



Journal of Educational Sciences

Journal homepage: <https://jes.ejournal.unri.ac.id/index.php/JES>



P-ISSN
2581-1657

E-ISSN
2581-2203

Development of Edu Pilot: A Web-Based Interactive Physics Laboratory on Temperature and Heat for High School Physics Learning

Rosyidah Rohmah*, Nyoman Sudana Degeng, Nurmida¹, Catherine Sitompul²

¹Faculty of Educational Technology, Graduate School, PGRI Adi Buana University, Surabaya, 60234, Indonesia

²Faculty of Educational Technology, Graduate School, PGRI Adi Buana University, Surabaya, 60234, Indonesia

³Department of Educational Technology, Faculty of Education, State University of Malang, 65145, Indonesia

ARTICLE INFO

Article history:

Received: 10 June 2026

Accepted: 20 July 2026

Available Online: 25 July 2026

Keywords:

Edu Pilot,
Heat Transfer,
Temperature and Heat,
Virtual Laboratory,
Web-Based Media

* Corresponding author:

E-mail: farodino.25@gmail.com

Article Doi:

<https://doi.org/10.31258/jes.10.7.p.1087-1102>

This is an open access article under the [CC BY-SA](#) license.



ABSTRACT

This study was initiated by pre research questionnaire results from high schools students in Indonesia, revealing difficulties in understanding temperature and heat topics. The data showed that students required visual media/interactive simulations to conceptualize conduction, convection, and radiation concretely, and demanded flexible web-based and virtual laboratory learning tools for independent study. This study aims to develop and test the feasibility, practicality, and effectiveness of a web based physics learning platform named Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT). The research and development (R&D) method was applied involving eleventh-grade students of SMA Hang Tuah 2 Sidoarjo. The validation results showed feasibility percentages of 89.1% from media experts, 91.6% from product design experts, and 94% from material experts, all categorized as highly feasible. The small group trial achieved an average score of 84% (very good), while the field trial score reached 83% (very good). Usability testing verified that the system performs exceptionally well with an overall average score of 84% (very good) and also based on pre-test and post-test analyses. So, it can be concluded that the Educational Physics Interactive Laboratory of Thermal Transfer platform is highly feasible and practical for use as high school physics learning medium for temperature and heat.

1. Introduction

Physics instruction at the senior high school (SMA) level requires students to not only equip themselves with formal theoretical understanding but also with the ability to construct physical understanding empirically and practically (Wijaya et al., 2022). The characteristics of the material in the Phase F physics curriculum,

particularly the topics of temperature and heat and the subtopic of heat transfer, involve students' understanding of dynamic, often abstract, microscopic phenomena (Utami et al., 2020). In practice, heat transfer processes, including conduction, convection, and radiation, require strong visual representations so that students are not merely memorizing mathematical formulas but also able to understand the particular interactions and underlying thermal energy transfer (Wardani & Danim, 2022). However, limited face-to-face class time, the lack of representative laboratory equipment, and the inherent characteristics of materials often pose major obstacles to concretizing these thermal concepts. For example since covid, there has been a problem where practical activities in the Basic Physics Practical course can no longer be carried out optimally because the learning model must be developed into a virtual physics laboratory as a medium for carrying out practical activities and analyzing the feasibility of the product (Kua et al., 2021).

Empirical conditions in the field indicate a significant gap between the competency demands of the curriculum and students' actual understanding in schools. Based on the results of a pre-research questionnaire conducted with 59 high school students from various schools in East Java, it was found that most students experienced fundamental difficulties in understanding the material on temperature and heat, particularly the concept of heat transfer. The inability to visualize particle movement and energy flow led to the material being perceived as tedious and theoretical (Becker & Syahputra, 2022). When exploring learning strategy preferences, 49.2% of students agreed and 42.4% strongly agreed that heat transfer would be much easier to understand if presented through visual media or interactive simulations rather than relying solely on printed textbooks and conventional teacher explanations. Furthermore, data on student needs showed that 49.2% agreed and 49.2% strongly agreed that they greatly needed innovative learning media capable of displaying clearer, more measurable, and engaging visualizations of conduction, convection, and radiation processes (Rice & Carter, 2021).

These findings strongly indicate that high school students require a more concrete, interactive, and experiential learning environment to optimally develop their cognitive construction of abstract physics concepts (Latifah et al., 2021). In the current era of digital transformation, the use of web-based technology and virtual laboratories offers an adaptive alternative solution to overcome the constraints of space and time in science learning. The results of the pre-research questionnaire also reflect the high level of student readiness and need for the adoption of digital-based learning. Fifty five percent of students agreed and 39% strongly agreed that the physics learning process would be much more engaging if websites containing interactive simulations were integrated. Student interest in conducting independent experiments was also high, with 54.2% agreeing and 39% strongly agreeing that they were interested in using digital simulations to conduct virtual physics experiments. In addition to interactivity, flexibility of access is a key orientation for students, as evidenced by data showing that 57.6% of students agreed and 39% strongly agreed that digital learning media that can be accessed independently anytime and anywhere, without being bound by the constraints of a formal classroom (Nielsen & Budianto, 2021).

