



## **Development of hots-based virtual laboratory with VBA Excel: improving understanding of temperature and heat concept**

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### **ABSTRAK**

This research discusses the limited tools and rare temperature and heat experiments in high schools in Depok, which hinder students' mastery of concepts and higher-order thinking skills (HOTS). This study proposes a virtual laboratory with VBA Excel that utilizes existing computer lab facilities and provides an effective and efficient way to learn physics<sup>1</sup>. The research method used is Research and Development (R&D) with the ADDIE model. Media and material experts validate the product, then tested by teachers and students using a tiered rating scale. The feasibility test scores from media experts are 93.61%, material experts 86.25%, and teacher responses 94.07%, with a very good interpretation. Furthermore, user trials were conducted with students, where one-on-one trials obtained a score of 90%, small group trials resulted in a score of 81.6% and field trials with a score of 81.48%. Based on the N-gain calculation, scores of 0.67 for small groups and 0.63 for field trials were obtained with moderate interpretation seen from the results of the pre-test and post-test scores calculation. Thus, it can be concluded that the virtual laboratory with VBA Excel on temperature and heat material can improve concept understanding and meet students' needs in higher-order thinking skills (HOTS).

**Keywords:** ADDIE, HOTS, Temperature and Heat, VBA Excel, *Virtual Laboratory*

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### **INTRODUCTION**

Physics learning in high schools requires practical activities to help students understand physics concepts and develop higher-order thinking skills (HOTS). (Nugroho, 2018). However, based on preliminary studies, the reality is that physics experiments in schools in Depok still face various obstacles, such as the limitations of tools and materials, lack of time and facilities, and difficulties in measuring and processing data. As a result, physics experiments are rarely conducted and are less effective in enhancing students' understanding of concepts and their

higher-order thinking skills (HOTS).

One solution that can overcome these obstacles is by using a virtual laboratory. (Lisa et al., 2022). A virtual laboratory is a computer simulation that mimics real-world experiments and allows students to explore and learn physics concepts safely and interactively (Fatimah et al., 2020).

According to Sapto & Jaya (2014), a virtual laboratory can provide opportunities for students, especially those who want to conduct experiments independently without being present in a natural laboratory. Especially when conducting experiments in stand-alone settings (Sohibun & Yolanda, 2019), this is effective for learning because students can develop the ability to learn independently without relying on an instructor or assistant as per the prevailing system (Guntara et al., 2023; Muhajarah & Sulthon, 2020).

Temperature and heat are physics topics that can be leveraged with a virtual laboratory to enhance students' understanding of concepts and critical thinking skills (Sundari & Sarkity, 2021). However, many students find it challenging to learn this material due to its microscopic and macroscopic nature, making it not readily observable in direct learning (Anisa et al., 2020). This impacts the low learning outcomes of students on the material of temperature and heat, resulting in low student learning results (Garira, 2020; Yuliana et al., 2019). Therefore, students need practical experiments that can help them understand the concepts of temperature and heat more profoundly and evaluate the students (Ipi et al., 2021).

To create a practical virtual laboratory, it is necessary to have a tool that can be used to create and manage data, graphs, and diagrams. (Safitri et al., 2020; Wijaya et al., 2020). One such tool that can be utilized is VBA Excel. MS Office, which many users already possess, can be customized to their needs. An advantage for Windows users is that Visual Basic is already available in the installed MS Office package (Herdi & Ester, 2018). VBA Excel can also help students develop computing and programming skills that will be useful in the future (Lee, 2016). VBA Excel is widely used to create simulations, animations, and programs for physics learning (Abdullah, 2020). Several researchers have created virtual laboratories to enhance students' thinking abilities in physics concepts (Alatas & Fachrunisa, 2019). Based on the research, VBA Excel will continue to evolve as a medium for virtual laboratories, especially in applying physics concepts (Akbar & Budiarti, 2022).

Based on previous research studies (Puspita et al., 2020), interactive media using Macromedia Flash only provided material, evaluation, and instructions, and the design part did not show other sub-chapters of the material nor were experiments conducted. In contrast, the development of learning media currently underway based on HOTS with Visual Basic for Application technology is a novelty in developing ideas about learning media with an educational principle that is interactive, allowing students to learn independently, with practical experiments presented in each material so that students can master the concepts of temperature and heat. The research conducted by Coto et al. (2023) states that VBA Excel was chosen because it is very accessible, provides a simple visual environment, allows files to be easily shared, and makes its programming very easy.

