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PhET-Aided Blended Problem Based Learning Rotation Model to Improve Junior High School Students' Higher-Order Thinking Skills

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Abstract: To face global challenges, students need to be equipped with Higher-Order Thinking Skills (HOTS). This study aimed at analyzing the positive contributes of the Physics Education and Technology (PhET)-aided Blended-Problem-Based Learning Rotation (BPBLR) model in improving HOTS and describing student responses to the PhET-aided BPBLR model. This study involved 98 seventh grade students in Singaraja who were spread across 3 experimental groups, namely 31, 33, 34, and without control group. This research design was a pre-test and post-test group design. The collected data were analyzed using paired-test, normalized gain (N-gain), and ANOVA. The results of the Paired-Test showed that there was a significant difference in students' HOTS achievement with the PhET-aided BPBLR Model between pretest and posttest for three groups at $p < 0.05$. The average N-gain HOTS values in each group are: 0.46, 0.45, and 0.46, which are in the moderate category. The ANOVA test results show that the average N-gain values of the three groups is consistent at $p < 0.05$. Student responses are in very high category. Thus, the use of the PhET-aided BPBLR model contributes positively to improve students' HOTS, and student responses are in very high category.

Keywords: BPBLR model; Higher-Order Thinking Skills; PhET

Introduction

In the 21st century, the educational process is geared toward skills and learning innovation. In the educational process, in addition to acquiring basic knowledge, students also develop critical and creative thinking skills, as well as the ability to solve unstructured and complex problems (Haryati et al., 2024; Ramadhani et al., 2022). The rapid advancement of 21st-century science and technology has impacted children's inability to recognize, understand, and solve problems around them. One solution is higher-order thinking skills (HOTS)-oriented learning. HOTS has become a key element of the 21st century, moving towards the information age (Fananta et al., 2017; Prihatni et al., 2016; Novili et al., 2017). HOTS are very important for the younger generation to master (Gading & Rohaeti, 2024; Hasan, 2024; Hasruddin et al., 2024; Muskhir et al., 2024; Setyani et al., 2024). HOTS have become a focus in the goal of providing education in Indonesia (Jumanto et al., 2024; Maryanti & Sartono, 2024; Jihannita et al., 2023). One subject that can train HOTS is science (Setiawati et al., 2019; Mukhtar & Hanin, 2019). Science learning is the foundation for HOTS training (Astuti et al., 2017).

Education plays a crucial role in every HOTS orientation in science learning (Griffin & Care, 2015; Jatmiko et al., 2018; Sujanem et al., 2024; Pratiwi et al., 2019). The main objective of HOTS is how to improve students' thinking skills at a higher level, especially those related to critical thinking skills (CTS) in receiving various types of information, thinking creatively in solving problems using knowledge and making decisions in complex situations (Gultom et al., 2021). Improving HOTS is crucial to support students in facing

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global educational challenges. HOTS is necessary to be trained and developed in learning. HOTS is key in education for solving problems. The chosen learning model must be focused on problem-solving goals and provide innovative solutions to those problems (Ichsan et al., 2022).

HOTS play an essential role and needs to be practiced and developed in learning (Collins, 2014). The higher a student's HOTS, the greater the impact on their work readiness (Hasan & Pardjono, 2019). HOTS is a crucial aspect of the teaching and learning process. It encompasses creative thinking skills and critical thinking skills (Sparman, 2021). However, the quality of science education remains low. The 2022 PISA study results showed that Indonesia's science ranking was 69th out of 81 countries, with the score of the student achievement, globally declined (OECD, 2023). This is also supported by research findings showing low critical thinking skills, which are part of HOTS, conducted by researchers (Riani et al., 2014; Sujanem et al., 2024).

The findings of this study confirm that students' HOTS is low. This is also supported by the results of research by Jangko & Yuwono (2024), Sujanem et al. (2024), and Alfiah & Dwikoranto (2022). Students' HOTS is low from year to year (Sari et al., 2021; Astuti et al., 2017). This shows that the quality of Indonesian science education is still low. Interpretation of these study results implies the need to implement HOTS-oriented learning. The low level of HOTS achievement of students is also caused by the assessment instrument. The instrument only measures the cognitive aspect of understanding, not the comprehensive cognitive level (Astuti et al., 2017; Alfiah & Dwikoranto, 2022). This is also reinforced by the results of the initial HOTS test study on temperature, heat, and expansion conducted at SMPN 1 and SMPN 6 Singaraja, the average scores were 32.0 and 36.0, respectively, categorized as low, even though students had received the lesson.