The accumulated pre research data demonstrates the clear urgency of developing flexible, interactive digital learning media that supports student self-regulated learning. To address this crucial need, an integrated web-based physics learning platform called the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) was developed. This web-based platform is an innovative interactive digital media platform that comprehensively integrates multimodal learning materials, interactive heat transfer simulations based on variable control, a virtual laboratory with a Problem Based Learning (PBL) approach, AKM assessment practice questions, and responsive online evaluations within a single, integrated web ecosystem (Fadhilah et al., 2021). Through a multimodal learning approach and visualization of kinetic particle motion, this platform is designed to bridge the abstraction of theoretical concepts into dynamic visual representations. The problem faced by private high school teachers and students is that they are not yet skilled in developing Minimum Competency Assessment (AKM) questions based on numeracy, literacy, and scholastics and need to increase the skills of private high school teachers and students in preparing Minimum Competency Assessment questions based on numeracy, literacy, and scholastics (Setyaedhi & Khotimah, 2023).

This research focuses on testing technical feasibility, learning design quality, operational practicality based on user experience, system usability testing, and the platform's effectiveness in boosting students' cognitive learning outcomes. The implementation of the EDU PILOT platform is expected to be able to transform conventional physics learning patterns that tend to be passive into active, exploratory, and meaningful digital scientific investigation activities for high school students, especially in the heat transfer material (Putra et al., 2021). The development contextual-based interactive physics e-modules on temperature and heat materials for junior high school students is really needed because learning media is still dominated by conventional teaching materials makes it difficult for students to understand concepts concretely and less motivated to learn independently as a solution to increase student learning motivation, so the development of digital based learning media is expected to be an effective solution to improve student motivation and quality of understanding (Azhari et al., 2025). The objective of this study is all data collected is empirical, there are no personal assumptions or researcher bias in this introduction section. So, this study aims to develop and test the feasibility, practicality, and effectiveness of a web-based physics learning platform named Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT).

2. Methodology

This study employed a Research and Development (R&D) method. The development model utilized a design oriented interactive digital learning media product that is periodically evaluated through formative testing to produce a valid, practical, and effective final product tailored to field needs. Subjects in this development research included expert validators and high school students as end-users. Product feasibility validation was conducted by three competent experts in

their respective fields: an instructional media expert, a product design expert, and a physics material expert. After undergoing revisions based on the recommendations and notes from the experts, the product was piloted with 11th-grade students of Hang Tuah 2 Senior High School, Sidoarjo, in the odd semester of the relevant academic year. The usability and operational practicality testing stages were conducted at two levels: a small-group trial involving 10 students with heterogeneous academic abilities, and a large-scale field trial implemented in a full class of 36 students.

The research data collection combined qualitative and quantitative assessment instruments. The main similar instruments used included: (1) a feasibility validation sheet for material, media, and design experts, adopting a five-level Likert scale (scored from 1 to 5) to measure the technical quality and substance of the instruction; (2) a student response questionnaire to assess practicality, instructional clarity, media readability, engagement level, and learning motivation; and (3) a system usability testing questionnaire to evaluate five dimensions of human-computer interaction: learnability, efficiency, memorability, error prevention, and satisfaction (Hake, 1998). In addition to the questionnaire, cognitive effectiveness was measured using an objective test instrument in the form of multiple-choice questions with Minimum Competency Assessment (AKM) characteristics, integrated into the platform's digital evaluation module.

The experimental design for this effectiveness test employed a One-Group Pretest-Posttest Design, in which subjects were given a pre-test before using the EDU PILOT website and a post-test after completing the entire learning process with the platform (Hayat et al., 2020). Quantitative percentage data analysis techniques were used to process data sourced from expert validation sheets and student response questionnaires. The actual scores obtained from completing the instruments were accumulated, then divided by the theoretical maximum score, and multiplied by 100 percent to obtain a percentage value for the product's feasibility or practicality (Tseng et al., 2023). This percentage result was then converted into feasibility interpretation criteria adapted from a Likert scale to determine the level of validity (for example, a percentage score above 80% is categorized as very feasible or excellent). Meanwhile, the level of effectiveness in improving students' cognitive learning outcomes was calculated using the Normalized Gain (N-Gain) formula based on the difference between pre-test and post-test scores. The obtained N-Gain index values were then interpreted into three effectiveness categories: high ($g > 0.7$), medium ($0.3 \leq g \leq 0.7$), or low ($g < 0.3$) to demonstrate the significant impact of using an interactive platform in reducing abstract misconceptions about heat transfer (Ridlo et al., 2023).