Researchers have not yet found a study on VBA Excel-based learning media for Temperature and Heat. Therefore, the researchers are developing learning media with that material. This research aims to meet the needs of Physics learning in schools that can effectively and efficiently build mastery of concepts and high-level thinking abilities.

## RESEARCH METHODS

This research uses the development method (Research and Development). The ADDIE model used in this study consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

The research was conducted over two months at three senior high schools: SMAN 5 Depok, SMA Muhammadiyah Sawangan, and SMAN 1 Parung. The subjects included three physics teachers and 50 11th-grade MIPA students. Data were collected through observations, interviews, questionnaires, and test instruments (Hamzah, 2019). The test instrument measures students' cognition by giving pre-test and post-test questions based on the researcher's indicators. Data were analyzed using equations from validator questionnaires, student questionnaires, teacher questionnaires, and test questions. The questionnaire results were processed with the equation (1).

$$TCR = \frac{\sum \text{respondent scores}}{\sum \text{maximum scores}} \times 100\% \quad (1)$$

Respondent Achievement Level Category from Expert Assessment Survey Results The respondents' achievement level categories from the expert assessment survey results can be seen in Table 1.

**Table 1.** Respondent achievement level category (TCR)

No	Scale	Criteria
1	81,26%-100%	Very Good
2	62,51%-81,25%	Good
3	43,76%-62,50%	Fairly Good
4	25,01%-43-75%	Not Good

(Sugiyono, 2011).

To measure the effectiveness of virtual laboratory media in enhancing students' conceptual understanding, the instrument used is the normalized gain (N-Gain). N-Gain represents the difference between pre-test and post-test scores. Post-test results indicate an improvement in students' conceptual mastery after using the virtual laboratory media compared to their pre-test performance (Hake, 1998). The Normalized Gain instrument is used to measure the effectiveness of VR media in improving students' concept mastery. N-Gain is the difference between the initial test score and the final test. The post-test results show increased student concept mastery after using VR media compared to the pre-test results (Hake, 1998). The N-Gain value can be calculated using the formula:

$$N\text{Gain} = \frac{\text{posttest-pretest}}{\text{ideal score-pretest}} \quad (2)$$

The calculation of the N-Gain value shows whether there is an increase in student learning outcomes after using the developed media. The N-gain criteria used refer to the requirements described by Hake.

**Tabel 2.** N-Gain criteria

N-Gain	Criteria
$g \geq 0,7$	High
$0,7 > g \geq 0,3$	Medium
$g < 0,3$	Low

## RESULTS AND DISCUSSION

The researcher developed the virtual laboratory learning media for temperature and heat following the ADDIE model, which aims to enhance students' conceptual understanding and high-level thinking skills effectively and efficiently. To determine the alignment of the product with user needs, the researcher conducted a needs analysis during the analysis phase. The analysis stage will analyze the causes of the performance gap in schools to determine whether it is necessary to develop VBA Excel. The steps taken by researchers in the analysis stage collect data through teacher interviews and observations at Depok High School. Based on the results of interviews obtained from teachers, teaching media is needed to support current learning, namely virtual labs, due to limited tools. Virtual lab media makes students interested in learning and is structured according to student needs, in line with Caroline's research that interactive media accompanied by simulations (virtual lab) makes it easier for students to learn (Caroline et al., 2020).

At this stage, Fadilah explains the three steps that must be considered: determining the material that is to the needs and abilities of students and the expected competencies, designing effective and exciting learning concepts, and designing learning media that support the learning process (Fadilah et al., 2022). The stage of determining the appropriate material is based on the study of the interview by the physics teacher; the interview results show that the heat and temperature material is still difficult for students, and the expansion practicum tool does not exist. Based on the results of student interviews of student needs, students say that physics is difficult to learn, so it is not difficult to use learning media without Kouta, and students can use Ms. Excel. Then, the concept design planning begins with displays of instructional videos, objectives, materials, and practicum. In terms of appearance, it presents a story in the syntax of apperception, problem formulation, hypothesis, experimentation, conclusions, and animation. It also discusses questions at the end of each sub-chapter.