Many factors contribute to students' low HOTS. One major cause is the lecture-based nature of science instruction in schools, where students receive only information and are presented with problems presented in numbers and calculations (Sujanem et al., 2024). Science practice questions are not designed to relate to contextual everyday phenomena and complex unstructured problems encountered in everyday life. The low achievement of HOTS students occurs because the packaging of education is often not in line with the nature of learning and teaching science. Therefore, it is necessary to design educational packaging that is in line with the nature of learning and teaching, namely: how students learn, how teachers teach, how the learning messages in the teaching materials are not solely on learning outcomes (Lawson, 1998; Brooks & Brooks, 1993). HOTS really need to be trained and developed in learning. HOTS is key in education to solve a problem. The model and tools are not yet oriented towards achieving HOTS. So far, model and tools are still dominant present concepts, examples, and practice questions. Therefore, it is necessary to design innovative models and along with technological advances.

One of the existing innovative learning models is a combination (blended) model between the face-to-face Problem-based Learning (PBL) model and online learning, known as Blended PBL or (BPBL) (Lawson, 1998; Shofiyah & Fitri, 2018; Donnelly & McSweene, 2009; Moeller et al., 2010). The BPBL model is a blended learning model between face-to-face and online PBL (Liu et al., 2020; Salari et al., 2018). This model presents problems as a stimulus for learning, both face-to-face and online. The problems presented are complex and unstructured, and are related to the students' real world (Arends, 2015). So far, the BPBL is still implemented separately, with some face-to-face and some online. The first meeting is face-to-face, the second can be online, and so on. This conventional BPBL model is a combination of online and face-to-face learning, which is static, where the offline/online learning portion is usually separated by day or used only for providing practical materials (Siregar, 2024). In this model, online platforms are generally used for uploading assignments or discussion forums. Problems are usually resolved through one-way discussions or full-group completion of Student Worksheets. This conventional BPBL model is a combination of online and face-to-face learning, which is static, where the offline/online learning portion is usually separated by day or used only for material delivery. In this model, online platforms are generally used for uploading assignments or discussion forums. Problems are usually resolved through one-way discussions or full-group completion of Student Worksheets.

The novelty offered in this study is that students continue to learn in class, but the learning remains online, known as BPBL Rotation (BPBLR) (Staker & Horn, 2012; Ambarli et al., 2020; Maryani et al., 2022; Khistow, 2011). The innovation lies in utilizing online learning at any time integrated with face-to-face learning in class. This allows students to learn in multiple directions, utilizing the internet at any time. At the same time, students focus on face-to-face learning with the teacher in class listening to the teacher's instructions as a facilitator and mediator.

On the other hand, several novelties emerged in the BPBLR model, including: Students rotate between learning activity stations (face-to-face, online collaboration, and virtual laboratories) in a single session or structured schedule. This BPBLR model has been adopted as a modern development standard. This model often incorporates interactive simulation media (such as PhET for science), allowing students to test their problem-solving skills in real time at one of their rotation stations (Siregar, 2024; Nugraha, 2020; Kumalasari & Pramono, 2024). Students are given the opportunity to practice HOTS through problem-solving and independent/digital exploration using PhET simulations. These results are then discussed in groups during face-to-face rotations. This model significantly increases the opportunities for student independence and time management, as students must be able to complete both online and offline assignments within the rotation deadlines (Kumalasari & Pramono, 2024).

The combined learning station rotation type allows students to visit multiple stations or centers repeatedly and non-linearly during a designated time for a specific subject matter (Nugraha, 2020). Each station may offer a different type of activity or learning content, such as an online learning station for reading articles, a face-to-face station for group discussions, or a lab station for experiments (Siregar, 2024).

Another innovation is the use of PhET simulations, which can facilitate practical activities despite the limitations of laboratory equipment. Due to limited laboratory equipment, PhET is assisted (Sujanem et al., 2024). This PhET integrated BPBLR model provides opportunities for HOTS acquisition (Sujanem et al., 2024; Alfiah & Dwikoranto, 2022). The developed BPBLR tool contains science phenomena, unstructured problems, PhET simulations, essential concepts, and examples & HOTS practice questions (Sujanem et al., 2024).

