The effect of problem-based learning assisted by Driving Question Board on students' problem-solving skills in excretory system learning

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Abstract
This research aims to examine the influence of the Problem Based Learning (PBL) model assisted by the Driving Question Board (DQB) on eighth-grade students' problem-solving skills in learning the excretory system. It also evaluates the effectiveness of the PBL-DQB model compared to the conventional PBL model. The study employed a quasi-experimental method with a pretest-posttest nonequivalent control group design. Data were collected using problem-solving skill tests, which included four indicators: identifying the problem, devising a plan, implementing the plan, and evaluating the results. Data analysis was conducted using the Paired Sample T-Test at a 0.05 significance level. The findings revealed that the PBL model integrated with DQB significantly enhanced students' problem-solving abilities, as indicated by a significance value of 0.000 (< 0.05). Each phase of the PBL syntax, when supported by DQB, contributed effectively to the increase of these skills. The model was also found to be more effective than PBL alone, with an N-Gain score of 0.60 categorized as moderate improvement.

1. Introduction

In the 21st century, learning has evolved to demand students to be proficient in critical thinking, problem-solving, effective communication, collaboration, creativity, and innovation (Elitasari, 2022; Alexandra & Carmen, 2024). In order to confront the global challenges that students must face, it is imperative that they develop problem-solving skills as a primary skill set. This skill enables students to employ systematic and logical thinking when planning and implementing strategies, informed by the available information, to solve problems (Kurniawati et al., 2019). Within the domain of Natural Sciences (IPA) education, this skill holds particular significance, as it entails the analysis of natural phenomena and the development of solutions through a scientific inquiry process that is founded on observation, experimentation, and reasoning (Ramadhani, 2021).

Measuring problem-solving skills requires elaborating problem-solving indicators based on their stages. Polya (1973) mentions 4 aspects of indicators of problem-solving skills described in Table 1.

Table 1. Indicators of Problem-Solving Skills

No	Indicator
1	Understand the problem
2	Devise a plan
3	Carry out the plan
4	Looking back

Based on the official report of the IEA in the TIMSS (Trends in International Mathematics and Science Study) 2015, Indonesia's scientific achievements are still concerning, which is ranked 44th out of 47 participating countries with an average score of 397, far from the international average of 500. Only 51% of students reach the lowest minimum standard (Low Benchmark) so there are still 49% of students in Indonesia who are not able to master even the most basic science knowledge according to the TIMSS 2015 standard (Mullis et al., 2016). This reflects significant weaknesses in the cognitive realm in TIMSS, one of which is reasoning, which results in students having weaknesses in solving problems that require in-depth analysis and synthesis. The realm of reasoning in the TIMSS framework requires the capacity of students to use scientific knowledge in complex contexts, which depends on the mastery of problem-solving skills so that it is expected to be able to boost students' reasoning skills according to the international standards set by TIMSS.

In an effort to overcome these problems, it is important to apply learning strategies based on constructivist theory. This theory asserts that knowledge is actively acquired by students through direct involvement in real-life situations as well as through social interaction (Pradipta et al., 2021; Wahab & Rosnawati, 2021). One of the

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models that refers to this approach is Problem Based Learning (PBL), which is a learning model that uses contextual problems as the initial reference for the learning process. PBL encourages students to develop curiosity, apply inquiry, and seek independent and collaborative solutions (Zhao et al., 2024). However, in its implementation, PBL still faces challenges in making it easier for students to learn science concepts, such as the excretory system, which involves the internal mechanisms of the human body (Maryana et al., 2021; Fadhilah et al., 2024).

To overcome these obstacles, learning aids are needed that are able to bridge the gap between abstract concepts and students' concrete experiences. DQB is a contextual learning tool to help students come up with ideas related to the relationship of phenomena on the topic discussed with students' experiences through sub-questions about the main phenomenon or problem posed by the teacher to trigger a scientific inquiry process to find solutions to problems that are useful for life both now and in the future (Shin et al., 2021; Ruggirello & Brockhouse, 2024). Based on this, DQB has a good role in contextualizing abstract concepts through contextualizing learning flows with learning objectives, thus guiding students in the stage of logical and systematic scientific investigation. However, research on the integration of DQB into PBL models, especially in excretory system materials, is still limited. Therefore, this study was conducted to examine the effect of the application of the Problem Based Learning model assisted by the Driving Question Board (PBL-DQB) on students' problem-solving skills on excretion system materials.

