Journal of Research in Instructional
e-ISSN: 2776-222X
Vol. 4(2) 2024, pp. 284 – 294
https://doi.org/10.30862/jri.v4i1.410

Problem-based learning assisted by virtual laboratory media: Its effect on students' understanding of concepts in excretory system material

Ratna Dewi Munthe*, Miza Nina Adlini

Universitas Islam Negeri Sumatera Utara, Indonesia

Submitted: 01-06-2024

Accepted: 24-06-2024

Published: 30-06-2024

Abstract: Learning concepts is an integral part of learning biology, including abstract (requiring analytical skills) and tangible (requiring observational experience) ideas. If the learning model used is not appropriate, it can cause boredom, a lack of understanding of the subject matter, and a monotonous appearance that makes students reluctant to learn. This is why students have difficulty understanding concepts. This study aims to ascertain whether problem-based learning with virtual laboratory media influences students' conceptual understanding. The type of research conducted was quasi-experimental. A total of 49 students from class XI, divided into two classes, became the population. Since complete sampling was used, 49 students became the sample. Problem-based learning strategies and virtual laboratory materials were used to teach the experimental class in XI-1. The control group in class XI-2 used conventional learning techniques. Five essay-based test questions served as research tools. After data collection, the impact of the problem-based learning paradigm supported by virtual laboratory media on students' conceptual knowledge was assessed using an Independent t-test and normality test. Students' conceptual understanding can be improved using the problem-based learning technique with virtual laboratory media to streamline the learning process and enable practical activities.

Keywords: Excretory system, problem-based learning, understanding of concepts, virtual laboratory

Abstrak: Konsep pembelajaran merupakan bagian integral dari pembelajaran biologi, termasuk ide-ide abstrak (membutuhkan keterampilan analitis) dan nyata (membutuhkan pengalaman observasi). Apabila model pembelajaran yang digunakan tidak tepat maka dapat menimbulkan rasa bosan, kurangnya pemahaman terhadap materi pelajaran, dan tampilan yang monoton sehingga membuat siswa enggan belajar. Inilah sebabnya mengapa siswa kesulitan memahami konsep. Penelitian ini bertujuan untuk memastikan apakah pemahaman konseptual siswa dipengaruhi oleh pembelajaran berbasis masalah dengan media laboratorium virtual. Jenis penelitian yang dilakukan adalah kuasi-eksperimental. Sebanyak 49 siswa dari kelas XI, dibagi menjadi dua kelas, menjadi populasi. Karena pengambilan sampel lengkap adalah pendekatan pengambilan sampel yang digunakan, maka 49 siswa menjadi sampel. Strategi pembelajaran berbasis masalah dan materi laboratorium virtual digunakan untuk mengajar kelas eksperimen di XI-1. Kelompok kontrol di kelas XI-2 menggunakan teknik pembelajaran konvensional. Ada lima soal tes berbasis esai yang berfungsi sebagai alat penelitian. Setelah pengumpulan data, dampak paradigma pembelajaran problem based Learning yang didukung media laboratorium virtual terhadap pengetahuan konseptual siswa dinilai menggunakan Uji-T Independen dan uji Normalitas. Pemahaman konseptual siswa dapat ditingkatkan dengan menggunakan teknik pembelajaran problem based learning dengan media laboratorium virtual untuk mengefisienkan proses pembelajaran dan memungkinkan kegiatan praktik

Kata kunci: Sistem ekskresi, pembelajaran berbasis masalah, pemahaman konsep, laboratorium virtual

*Corresponding author: ratnadewimunthe@uinsu.ac.id

INTRODUCTION

Learning is the process of guiding or helping students during learning (Aristawati et al., 2018; Zhao et al., 2020). This learning activity cannot be separated from the other

elements it contains and how these elements interact with each other (Marianus et al., 2020). Biology learning cannot be separated from concepts, both tangible and abstract, each of which requires observational experience and analytical skills (Nasir et al., 2020; Saharsa et al., 2018). It is very important for students to understand concepts because this can help them learn the taught content more easily (Sayekti, 2020).

Concept understanding is essential for understanding biological knowledge, especially with regard to the excretory system, which includes content that in Latin is categorized as difficult due to the organs involved, the difficulty of distinguishing human excretory processes, and complex concepts. By placing a strong emphasis on concepts, teachers can help students develop enduring concepts that they can apply to other concepts (Nasir et al., 2024; Sugiharti & Sugandi, 2020). The breadth of biological research causes inaccuracies in the interpretation of the concepts learned, so students have difficulty understanding them (Alfiah & Dwikoranto, 2022). Additional factors include the application of ineffective learning models, which can make students bored, do not understand the subject matter, and seem boring, thus reducing learning motivation (Saputri et al., 2023). Due to the lack of visualization, students using traditional learning models are less motivated to acquire and understand concepts (Nasir et al., 2023; Rihi & Bano, 2022). Conversely, when using the lecture teaching method, students sometimes have a tendency to be passive and only the teacher actively participates. In fact, it is very important for students to understand the concepts they are learning because failure to understand them will prevent them from developing and using these concepts in real-world contexts. (Rahayu & Prayitno, 2020)

Given this, it is important to use teaching strategies that are imaginative, practical and engaging. To obtain an excellent level of conceptual knowledge, these strategies aim to provide students with opportunities to learn actively and increase their desire to learn (Kern, 1990). One strategy to increase student engagement and conceptual understanding is to use a learning model that is appropriate to the students' conditions (Apriyani & Alberida, 2023). Therefore, all students who take part in classroom learning should be able to use the learning model used in class to solve problems (Kurniawan et al., 2023). For example, by using a problem-based learning approach (Septiana & Ikhsan, 2017; Zhang, 2023). By using problem-based learning (PBL) strategies, teachers can enable each student to play an active role in the learning process (Indriani et al., 2022).