Students are given the opportunity to practice HOTS through problem-solving and independent/ digital exploration with PhET simulations. According to Saputra et al. (2020), PhET simulations are teaching tools that contain specific content for virtual reality training simulations. On the other hand, Khairunnastuti et al. (2026) and Saputra et al. (2020) also revealed that the use of PhET simulation media influences students' physics learning outcomes. Furthermore, Susilawati et al. (2021) stated that through PhET, there is an emphasis on the relationship between practical phenomena and underlying knowledge, encouraging interaction and constructivism, offering feedback, and creating a work environment.

Based on the above explanation, regarding the low HOTS scores of students, it is necessary to design a learning model that integrates learning that provides opportunities for the growth and development of students' HOTS, namely the PhET-assisted BPBLR model equipped with learning tools.

The primary innovation of the PhET-aided BPBLR model lies in the flexibility of problem exploration and independent and group learning, where students alternate between face-to-face collaborative problem-solving and online stations for independent science literature. This allows students to learn in multiple directions, utilizing the internet at any time, while simultaneously focusing on face-to-face learning with the teacher in the classroom, listening to the teacher's instructions as a facilitator and mediator. Another innovation is the use of PhET simulations, which can assist practical activities despite the limitations of laboratory equipment.

In this BPBLR model, Students engage in online learning independently, while face-to-face learning with the teacher remains in the classroom (Staker & Horn, 2012; Ambarli et al., 2020; Maryani et al., 2022; Khistow, 2011). This learning model presents problems as a stimulus for learning both face-to-face and online simultaneously. The problems presented are very complex and unstructured, and related to the students' world. Problem-based learning conducted face-to-face in class and also online aims to enable students to identify and find solutions to problems both academically and in everyday life, and can improve CTS and HOTS (Staker & Horn, 2012; Ambarli et al., 2020; Maryani et al., 2022; Khistow, 2011; Liu et al., 2020; Saputro et al., 2020; Savery, 2015; Sulasih et al., 2018).

The theoretical foundations supporting the use of the PhET-assisted BPBLR model are constructivism, blended learning, PBL, meaningful learning theory, Vygotsky's learning theory, Albert Bandura's learning theory, and online learning theory. According to constructivism, learning means constructing meaning (Pebriyanti et al., 2015; Ismiyati et al., 2019; Rillero & Camposeco, 2018). Meaning is created by students from what they see, hear, feel, and experience. The blended learning model can encompass any form of instructional technology with instructor training to enhance learning transfer (Ng et al., 2020).

The integration of ICT, such as PhET simulations in education, particularly in blended learning, has revolutionized learning and provided opportunities for achieving HOTS and higher learning outcomes (Staker & Horn, 2012; Ambarli et al., 2020; Maryani et al., 2022; Khistow, 2011; Sulaiman, 2013; Sulaiman et al., 2017; Sari et al., 2021). Blended learning also shortens students' learning time, enabling them to become independent and improve their learning abilities at their own pace (Jangko & Yuwono, 2024; Syifa et al., 2022). This not only facilitates better understanding for students but also opens up opportunities to create a more interactive and engaging learning environment. The blended learning model is also an integral part of teacher professional development (Hikmawati et al., 2023; Husnawati & Rakhmawati, 2024).

The main objective of this study is to determine the positive contributions of the BPBLR model in improving the HOTS of Singaraja junior high school students in science learning. HOTS indicators include: analyzing, evaluating, and also creating (Anderson & Krathwohl, 2001). The use of higher-order thinking is a characteristic of HOTS. In the use of HOTS, it needs to be supported by facts, linking; connecting one fact to another, categorizing, manipulating, and used to find new solutions and make the right decisions in facing problems (Setiawati et al., 2019; Mukhtar & Hanin, 2019). If students are encouraged to think at a higher level, they will also be able to analyze, evaluate, and elaborate a concept well, and then be able to implement it in the process of daily life. Based on the acquisition of HOTS, students will be able to learn, improve their performance, and improve their weaknesses (Anderson & Krathwohl, 2001; Mukhtar & Hanin, 2019; Setiawati et al., 2019). The higher a student's HOTS, the greater the impact on their work readiness (Hasan & Pardjono, 2019). One subject that can train HOTS is science (Setiawati et al., 2019; Mukhtar & Hanin, 2019).