2. Method

The research uses a quasi-experimental research method with a pretest posttest nonequivalent control group design. The sample was grade VIII students who were selected using the cluster random sampling technique, consisting of an experimental class that was given Problem Based Learning (PBL) treatment combined with Driving Question Board (DQB) and a control class that was only given Problem Based Learning (PBL) treatment. Data collection techniques include testing of problem-solving skills and observation of syntax implementation. The instrument was validated through tests of content and construct validity, reliability, difficulty level, and differentiating power. Data were analyzed using the Paired Sample T-test and N-Gain calculation.

3. Results and Discussion

The results of in-depth observations carried out in the learning process showed that the application of both models in the experimental and control classes was carried out very well with a total score percentage of 100%. The results showed that the Problem Based Learning (PBL) learning model assisted by the Driving Question Board (DQB) had a significant influence on students' problem-solving skills in excretory system materials. Control and experiment class problem solving skills test result can be seen in Table 2.

Table 2. Control and Experiment Class Problem-Solving Skills Test Results

Data Description	Control Class		Experiment Class	
	Pretest	Posttest	Pretest	Posttest
Average	42.53	78.38	56.50	86.19
Minimum Score	17	50	17	50
Maximum Score	83	100	100	100
Standard Deviation	16.13	14.62	19.40	12.12

The striking difference in learning outcomes can be seen from the posttest scores between the two groups. The group that received intervention through PBL with the help of DQB recorded an average score of 70.3, far exceeding the group that only received PBL, which had an average of only 36.7. This value gap indicates that the integration of DQB in the PBL model contributes greatly to improving students' academic performance. The validity of these findings is supported by the results of the T-Test analysis which can be seen in Table 3.

Table 3. Paired Sample T-Test Results

Data	Sig. (2-tailed)	Description	Decision
Experimental class pretest-posttest scores	0.000	Sig. (2-tailed)<0.05	H0 rejected

The results of the paired sample t-test showed that the data of the problem-solving skills test received sig. (2-tailed) of 0.000. The value of sig. (2-tailed) <0.05 so that it is interpreted that there is a difference in problem-solving skills between before and after the application of the problem-based learning model assisted by driving question board. This shows that the problem-based learning model assisted by driving question board has a significant effect on students' problem-solving skills. Furthermore, the N-Gain test was carried out to see the magnitude of the increase in pretest and posttest results before and after treatment. This test can support the decision of the paired sample t-test. The results of the N-Gain test are presented in Table 4.

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Table 4. N-Gain Test Results

Class	*N-Gain Score*	Category
Experiment	.60	Medium
Control	.59	Medium

The N-Gain test confirmed a significant difference between the two groups after the effect of the initial value (pretest) was controlled. Furthermore, the N-Gain calculation showed that the experimental class obtained an increase of 0.60 (medium category), while the control class only reached 0.18 (low category). This fact implies that in addition to encouraging final learning outcomes, the implementation of PBL assisted by DQB is also able to strengthen the effectiveness of the overall learning process (Hake, 1998). Figure 1 shown a application of DQB in experimental classes.

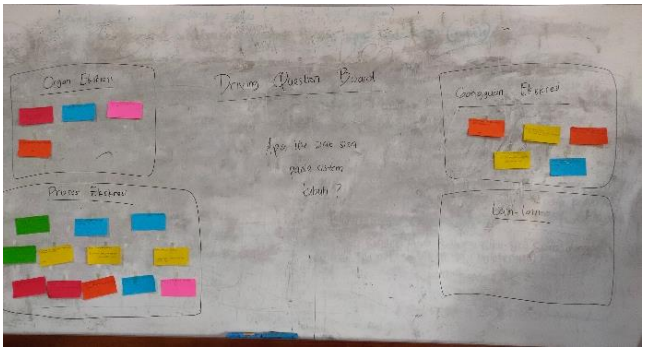

Figure 1. Application of DQB in Experimental Classes

DQB plays an important role in facilitating student roles because it provides a space for question visualization that leads students to build and improve their thinking paths individually and in groups. When given the initial phenomenon, students write down the questions that come to their minds on the DQB, which are then classified together into investigative sub-topic categories. This process sparks curiosity and focuses students' attention on relevant aspects of the problem at hand with the topic and learning objectives. In accordance with the constructivist view, knowledge formation occurs as a result of the individual's direct involvement in real experience as well as through experience and social interaction (Wahab & Rosnawati, 2021), the DQB-assisted PBL model allows for the creation of an active and investigative learning atmosphere, where students gradually construct an understanding of science concepts from meaningful hands-on experience.