3. Results and Discussion

EDU PILOT Platform Development

This research successfully developed the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) platform as a web-based physics

learning medium for temperature and heat. This platform integrates five main features into one integrated system: a homepage based on a card interface navigation; a Material Menu that implements multimodal learning with visualization of kinetic particle movement; an Interactive Simulation Menu to model conduction, convection, and radiation phenomena in real time; a Virtual Lab Page using the Problem Based Learning (PBL) approach "Design a Simple Thermos"; and a Knowledge Evaluation Module equipped with an immediate feedback feature supported by a guided inquiry-based Student Worksheet (LKPD) (Sulaeman et al., 2020). This results show the root of the problems at SMA Hang Tuah 2 Sidoarjo in the learning process of temperature and heat through the development of EDU PILOT and the problems that emerged include:

1. Frequent misconceptions, such as the assumption that "hot objects must have a higher temperature" without understanding the amount of heat. For example, students think that objects with a higher temperature always contain more heat, when in fact the amount of heat is influenced by mass and specific heat.
2. Poor conceptual understanding, especially in reading temperature-time graphs, understanding specific heat, and distinguishing between conduction, convection, and radiation. Lack of opportunities to conduct experiments makes it difficult for students to read heating graphs, differentiate between conduction, convection, and radiation mechanisms, and reason scientifically about thermal phenomena.
3. The current limitations of laboratory facilities at Hang Tuah 2 High School, Sidoarjo, include the lack of dedicated laboratory staff; instead, administrative staff are assigned to assist physics, biology, and chemistry teachers. This requires extensive preparation time, making experimental activities impossible to conduct routinely.

The Systematic Development Stages of EDU PILOT: Needs Analysis, Interface Design, Development of Temperature and Heat Simulation Features, Integration of Virtual Experiments, and Product Testing and Revision

So, to develop the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) platform as a web-based physics learning medium for temperature and heat for students, Analysis, Design, Development, Implementation, and Evaluation (ADDIE) were conducted. The results also show that this study connects physics learning problems, supporting theories, and multimedia development models into a logical flow that leads to a solution in the form of the EDU PILOT system. This system is not only expected to address existing problems but also to make a significant contribution to improving the quality of physics learning at SMA Hang Tuah 2 Sidoarjo. Through this integrated approach, it is hoped that students will not only gain knowledge but also critical thinking skills that will be useful in their future lives. The development of EDU PILOT is positioned as a solution to address misconceptions, the lack of interactive media, and limited access to physics laboratories. This system is expected to provide an exploratory, interactive, and independent learning experience. Thus, EDU PILOT functions not only as a

learning aid, but also as a platform that encourages students to think critically and creatively in understanding the concepts of temperature and heat.

Needs Analysis

The description of this stage is to identifying learning needs and problems through analysis of teacher and student needs related to learning physics on temperature and heat, analysis of the Phase F curriculum for grade 11, analysis of student characteristics (learning styles, initial abilities, digital literacy), analysis of limitations in laboratory practical learning, and analysis of school ICT facilities and infrastructure. So, it is really important to make the description of the learning needs, description of learning problems, until the specification of EDU PILOT system requirements. A student needs analysis was conducted to identify the extent to which students require alternative learning media to help them understand the abstract concepts of temperature and heat. Based on classroom observations during the lesson, it was discovered that 11th-grade students in Phase F of Hang Tuah 2 Senior High School, Sidoarjo, struggled to grasp the concepts of temperature and heat. Temperature and heat are topics that address energy transfer at the atomic level, making them difficult to observe through direct experiments. Learning time at school is very limited, in contrast to the extensive physics material covered in 11th-grade Phase F. The co-curricular project schedule, which includes cross-subject projects each semester, automatically reduces classroom practicum time. Conditioning students for hands-on practicum is more challenging and requires a long time, especially considering the estimated time spent moving students from the classroom to the physics laboratory. Therefore, students need media that provide concrete visualizations of heat transfer processes, changes in state of matter, the relationship between temperature and energy, and heating graphs. This need emphasizes the need for interactive, easily accessible digital media that can provide learning experiences that resemble real experiments.

Interface Design

The description of this stage is to designing a web-based learning solution through developing learning objectives on temperature and heat, designing the content structure and learning path, designing the virtual laboratory features for heat transfer, developing a system storyboard and flowchart, designing the interface (UI/UX), and developing evaluation instruments (validation, questionnaires, observations). So, it is really important to make the description of the designing the EDU PILOT system, storyboarding and flowchart, designing the UI/UX, and drafting research instruments. Here, it is important to consider various design elements, such as user interface, navigation, and interactivity. For example, in the development of the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) system, an intuitive and engaging interface design can increase student engagement. Furthermore, the use of appropriate colors and visual elements can help students grasp complex concepts more easily as seen in Figure 1. An initial prototype can be created to obtain user feedback before proceeding to the development phase.