The integration of ICT in the world of education is carried out according to the BPBLR-based learning package referring to the basic theories of constructivism, Blended Learning, PBL, online learning (Lawson, 1998; Shofiyah & Fitri, 2018; Donnelly & McSweene, 2009; Moeller et al., 2010; Naidu, 2006). This model combines BL, Rotation-type PBL packaged in the BPBLR model assisted by PhET. This BPBLR model is referring to the PBL syntax (Arends, 2015) combined with online learning. The implementation of the blended PBL or BPBL model refers to the provisions of blended learning Khistow (2011) and Bersin (2014), namely learning is carried out in class and at the same time students learn online. This BPBLR step follows the PBL stages according to the PBL steps from Arends (2015) and is assisted by online learning. In online learning, according to the learning of Eldy & Sulaiman (2019), where learning utilizes technology such as computers or mobile phones, and the internet in designing, communicating, and organizing materials in a comprehensive and flexible manner.

Through the BPBLR model, students will be trained in groups to access contextual science concepts online, assisted by the use of PhET simulations. On the web, interconnected concepts are structured. Learning begins with unstructured real-world problems. Students formulate these real-world problems, which will then lead to solutions that require conceptual understanding, argumentation, problem-solving, decision-making, and conclusions. All of this leads to scientific performance, which is an indicator of HOTS. Students' HOTS acquisition can also be developed during the investigation phase, involving activities such as formulating hypotheses, conducting experiments, providing arguments, conducting analysis, and interpreting. Furthermore, students' HOTS can also be developed during the development and presentation stages of their work, facilitated by teaching materials packaged in problem-based learning materials.

The HOTS components that emerge are students' ability to analyze, provide arguments, be able to present, and make decisions. At the end of the use of the PhET-aided BPBLR model is analyzing and evaluating the problem-solving process. In this section, the HOTS component is trained through students providing solutions or suggestions according to the problem or theory. The use of BPBLR learning that combines integrated classroom and online learning simultaneously will provide opportunities for more comprehensive access to learning from various sources. Through the use of this validated PhET-aided BPBLR model, students will be trained in HOTS achievement, thus students' HOTS will increase after using this BPBLR model. Research in the field of science education has shown that the BPBL model has great potential in increasing students' acquisition of CTS and HOTS. Several studies highlight the effectiveness of BPBL in encouraging active and independent learning, especially in science and physics learning (Shofiyah & Fitri, 2018; Donnelly & McSweene, 2009; Moeller et al., 2010). Several studies show the effectiveness of BPBL in science learning in elementary and secondary schools (Donnelly & McSweene, 2009; Moeller et al., 2010). There has not been much development of learning models that systematically combine Blended Learning, PBL, Blended Rotation and PhET simulations to teach students in achieving HOTS.

Method

The positive contributes of the PhET-aided BPBLR model is described based on data on students' HOTS improvement and student responses to the positive contributions of the PhET-aided BPBLR model in science learning. The research design used is a group pretest and posttest design, namely:

O_1	X	O_2
O_3	X	O_4
O_5	X	O_6

Figure 1. The research design (Fraenkel & Wallen, 2012)

Description:

X : Treatment given to the experimental class with the PhET-aided BPBLR model

O_1, O_3, O_5 : HOTS pretest in each class before treatment is given

O_2, O_4, O_6 : HOTS pretest in each class before treatment is given

The subjects of this study were seventh-grade junior high school students in Singaraja City, which consisted of three groups (A, B, and C). Each group consisted of 31, 33, and 34 students, respectively, totaling 98 students. The groups were randomly selected as experimental classes without a control group.

The treatment given to the experimental class with the PhET-aided BPBLR model is as follows, namely. Phase 1: Orienting students to the problem. Learning objectives are presented, beginning with face-to-face stations and continuing with online stations. Students access unstructured complex problems on the web. The learned HOTS indicator is analyzing (C4) in formulating complex problems into simpler ones. Phase 2: Organizing Students for Learning. The teacher facilitates students in dividing learning tasks at the face-to-face station. Then, at the online station, the students access assignments online based on the assignments and learning materials. Next, students discuss the problem formulation again. The learned HOTS indicators are cognitive domain C4 (sorting dividing learning tasks), dividing tasks for designing PhET simulations (C6).