The purpose of this development stage is to produce the expected media. The step taken is to produce the content of the material or content of this step to create and develop the content of the material. Then, a learning evaluation sheet will be formulated to determine the ability of students to achieve learning objectives. After preparing a formative evaluation plan, this step is carried out by formulating research instruments in the form of media validation sheets by learning media experts and learning material experts. The following is a media display that experts have validated.

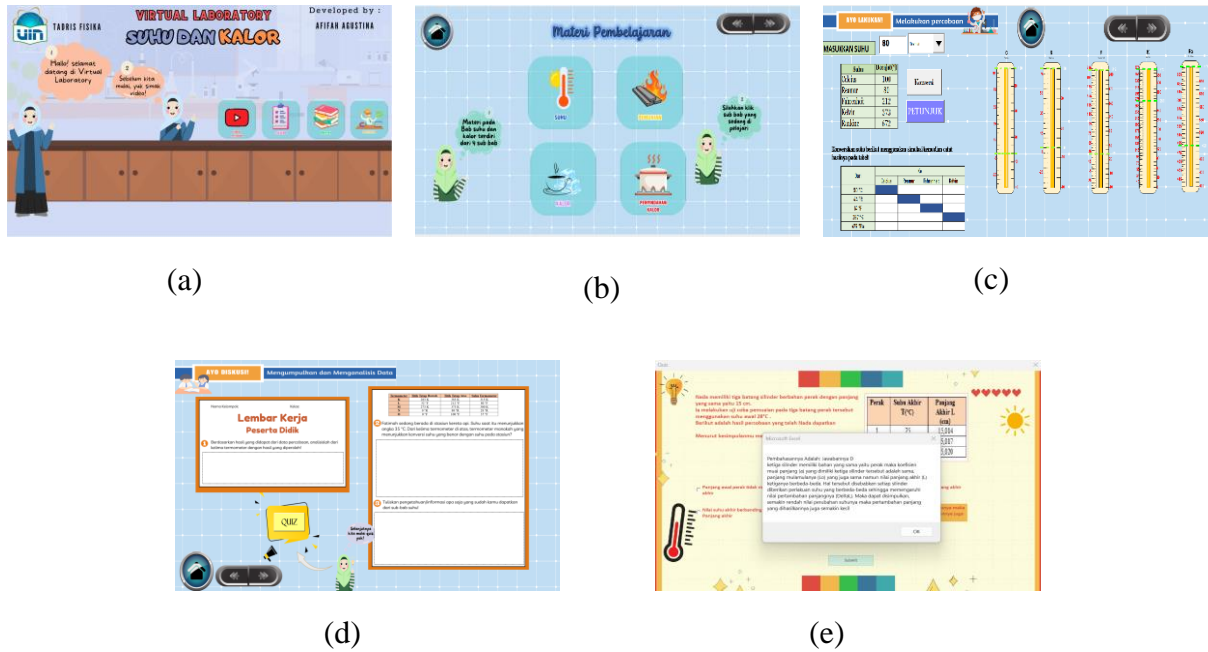


Figure 1. VBA media display (a) Menu (b) Material (c) Practicum (d) LKPD (e) Quiz

Virtual lab media using VBA Excel are instructional videos, learning objectives, learning materials, and practicum on the menu. Each sub-chapter of the material consists of practicum experiments, animation, LKPD, and Quiz. On the quiz menu, students get a score displayed directly along with the discussion. Then, the results of media expert validation were obtained, and the material was reviewed in several aspects. The validation results are displayed as follows