Figure 1. EDU PILOT Logo and Main Menu

The results are the user interface and user experience design for EDUPILOT. The UI/UX design was created using Figma AI, as it has been proven to facilitate the creation of consistent and user-friendly interactive media layouts. Wireframes, storyboards, icons, interaction diagrams, and navigation designs were designed to ensure the media is easily understood by students. The EDU PILOT homepage contains the EDU PILOT logo and homepage, as well as an overview of the menu.

Development of Temperature and Heat Simulation Features

The description of this stage is to developing and validating the product through developing a web-based EDU PILOT platform, integrating temperature and heat materials and virtual labs, developing multimedia learning materials (text, images, simulations), and conducting validation with media and subject matter experts, conduct revisions based on expert input as seen in Figure 2. So, it is really important to make the description of the initial EDU PILOT product, expert validation results, and revised product from the development stage.

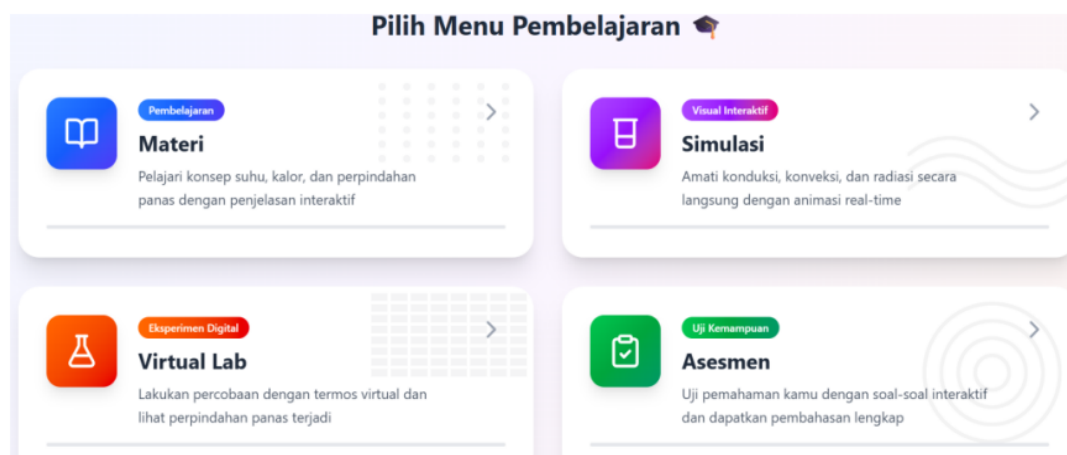


Figure 2. Main Menu Options on the EDU PILOT Page

Researchers built a web interface based on the design created in the previous stage. The development was carried out using Figma AI as a design tool and then converted into a web platform that supports student interaction. The interface was kept as simple as possible to make it easy for high school students to understand. On the home page, scrolling down will display menu options and specific information, including: materials, simulations, virtual labs, and assessments. For example, the Assessment menu contains quizzes and questions to measure the learning achievement.

The Learning Materials page contains specific choices for the material to be studied, including temperature, heat, expansion, and heat transfer as seen in Figure 3. The material is aligned with the high school curriculum content for physics, phase F, grade 11, and is also fully aligned with the basic concepts of temperature and heat. Researchers also designed learning interaction models, such as virtual laboratory simulations, heat transfer animations, and particle motion visualizations. This design follows the principles of multimedia learning, namely that content must combine text, images, animation, and interaction proportionally to reduce students' cognitive load.