Phase 3: Guiding individual and group investigations. The teacher guides students in their investigations. At the online station, students formulate hypotheses, while at the face-to-face station, students conduct experiments using PhET simulations, analyze data, provide arguments, and draw conclusions. The learned HOTS indicators are: formulating hypotheses (C6), designing PhET simulations (C6), analyzing data (C4), providing arguments (C5), and drawing conclusions (C6). Phase 4, Developing and presenting work results. The teacher facilitates students to plan and design appropriate work such as presentation material reports simultaneously at online and face-to-face stations. Next, at the face-to-face station, students present/submit the results of group work, and end with a question and answer session at the face-to-face and online stations simultaneously. The learned HOTS indicators are: comparing (C5) between the results of the PhET simulation of the presenter and the questioner. The presenter responds to and assesses the questioner's answers (C5), Evaluating (C5) participants' questions, (C6).

Phase 5: Analyzing and evaluating the problem-solving process. The teacher analyzes and evaluates the discussion participants. At the face-to-face station, students provide arguments and clarification regarding the problems presented by the teacher. At the online station, students evaluate/respond to and make decisions regarding the phenomena presented online. The learned HOTS indicators are: students are able to evaluate problems (C5) presented by the teacher and provide arguments (C5), respond to and assess answers (C5), and make decisions (C6).

The PhET-aided BPBLR model is contributes positively in improving HOTS if it meets the criteria for contributing positively. the positive contribution data includes the effectiveness aspects. Effectiveness data includes HOTS and student responses.

Student HOTS data was collected using a HOTS test instrument. Data collection was conducted before (pre-test) and after (post-test) students participated in the learning process. Each test item refers to a HOTS indicator: analyzing, evaluating, and creating. The HOTS test questions were in the form of problem narratives. Data on student responses to the PhET-aided BPBLR model were collected using a questionnaire. Student response data on the PhET-aided BPBLR model was collected by questionnaire. The components of student responses to learning with the PhET-aided BPBLR model are related to the novelty of the learning model; the interestingness of the learning; student interest in participating in the learning; student motivation towards the model; the relationship between concepts and natural phenomena; the integration of learning through online and simultaneous face-to-face facilities; Ease of the PhET simulation use; the usefulness of the lesson in everyday life.

Data were analyzed descriptively and quantitatively, covering: HOTS increase (N-gain) and student responses to the model implementation. To determine whether there is a significant difference between the pre-test and post-test in each group, a paired t-test was used (Fraenkel & Wallen, 2012). This statistical test uses the SPSS Statistical Package software version 31. The requirements that must be met in using this data analysis technique are normality testing or non-parametric analysis with the Wilcoxon test analysis. Data normality testing uses the Shapiro Wilk test. To describe the HOTS improvement category for each group, the N-gain score is used. The N-gain criteria are: high if $g \geq 0.7$; medium if $0.3 < g < 0.7$; and low if $g \leq 0.3$. (Hake, 2007).

The positive contributes of the PhET-aided BPBLR model in improving HOTS is determined by the moderate category if all groups meet the HOTS improvement category. The PhET-assisted BPBLR model contributes positively to improving students' HOTS if the HOTS improvement for all groups falls within the moderate category.

To test the consistency of students' HOTS improvement in the use of the PhET-aided BPBLR model from three independent groups without a control group, an ANOVA test was used. This test was conducted if the average N-gain for each of the three groups came from a population with a normal distribution and the homogeneity test was met. Student response data was analyzed using the Guttman scale. The percentage of student response scores was used to determine the category of student responses. To determine the student response category, the following calculation is used. $P =$

$\frac{\sum K}{\sum N} \times 100\%$, where P is the percentage of student response scores; $\sum K$ is the number of students who chose Yes or No, and $\sum N$ is the number of students who completed the questionnaire. The percentage of student responses is converted using the following criteria: (0% - 20%): Very Poor; (21% - 40%): Poor; (41% - 60%): Sufficient; (61% - 80%): High; and (81% - 100%): Very High.