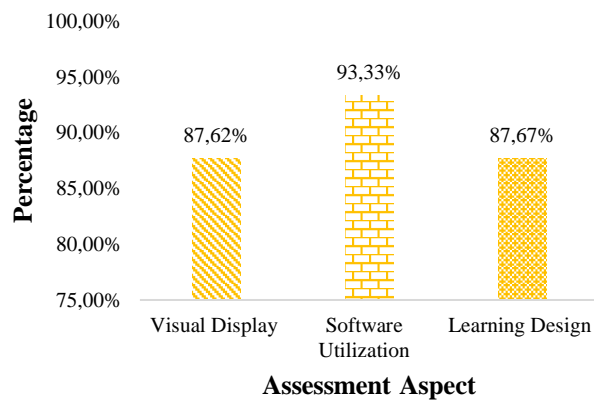
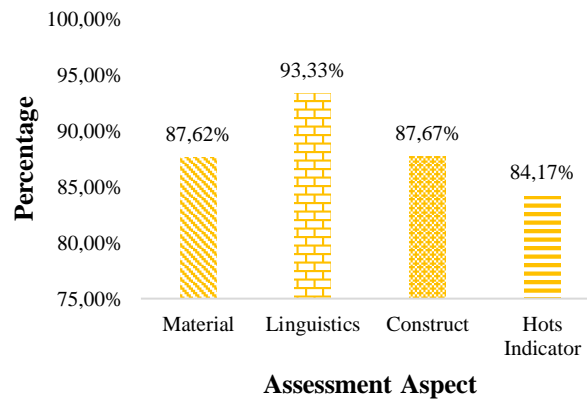


Figure 2. Graph of media expert validation results



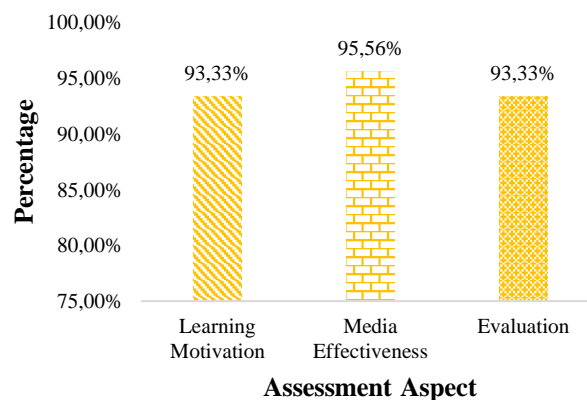
**Figure 3.** Graph of material expert validation results

**Table 2.** Description of expert validation results

Description	Classification			
	Amount	Value	TCR (%)	Category
Media Expert	337	360	93.61	Very Good
Content Expert	414	480	86.25	Very Good

From the data analysis, the conclusion is that virtual labs are feasible using VBA Excel in the "Very Good" category using a rating scale according to Table 1. Research conducted by Gusti states, "Excel-based interactive learning media on high school parabolic motion material developed is in the category of very good to use in the learning process based on the results of the effectiveness validation test" (Gusti et al.,2022). Similar to the research conducted by Swandi on parabolic motion material, interactive simulation media using VBA Excel meets the valid and reliable categories with a reliable average percentage of 92.9% (Swandi et al., 2021)

The implementation phase aims to collect data related to the effectiveness and practicality of the virtual laboratory media by students. This is achieved through individual testing, small group testing, field testing, and teacher trials when used in the classroom learning process. Data are obtained from questionnaires filled out by both teachers and students.



**Figure 4.** Graph of teacher response results

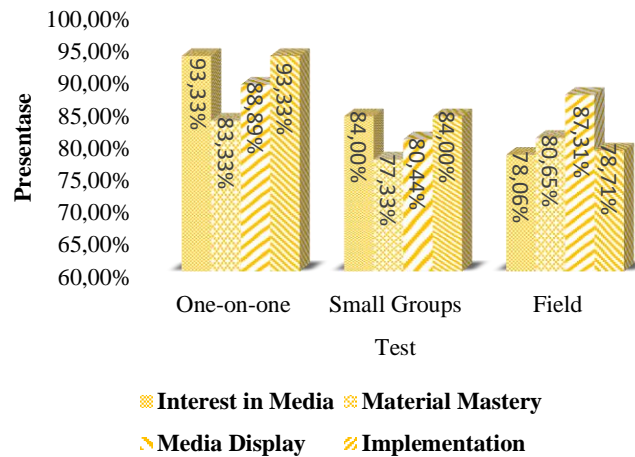


Figure 5. Graph of student response results

This indicates that the virtual lab developed using VBA Excel is “highly suitable.” Additionally, the researcher collected data through interviews with several students, and according to the students, the “developed media can assist the learning process, enhance motivation, and is effectively utilized.” These findings align with a study conducted by (Soprihatin & Haqiqi, 2021), which stated that interactive simulations are particularly suitable for supporting the learning process, especially in temperature and heat topics.