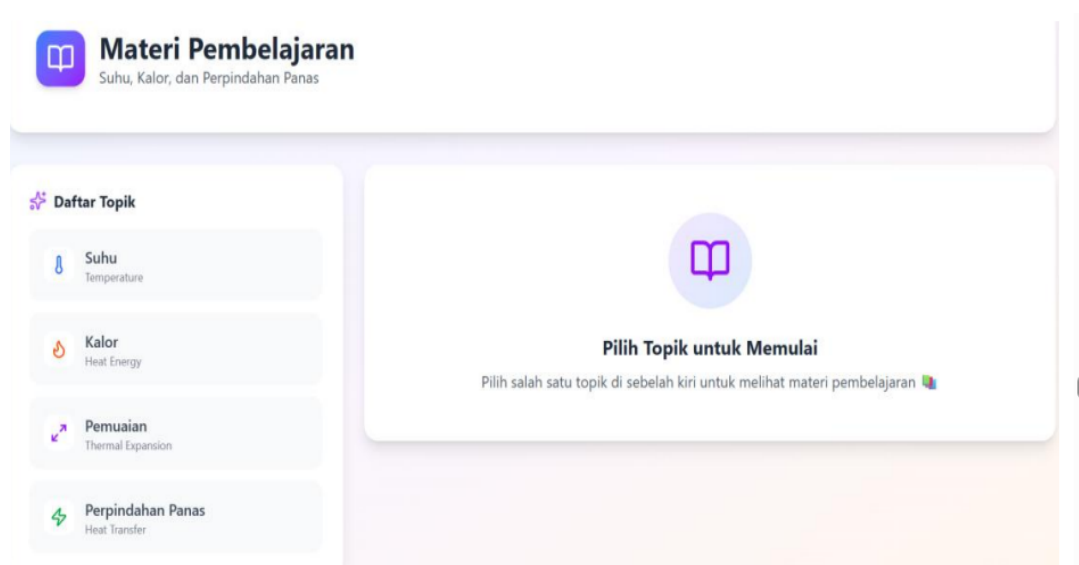


Figure 3. User Interface of Learning Materials in EDU PILOT

Physics learning content was developed in the form of narrative text, illustrative images, demonstration videos, and animations of thermal phenomena. Animation was chosen because it effectively facilitates understanding of abstract concepts such as specific heat, heat transfer, and temperature-time graphs. Researchers developed a virtual laboratory simulation that allows students to conduct digital experiments such as heating substances, measuring temperature, and analyzing heating graphs.

Integration of Virtual Experiments

The description of this stage is to testing the practicality and acceptability of the product through one-on-one trial with 3-5 students, small group trial with 8-12

students, limited field test in one eleventh-grade class, and teacher mentoring in system use. So, it is really important to make the description of the student and teacher response data, observation data on use, and revised product from implementation. Therefore, students from certain classes were selected as trial subjects because they align with the target users of the EDU PILOT system, particularly in the topic of temperature and heat, which requires virtual experiments to enhance conceptual understanding. The objectives of the field trial included measuring learning effectiveness, which was assessed based on a comparison of pre-test and post-test scores, assessing student acceptance of the system, including interest, motivation, and engagement during media use, observing the system's suitability within the classroom learning flow, including integration with the teacher's teaching methods, and identifying technical and pedagogical challenges that might arise during full-scale use. The field trial is the final stage before the system is declared suitable as a development product that can be recommended for use in physics learning in schools. These results indicate that students responded positively to the use of the EDU PILOT platform in physics learning on heat transfer. Students found learning using the web-based platform more engaging than conventional learning because it includes interactive simulations, concept visualizations, and a more communicative interface.

Product Testing and Revision

The description of this stage is to evaluating and assessing the feasibility and effectiveness of the product through formative evaluation at each stage of ADDIE, analysis of expert validation results, analysis of user trial results, analysis of effectiveness on student learning outcomes, and refinement of the final product. So, it is really important to make the description of the final product EDU PILOT, conclusions on feasibility and effectiveness, and recommendations for implementation. The Evaluation feature on the EDU PILOT platform was developed as the final part of the learning series to measure students' level of understanding after studying the material, observing interactive simulations, and engaging in activities in the virtual laboratory. The evaluation is presented in the form of multiple-choice questions designed based on learning indicators for the temperature and heat topic, particularly the concept of heat transfer. Through this feature, students can re-examine their conceptual understanding and identify areas of the material that require further study. In addition to serving as a tool for measuring learning outcomes, the evaluation feature also serves as a means of reflection for students to independently assess their learning outcomes, as seen in Figure 4.

After students complete all the questions, the EDU PILOT system provides immediate feedback on the answers they choose. This feedback not only displays correct or incorrect results but also includes relevant conceptual explanations, helping students understand the rationale behind each answer. This feature allows for immediate feedback and minimizes the emergence of misconceptions in the heat transfer topic. With systematically presented learning outcome indicators and information, the evaluation feature becomes an important component in supporting independent learning while ensuring that the learning experiences gained through

simulations and virtual laboratories can be internalized into deeper conceptual understanding. Based on these results, researchers made revisions by adding simpler and more communicative user instructions to several parts of the system, simplifying navigation for certain features, improving font size, and color consistency.



Figure 4. EDU PILOT Knowledge Evaluation Features

The content and language aspects also received the highest scores of 96% each, indicating that the heat transfer material presented aligns with the physics learning outcomes of Phase F and uses communicative language that is easy for high school students to understand. There is no ambiguity in the delivery of the material, the sentences used are not complicated or convoluted, so there is a connection between the material, simulations, and experiments. The user satisfaction aspect achieved the highest percentage of 88%, categorized as very good. The high score in this aspect indicates that students are satisfied with using the EDU PILOT platform in learning physics. Students stated that learning using interactive digital media is more engaging, less boring, and helps improve understanding of the concept of heat transfer.

Platform Feasibility and Practicality

The researchers then presented the quantitative data analysis. To efficiently test the platform's feasibility and practicality, validation by three experts (media, product design, and materials) and user trials were conducted in two stages (small group and large-scale field trials with 11th grade students at Hang Tuah 2 Senior High School, Sidoarjo). The expert validation data are summarized in Table 1, while student response data and system usability testing are summarized in Table 2. The summary from the experts is very important for the sustainability of the development of EDU PILOT for high school students as seen in Table 1 and shows the accumulated assessments from all expert validators yielded an average score of 91.6%, categorized as very feasible. This demonstrates that the EDU PILOT

platform meets digital media quality standards, both in terms of technological functionality and the validity of the physics concept substance.

