledge Construction Model on Academic Achievement and Conceptual Understandings of High School Students on Heat and Temperature. *Education and science*, 171-188.
- Buchholtz, N. F. (2018). Combining and Integrating Formative and Summative Assessment in Mathematics Teacher Education. *ZDM - Mathematics Education*, 50(4), 715–728. <https://doi.org/10.1007/s11858-018-0948-y>.

- D. Mulhayatiah, E. K. (2019). Work and Energy by Guided Inquiry Worksheet: Analysis of Critical Thinking Skill in Madrasah. *J. Phys.: Conf. Ser.*, vol. 1155, no. 1, p. 012072.
- I. Aykutlu, S. B. (2017). An Assessment of High School Students' Conceptual Structures of Heat And Temperature Through Concept Maps. *in Turkish Physical Society 32nd International Physics Congress*, , vol. 1815, pp. 1–4.
- K. W. B. Putra, I. M. (2017). Pengembangan E-modul Berbasis Model Pembelajaran Discovery Learning pada Mata Pelajaran “Sistem Komputer” untuk Siswa Kelas X Multimedia SMK Negeri 3 Singaraja. *J. Pendidik. Teknol. Kejuruan*, 40-49. 14(1).
- Mardikaningsih, A. K. (2023). Studi Kuantitatif Berpikir Kritis Mahasiswa Pada E-Scaffolding Konseptual dalam Blended Learning. *Jurnal Teknologi Pembelajaran (JTeP)*, 3 (2).
- Ni'mah, S. M. (2019). Analisis Miskonsepsi dan Kemampuan Berpikir Kritis Siswa pada Materi Suhu dan Kalor Menggunakan Pembelajaran Modeling Instruction Disertai Web-Based Formative Assesmen.
- Nur'aini, D. A. (2020). Pengembangan Asesmen Formatif Berbasis Komputer untuk Mengetahui Penguasaan Konsep Siswa pada Materi Hukum Bernoulli. *Jurnal Riset Pendidikan Fisika*, 5 (2). 106 - 112.
- Setiawan, T. H. (2018). xplorasi penggunaan E-Scaffolding prosedural dan strategi dalam menyelesaikan soal-soal kinematika gerak lurus. *Quantum: Seminar Nasional Fisika, Dan Pendidikan Fisika*, 323 - 332.
<http://seminar.uad.ac.id/index.php/quantum/article/view/280>.
- Sofianto, E. W. (2020). The Analysis of Heat Temperature Misconception and Integration with Al Quran. *Journal of Physic Conference Series*, , 1422.1.
- Ubaidah, N. Z. (2022). Aktualisasi Mathematical Literacy berbasis E-Scaffolding di Era Digital. *Prosiding Seminar Nasional Pascasarjana*, 776-781