Result and Discussion

Result

The findings of this study confirmed that the average pretest and posttest scores of groups A, B, and C of seventh-grade students at SMP Negeri 1 and SMPN 6 Singaraja were as shown in Table 1.

Table 1. HOTS pre-test and post-test scores

Description	Group A		Group B		Group C	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Average	35.70	64.93	33.94	63.64	35.34	65.30
Deviation Standard	7.23	10.92	8.37	8.85	8.60	7.08

Table 1 reveals that the average HOTS scores before learning (pre-test) on temperature, heat, and expansion for the three groups were 35.70, 33.94, and 35.34, respectively, categorized as poor. After learning with the PhET-assisted BPBLR model, the average HOTS scores (post-test) for the three groups were 64.93, 63.64, and 65.30, respectively, categorized as good.

To test for significant differences in students' HOTS pre-test and post-test data, a normality and homogeneity test is first conducted. The analysis results with $p < 0.05$ shows that the three groups have met the normality and homogeneity criteria. Using a paired t-test, with $p < 0.05$, a significant difference is obtained between the students' HOTS pre-test and post-test for the three groups, as shown in Table 2.

Table 2. Results of paired t-test between pre-test and post-test scores

Data	Average Test (t)	df	p (2-tailed)	Remark
Group A	-29.161	30	0.0000	Ho is rejected
Group B	-29.697	32	0.0000	Ho is rejected
Group C	-29.412	33	0.0000	Ho is rejected

Table 2 shows that the p-value for the paired t-test results of the HOTS pre-test and post-test scores in the three groups is < 0.05 and overall has a negative value. "The negative t-values indicate that the post-test scores are significantly higher than the pre-test scores ($p<0.05$)." This means there is a significant difference (statistically) in students' HOTS between before and after the use of the PhET-aided BPBLR model.

By using N-gain normality analysis, the findings of this study confirmed that the HOTS increase of students from the three groups A, B, and C was 0.46; 0.45; and 0.46 as shown in Figure 2. HOTS improvement falls into the moderate category.

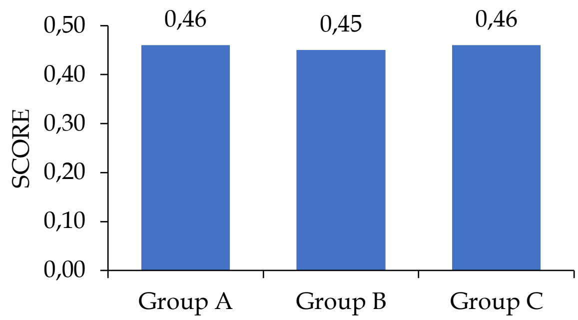

Figure 2. Average N-gain HOTS results of the PhET-aided BPBLR model study

To test the consistency of students' HOTS improvement, the ANOVA test was used. The analysis results with $p < 0.05$ showed that the N-gain for the three groups had met the criteria for normality and homogeneity. The ANOVA results are shown in Table 3.

Table 3. ANOVA results of students' HOTS improvement

Data	F	df	p	Remark
Average N-gain of the HOTS of Groups A, B, and C	0.173	76	0.841	Ho is accepted

*p < 0.05

Based on Table 3, the p-value for the ANOVA results for groups A, B, and C is 0.841. This shows that the p-value > 0.05, then statistically means there is no difference in the average increase in students' HOTS (consistent) for the three groups A, B, and C. Students' responses to the PhET-aided BPBLR model which state that it is fun, interesting, motivating to learn, and has elements of novelty, easy to learn for the material of temperature, heat, and expansion range from 80.0% to 100%, with an average of 92%.

Discussion

The findings of this study confirmed that, based on the N-gain score, students' HOTS increased to the moderate category. This is in line with the findings of previous studies that stated that combined (blended) problem-based learning can improve HOTS (Shofiyah & Fitri, 2018; Rachman et al., 2019). This increase in HOTS in the moderate category is because in the use of the PhET-aided BPBLR model, students are trained in achieving HOTS indicators at each stage, namely: at the problem orientation stage, students have been trained to formulate problems, where students examine complex, unstructured everyday problems of temperature and heat, and identify problems based on theoretical foundations, students conduct deductive analysis.