Table 1. Summary of Expert Feasibility Validation Results

No	Validator Expert	Main Assessment Aspect	Presentation	Category
1	Media Expert	Visual Display, Interactivity, Multimedia, Media Techniques	89,1%	Very Good
2	Product Design Expert	UI, UX, Learning Design, Product Innovation	91,6%	Very Good
3	Physics Material Expert	Content Feasibility, Language, Presentation, Learning Evaluation	94,0%	Very Good
Average Feasibility			91,6%	Very Good

Then, in prioritizing feedback from a trial of a learning system, responses are needed from users, namely students, and the usability of the platform as seen in Table 2, so the EDU PILOT platform proved to be highly practical and highly accepted by students, with an average practicality score of 83.7% (Very Good). The integration of virtual laboratory components and interactive visualizations into the platform proved effective in stimulating student interest in learning (86% in the field test) and providing high user satisfaction (88% in the usability test).

Table 2. Summary of User Responses and Platform Usability

No	Testing Stage	Dimension/Main Assessment Aspect	Average	Category
1	Small Group Test	Ease of Use, Display, Instructions, and Simulation	84,0%	Very Good
2	Field Test	Interest, Ease of Use, Understanding, Independence, Motivation	83,0%	Very Good
3	Usability Test	Learnability, Efficiency, Memorability, Error Prevention, Satisfaction	84,0%	Very Good
Average Practicality			83,7%	Very Good

Effectiveness of Improving Cognitive Learning Outcomes

The effectiveness test was conducted using a one group pretest until posttest design on 36 students in grades XI-C1 using a multiple choice test instrument based on the AKM. The results of the cognitive learning outcome test and the Normalized Gain (N-Gain) index analysis are summarized in Table 3, which is important to enhancing self- efficacy, particularly the strength dimension, can improve

numeracy skills and AKM readiness and this underscores the importance of tailored interventions to strengthen self-efficacy and recommends further students into additional factors affecting numeracy performance and interdisciplinary approaches to teaching numeracy across subjects (Alatas et al., 2025). The data in Table 3 shows a significant shift in students' average cognitive scores, from 38.25 to 72.47. Based on the mathematical calculation of the achievement difference, the N-Gain value was 0.55, which falls into the Moderate category.

Table 3. Results of the Analysis of Students' Pre-test, Post-test, and N-Gain Index

Evaluation Parameter	Student Cognitive Score	N-Gain Index	Effectiveness Category
Number of Students Respondents	36		
Average Pre-test Score	38,25		
Average Post-test Score	72,47	0,55	Moderate
Pre-test Score Range (Lowest - Highest)	20 – 67		
Post-test Score Range (Lowest - Highest)	30 – 90		

The results of this study relate to constructivism-based learning theory, inquiry-based learning, and the use of virtual laboratories that allow students to explore, observe, and test hypotheses independently. Therefore, the research findings not only demonstrate the effectiveness of the product but also demonstrate the pedagogical mechanisms that support this effectiveness. This is also based on previous literature, for example about the analysis that conducted on class VIII students at SMP Negeri 8 Pekanbaru regarding their perceptions of science learning at school, it is known that almost all class VIII students do not understand science lessons and can be used is PhET Simulation to determine the cognitive learning outcomes of physics science through the application of the PDEODE learning model, including posttest (Faza et al., 2024).

Next, The low learning outcomes of fourth grade students at SD Negeri 1 Jamblang are the main reason for the implementation of the Problem Based Learning (PBL) model in improving learning outcomes for achieved the Minimum Competency (KKM), so the model has proven effective in improving the activeness and learning outcomes of fourth grade students (Gunawan et al., 2026). Another research aims to develop Augmented Reality (AR) based learning media for the IPAS subject, focusing on the Plant Body Parts material for fourth-grade students at Lasoani State Elementary School through Research and Development (R&D) approach, and the results demonstrate that the AR based media effectively transforms abstract content into interactive visualizations, increases student engagement, and supports meaningful learning (Munawarah, 2025).

There is also a study about the learning outcomes of students whose learning uses the Guided Inquiry learning model on students' critical thinking skills in the science

course in grade IV of SD Inpres 2 Besusu with a pre-experimental experimental design in the form of a pretest-posttest design for one group, so the result is Critical Thinking Ability of Social Science Students on the Influence of Social Science Learning Outcomes was successful (Nuraini et al., 2025). Next, the ability to think creatively and learn independently is an important factor in student success in the learning process, and one model that plays an important role in increasing creative thinking and independent learning is the project based learning (PjBL) model to improve creative thinking abilities and learning independence to students at a high school in Pekanbaru (Sundari et al., 2025). So finally is really important to increase in learning outcomes after implementing the problem based learning model, for example assisted by video media and also to improve the learning outcomes of class XI students at SMAN 1 Haharu through calculating student learning completeness in cognitive assessment and calculating student learning completeness in affective assessment (Tonda et al., 2024).