The stages of PBL are related to improving problem-solving skills. This learning bridges students in creating mastery of problem solving. Assisted by learning tools in the form of DQB is a good step to support these skills because this tool is related to the concept of problem solving. The relationship between PBL and DQB in improving problem-solving skills is presented in Table 5.

Table 5. The Relevance of PBL to DQB's Assisted PBL on Problem-Solving Skills

Problem solving indicator (Polya, 1973)	Syntax PBL (Arends, 2008)	Role	PBL	PBL Assists DQB
Understand the problem	Problem orientation	Teacher	Provide real problems and motivate students to engage	Presenting the phenomenon and triggering students to raise questions on the DQB board
		Student	Identify what information is on the issue	Record phenomena and formulate initial questions on the DQB board
Devise a plan	Organizing to research	Teacher	Help students define problem-related study assignments	Help students group questions in the DQB for investigation plans
		Student	Divide group tasks and plan completion steps	Selecting questions in the DQB to be answered through experiments/literature
Carry out the plan	Independent and group investigations	Teacher	Encourage students to gather appropriate information	Monitor the student inquiry process based on the sequence of questions in the DQB
		Student	Run experiments or search for data for solutions	Conduct research to answer the sub-questions on the DQB board
Looking back	Develop and present results	Teacher	Guiding students in preparing works	Help students match the results of the investigation with the questions in the DQB

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Problem solving indicator (Polya, 1973)	Syntax PBL (Arends, 2008)	Role	PBL	PBL Assists DQB
		Student	Presenting the results of the problem solving in front of the class	Presenting answers to questions in DQB and revising initial understanding
	Analysis and evaluation	Teacher	Guiding reflection on the problem-solving process	Guiding students to see the interconnectedness between concepts in DQB in their entirety
		Student	Evaluate the steps taken in finding a solution	Review the DQB board to make sure all questions have been answered

Specifically, improvements occurred in all indicators of problem-solving skills based on the stages presented by Polya, namely understanding the problem, designing a plan, executing the plan, and checking back. In the problem understanding indicator, students in the experimental class showed improved skills in identifying important information and relating phenomena to science concepts, thanks to the support of the question structure in the DQB. The indicator of preparing a plan also increased because students were used to compiling completion steps based on questions that had been prepared beforehand. The stages of implementing the plan appear to increase through experimental activities and group discussions, while the re-examination indicators develop along with the reflection and clarification activities of the answers carried out through the DQB. Teachers also note that students become more reflective and systematic in thinking, not just guessing or answering instantly. Thus, DQB-assisted PBL learning not only improves learning outcomes quantitatively, but also strengthens the dimension of students' scientific thinking process.

Students find it helpful to be able to visually "see" the flow of their investigation, so it is not easy to lose focus. DQB makes discussions more directed, as well as helps students build understanding gradually. These findings are reinforced by previous research that states that DQB is able to strengthen the process of scientific inquiry and connect students' personal experiences with scientific concepts in a more contextual way (Ruggirello & Brockhouse, 2024; Shin et al., 2021). In the context of science learning that is full of abstract concepts such as the excretory system, the existence of DQB has been proven to be able to bridge the gap between theoretical information and students' concrete learning experiences (Maryana et al., 2021; Fadhilah et al., 2024). Therefore, it can be concluded that the DQB-assisted PBL model is very suitable in optimizing students' problem-solving skills because it combines a problem-based approach with question visualization support that guides students' thinking processes systematically and logically. This strategy is relevant to be applied in science learning to form 21st century skills that are not limited to focusing on results, but also on deep scientific thinking processes.

4. Conclusion

Referring to the findings of the research obtained, it can be summarized that the implementation of Problem Based Learning (PBL) assisted by the Driving Question Board (DQB) has a significant impact on students' problem-solving skills. This model has been proven to be able to improve students' skills in observing problems, designing solution strategies, implementing solutions, and evaluating the results achieved. Compared to the implementation of PBL without the help of DQB, the DQB-assisted PBL model showed higher effectiveness in developing students' critical and systematic thinking skills during the learning process.

5. Suggestions

In connection with these findings, it is suggested that teachers can consistently apply the DQB-assisted PBL model in learning activities, especially in materials that require problem-solving skills and active involvement of students. Schools are also expected to provide support through the provision of supporting facilities and media, such as question boards, structured worksheets, and teacher training on the implementation of this model.

For future research, it is recommended that researchers expand the scope of the study by investigating other factors that have not been explored in this study that may be influenced by this learning model. In addition, further research can also be conducted at other levels of education, both at the primary and secondary levels, to prove the consistency and effectiveness of the DQB-assisted PBL model in the broader learning context.

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The author declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analysed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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