At the learning organization stage, students formulate complex problems into simple problems based on temperature and heat phenomena. At the investigation stage, students provide arguments, conduct inductive analysis, provide solutions or suggestions according to the problem or theory (provide decisions), and conduct inductive analysis. At the stage of developing and presenting the results of the work, students provide arguments, analyze deductively, conduct evaluations, provide decisions. Next, at the stage of analyzing and evaluating the problem-solving process, students provide arguments, analyze inductively, deductively, provide decisions (provide solutions or suggestions according to the problem or theory), deliver examples of applications and answers to HOTS practice questions.

The consistency of students' HOTS improvement for the three groups is shown in Table 3. The N-gain in the three groups, namely groups A, B, and C, did not differ from each other or were consistent. This reflects that the use of the PhET-aided BPBLR model can consistently improve students' HOTS. This is in line with the schema theory which states that when someone reconstructs information, the person adapts to previous knowledge that already exists in their mind (Santrock, 2017).

In learning with the BPBLR model aided by PhET, students are able to give meaning to science learning, especially related to the material of temperature, heat, and expansion. This is in line with the schema theory which states that when someone reconstructs information, people adapt to previous knowledge that already exists in their minds (Santrock, 2017; Isna et al., 2017; Owen et al., 2017).

Based on the results of the average difference test between the pretest and posttest using the paired t-test as stated above, it was found that the application of the PhET-aided BPBLR model can significantly increase students' HOTS, at $p < 0.05$. Thus, it can be said that the use of the BPBLR model aided by PhET contributes positively to increasing HOTS. This result is in line with previous research which states that blended PBL learning can improve students' HOTS. Furthermore, PBL models, both face-to-face and online, are effective ways to develop various important skills such as communication skills, teamwork, inquiry-based learning, peer learning, project management, collaborative and individual innovation, and creativity (Lim et al., 2020). Furthermore, research results reveal that HOTS includes analyzing, evaluating, and also creating (Anderson & Krathwohl, 2001).

The implications of findings from the use of the PhET-aided BPBLR learning model have a very positive pedagogical impact. The findings from the use of PhET simulations have proven to contribute positively to improving students' HOTS. This combination allows students to visualize the abstract concepts of heat temperature and construct knowledge independently. The PhET virtual simulation bridges students' understanding from the concrete to the abstract realm. This is crucial for practicing analysis and evaluation, which are indicators of HOTS.

The research findings show that HOTS improvement consistently occurs in all experimental groups without the control group refers to the research design. Each group act as its own control (comparing pre-test and post-test scores independently). The uniform improvement results prove that the treatment (PhET–aided BPBLR) has a very strong and dominant influence on students' cognitive development.

Conclusion

Based on the research results and discussions, the following conclusions can be drawn. The use of the PhET-aided BPBLR model positively contributes to improve students' HOTS. This is indicated by a significant difference in students' HOTS achievement ($p < 0.05$) between the pretest and posttest in the experimental group without a control group. There is an increase in students' HOTS achievement with an N-gain of 0.46, 0.45, and 0.46, categorized as moderate, in each group. This increase in students' HOTS is consistent at $p < 0.05$ for all three groups. This increase in students' HOTS is due to the opportunity to rotate from one learning station to another. Students are able to learn in multiple directions, utilizing the internet at any time, while simultaneously focusing on face-to-face learning and paying attention to teacher directions. The use of PhET simulations facilitates practical activities with limited laboratory equipment. Student response to the PhET-aided BPBLR model is very high. Students show high enthusiasm and motivation due to the novelty of online activities, face-to-face interactions, student-teacher collaboration, engaging learning models, the practicality of PhET, the interconnectedness inter-concepts and ease of understanding, meaningful and useful learning, and enhance more interactive and enjoyable learning experience. In using the PhET-aided BPBLR model, it is recommended to intensively integrate PhET simulations into the investigation and problem-solving stages facilitated by Student Worksheets to improve students' HOTS achievements.

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Author Contributions

Conceptualization, R.S. and K.S.; validation, K.S. and P.S.; formal analysis, investigation, P.Y., I.Y., and P.S.; writing—original draft, writing—review and editing, R.S., K.S., and P.S.; All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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