Finally, the results empirically demonstrate that the Web-Based Interactive Physics Laboratory on the EDU PILOT platform is effective as a learning medium for improving high school students' conceptual understanding. Through visualizations of convection circulation currents, conduction contact transfer, and Stefan-Boltzmann radiation modeling, this platform successfully reduces the abstraction of temperature and heat material into a concrete, interactive digital experimental environment that supports student independent learning (Widoyoko et al., 2019). So computational thinking skills are among the essential competencies students must master to face the challenges of the digital era and the feasibility, characteristics, and impact of a STEM-based 3D virtual laboratory on students' computational thinking skills in the topic of temperature, heat, and expansion are very important (Wintribrata et al., 2025). The development of EDU PILOT is positioned as a solution to address misconceptions, the lack of interactive media, and limited access to physics laboratories. This system is expected to provide an exploratory, interactive, and independent learning experience. Thus, EDU PILOT functions not only as a learning tool, but also as a platform that encourages students to think critically and creatively in understanding the concepts of temperature and heat. For example, students can conduct virtual experiments that allow them to change variables and see the results directly, thus learning to connect theory with practice. Therefore, a web-based physics learning platform called the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) is better for building conceptual understanding than conventional learning or practical work, which is limited by physical laboratory facilities.

4. Conclusion

Based on the results of the research and development conducted, it can be concluded that the Educational Physics Interactive Laboratory of Thermal Transfer (EDU PILOT) platform is highly feasible and practical for use as a high school physics learning medium for temperature and heat. Assessments by expert validators, covering media, product design, and physics materials, resulted in an average validity, categorized as highly feasible. Furthermore, the platform's practicality and

acceptability among end-user students also demonstrated excellent performance, with an average student response score and system usability test score supported by a high level of satisfaction with the interface. Beyond feasibility and practicality, the EDU PILOT platform has proven effective in transforming conceptual understanding and boosting cognitive learning outcomes among high school students. The implementation of this web-based media significantly increased students' average score in the pre-test and the post-test, and resulted in a Normalized Gain (N-Gain) index, categorized as moderately effective. Based on these results, researchers also made revisions by adding simpler and more communicative user instructions to several parts of the system, simplifying navigation for certain features, improving font size, and color consistency. The integration of virtual laboratory features, interactive simulations based on variable control, and guided inquiry worksheets (LKPD) proved effective in meeting students' needs in the field by reducing the abstraction of heat transfer material into a concrete, interactive, and adaptive digital experimental environment, facilitating independent and flexible student learning.

References

- Alatas, F., Latifah, J., Budiyo, A., & Panre, A. M. (2025). Unveiling the Link Between Numeracy Skills and Self Efficacy : A Study on Physics Learning Through AKM Assessments. *16*(4), 340–351. <https://doi.org/10.26877/jp2f.v16i4.1866>
- Azhari, G., Aminoto, T., & Aj, S. (2025). I Interactive Contextual-Based Physics E-Module on Temperature and Heat Material to Enhance Middle School Students' Understanding. *KUANTUM: Jurnal Pembelajaran dan Sains Fisika*, *6*(2), 249-256.
- Becker H. J., & Syahputra, M. R. (2022). Immediate Feedback Systems in Web Based Physics Evaluation: Reducing Misconceptions in Heat Transfer. *International Journal of Science Education*, *44*(11), 1765–1783
- Fadhilah, N., Wahyuni, S., & Mahardika, I. K. (2021). Developing Guided Inquiry Student Worksheets (LKPD) Integrated With Digital Physics Experiments. *Jurnal Pendidikan Sains Indonesia*, *9*(3), 412–425
- Faza, F. F., Nasir, M., & Rahmad, M. (2024). Application of the PDEODE Learning Model Assisted by PhET Simulation to Improve the Cognitive Learning Outcomes of Physics Science for Class VIII Students. *Journal of Educational Sciences*, *8*(2), 187-194. <https://doi.org/10.31258/jes.8.2.p.187-194>
- Gunawan, W. A., Darmini, M., & Sati, S. (2026). Implementation of Problem Based Learning Model to Improve Learning Outcomes of Fourth Grade Students at SDN 1 Jamblang. *Journal of Educational Sciences*, *10*(1), 38-47. <https://doi.org/10.31258/jes.10.1.p.38-47>
- Hake, R. R. (1998). Analyzing Change and Gain Scores in Learning Physics Concepts Using One Group Pretest Posttest Design. *American Journal of Physics*, *66*(1), 64–74
- Hayat, M. S., Sukarso, A., & Rahmat, A. (2020). Problem-Based Learning Via Virtual Laboratory to Enhance Students' Critical Thinking Skills. *Journal*
-