The final evaluation phase aims to determine whether students have experienced an improvement in their learning outcomes after using the VBA Excel that has been developed. Student evaluation results can be obtained from pre-test and post-test scores, reflecting their understanding of temperature and heat concepts. Please observe the following analysis:

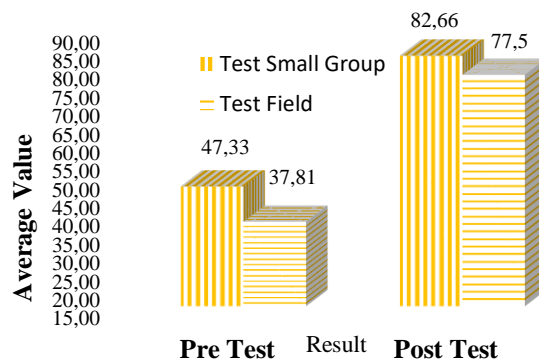


Figure 6. Graph of pre-test and post-test results

Table 3. Result N-Gain, pre-test and post-test

Score	Small Group	Field
Pre-test	47.33	37.81
Post-test	82.66	77.50
N-Gain	0,67	0.63
Kriteria	Medium	Medium

This research concludes that the virtual laboratory using VBA Excel on the topic of temperature and heat is effective in enhancing students' conceptual understanding and is suitable for use in the learning process; the research conducted by (Ain et al., 2022) states that VBA media facilitates teachers in teaching concepts effectively to students who participate in learning. In line with the research by Permana & Purwaningsih (2022), virtual simulations can help students understand physics concepts more deeply. Consequently, students' physics learning outcomes can improve. The researchers then observed high-level thinking skills through the VBA Excel media that students had to work on, as follows the results worked on.

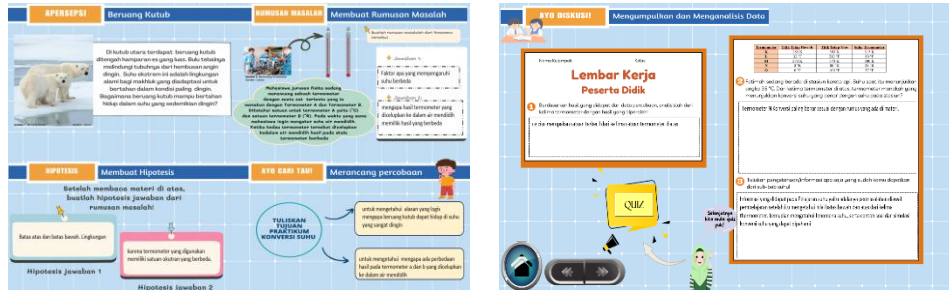


Figure 7. Student learning outcomes

Based on the above results, the process involves specific steps, such as formulating problems, hypotheses, and experimental objectives. These steps are designed to enhance students' critical thinking skills (Listiantomo & Dwikoranto, 2023); subsequently, during data collection, students conduct experiments and work on worksheets (LKPD) to assess their understanding of the material. Furthermore, students engage in quizzes with questions about Higher Order Thinking Skills (HOTS), explicitly addressing indicators C4, C5, and C6. The findings indicate that VBA Excel can effectively implement students' high-level thinking abilities. This aligns with research by Akbar & Budiarti (2022), which suggests that virtual practicals with VBA Excel measure students' higher-order thinking skills in physics concepts.

## CONCLUSION

The research successfully developed an interactive virtual lab learning media based on higher-order thinking Skills (HOTS) using VBA Excel for the topics of temperature and heat. This learning media was deemed highly suitable by experts, teachers, and students, and it was found to help students understand the concepts of temperature effectively. After conducting the virtual laboratory development research on temperature and heat, the researchers identified areas for improvement that could be addressed in future research, with suggestions to ensure the learning media created meets the needs of students. It is also recommended that all components, such as computer labs, be checked to ensure smooth implementation. This research is significant as it can develop computational and programming skills that benefit the future.



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