-
- of *Baltic Science Education*, 19(2), 231–243
- Kua, M. Y., Suparmi, N. W., Ngurah, D., & Laksana, L. (2021). Virtual Physics Laboratory With Real World Problem Based on Ngada Local Wisdom in Basic Physics Practicum. *Journal of Education Technology*, 5(4), 520–530
- Latifah, S., Khoeriyah, K., & Samsudin, A. (2021). Multimodal Learning Strategy in Physics: Visualizing Heat Transfer Through Digital Media. *Journal of Physics: Conference Series*, 1806(1), 012015
- Munawarah, S. (2025). Development of Augmented Reality-Based Learning Media in Science Learning on Plant Body Parts Material for Grade IV of Lasoani State Elementary School. *Journal of Educational Sciences*, 9(4), 2884-2894. <https://doi.org/10.31258/jes.9.4.p.2884-2894>
- Nielsen, J., & Budianto, R. (2021). Usability Testing of Virtual Laboratory Networks for High School Science K-11 Classrooms. *IEEE Transactions on Learning Technologies*, 14(5), 602–614
- Nuraini, N., Sari, D. A., Zulfuraini, Z., Aras, N. F., & Khairunnisa, K. (2025). The Influence of the Guided Inquiry Learning Model on Students' Critical Thinking Skills in Fisheries Subjects in Grade IV of SD Inpres 2 Besusu. *Journal of Educational Sciences*, 9(5), 4695-4706. <https://doi.org/10.31258/jes.9.5.p.4695-4706>
- Putra, B. Y. G., Wijaya, I. G. N. Y., & Sunarya, I. M. G. (2021). Designing Card Interface and Navigation Bar System for Responsive E-Learning Platforms. *International Journal of Interactive Mobile Technologies*, 15(8), 78–92
- Rice, M. F., & Carter, N. (2021). Self-Regulated Learning in Digital Environments: High School Students' Experiences With Web Based Science Platforms. *Educational Technology Research and Development*, 69(3), 845–863
- Ridlo, Z. R., Astutik, S., & Bektiarso. (2023). The Effectiveness of Web Based Interactive Physics Laboratory Toward Student Engagement and Cognitive Outcomes. *Jurnal Pendidikan IPA Indonesia*, 12(1), 15–26
- Setyaedhi, H. S., & Khotimah, K. (2023). Workshop for Preparation of Minimum Assessment for Private High School Teachers. 7(3), 282–292
- Sulaeman, A. R., Sumantri, M. S., & Hakim, A. R. (2020). Interactive Virtual Laboratory: A Tool for Overcoming Abstract Concepts in High School Physics Learning. *Jurnal Pendidikan Fisika Indonesia*, 16(2), 112–120
- Sundari, A., Yennita, Y., & Syafii, M. (2025). Analysis of Project-Based Learning Design Needs: Building Students' Creative Thinking Skills and Independent Learning. *Journal of Educational Sciences*, 9(2), 936-953. <https://doi.org/10.31258/jes.9.2.p.936-953>
- Tonda, M. R., Makaborang, Y., & Enda, R. R. H. (2024). Application of the Pbl Learning Model Assisted by Video Media to Improve Student Learning Outcomes at Sman 1 Haharu. *Journal of Educational Sciences*, 8(1), 12-21. <https://doi.org/10.31258/jes.8.1.p.12-21>
- Tseng, K. H., Chang, C. C., & Lou, S. J. (2023). Experiential Learning With Web Based Simulations in High School Physics: A Case Study on Thermal Dynamics. *Interactive Learning Environments*, 31(2), 998–1012
- Utami, N. W., Astra, I. M., & Nasbey, H. (2020). Development of Web Based Interactive Physics Simulation on Temperature and Heat Topics. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 6(1), 45–54
- Wardani, R. T. S., & Danim, S. S. (2022). The Effect of Dynamic Kinetic Particle
-

- Simulations on Conceptual Understanding of Thermal Physics. *Journal of Science Education and Technology*, 31(4), 491–503
- Wijaya, A. F. C., Wibawanto, S. C., & Utomo, H. B. (2022). Real Time Simulation of Conduction and Convection using Color Gradations in Web Environments. *Computers & Education*, 178, 104390
- Wintribrata, B. H., Amelia, R. N., & Listiaji, P. (2025). Thermolab for STEM: An interactive 3d virtual lab to strengthen students' computational thinking in heat, temperature, and expansion. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 14(2), 138-156.
- Widoyoko, E. P. (2019). *Teknik Penyusunan Instrumen Penelitian dan Penilaian Skala Likert*. Yogyakarta: Pustaka Pelajar.

How to cite this article:

Rohmah, R., Degeng, N. S., Nurmida., & Sitompul, C. (2026). Development of Edu Pilot: A Web-Based Interactive Physics Laboratory on Temperature and Heat for High School Physics Learning. *Journal of Educational Sciences*, 10(7), 1087-1102.