The application of the PBL model in biology learning can help students achieve the desired conceptual knowledge (Damopolii & Kurniadi, 2019; Pratiwi et al., 2019). PBL fosters critical thinking, problem-solving skills, and knowledge construction in students (Rahayu & Prayitno, 2020; Yomaki et al., 2023). Rahmadhani and Acesta (2017) stated that because the PBL paradigm requires students to actively search for problems and answers during the learning process, it can improve students' conceptual understanding (Kurniawan et al., 2020). Students' perspectives will be broadened and opened with this approach, so they can apply it in real-world situations (Zannah et al., 2022). Saharsa et al. (2018), and Silahooy et al. (2024) stated that problem-based learning approaches are too complicated or leave out interesting phenomena or problems that provide significant challenges for learners. Meanwhile, learning that encourages students to learn through visualization is needed to improve students' conceptual understanding (Faiza et al., 2023).

Virtual laboratory learning materials can be used to implement visualization learning. To achieve students' conceptual understanding of learning materials, practicum must be used as a complement to concrete biology learning (Syahril et al., 2019). The lack of facilities or infrastructure in schools such as biology laboratories and adequate practicum equipment does not prevent the biology practicum from running. Virtual laboratories can be utilized as a medium that facilitates visual laboratories through virtual practicum. Virtual laboratories are a solution to problems that are highlighted in learning (Siswono et al., 2014). Practical activities in the laboratory will make it easier for students to understand what they are learning and learning conditions in the laboratory will be fun. One of the media that can be used to carry out practicum activities is by using a virtual laboratory through Olabs. However, by utilizing the virtual laboratory application, practicum activities can be carried out online. Virtual laboratories can visualize experiments that are difficult to do in real laboratories equipped with simulation designs, animations, videos, and provide experimental tools (Rihi & Bano, 2022). According to Swandi et al. (2015) that the use of virtual laboratories with the Olabs app can increase student activity so that learning becomes more interesting and interactive and is able to encourage student motivation to understand learning concepts and study material both individually and in groups.

There have been many studies conducted on PBL and assisted learning media. For example, Siswono et al. (2014) Analyzed the impact of virtual laboratory media supported by PBL on students' conceptual mastery. In learning biology, students' ability to understand learning concepts is an important competency to be developed because biology is part of science that examines various abstract and procedural sciences. In biology, scientific terms are used to express concepts or ideas. The use of scientific terms is often perceived by students as something they understand in learning. One of the biology learning materials that are difficult to teach at the SMA/MA class XI level is the human excretory system. On the topic of the human excretory system, various scientific terms and bioprocess mechanisms are studied. In the learning process, students need to have mastery of scientific concepts in the good category. Students with good mastery of scientific concepts will more easily develop their understanding skills (Aswanti & Isnaeni, 2023).

The material on the excretory system in biology education is highly intricate and closely correlated with real-world phenomena. Since the excretory system is a complex and abstract concept, it is insufficient to merely memorize the theory (Sogen et al., 2018). The concept of the excretory system in biology is not straightforward (Olumorin et al., 2022). This requires students to have problem-solving skills to be able to understand the theory and compare it with daily life phenomena (Rindah et al., 2019). This study combines PBL with virtual laboratory media to stimulate biology learning, especially regarding the excretory system, to assist practicum and assess its effect on students' conceptual understanding of the topic. Research is needed to ascertain whether PBL combined with virtual laboratory learning media has an impact on students' conceptual understanding, taking into account the challenges and previous descriptions.

RESEARCH METHODS

As a quantitative methodology, this study used a quasi-experimental design. Since students are the subjects of the study, a quasi-experimental approach is used because there are many external factors beyond control that can affect the results (Ekasari, 2023).

Students' understanding of biological concepts will be the factor examined in this study. The data collection strategy used in this study is known as test methodology. This research was conducted in a private school in Sampali in April 2024. The study population was 49 students of class XI.

Meanwhile, sampling was conducted using a total sampling approach. Total sampling is a sampling approach where the number of samples and populations are the same. States that the population is smaller than 100 and the entire population is used as a research sample; therefore, a complete sampling approach is used. The population in this study was claimed to be equal to the number of samples because there were only two classes in the school, namely XI-1 which amounted to 25 students as the experimental class and XI-2 which amounted to 24 students as the control class. Both classes were used as samples.

The research instrument was an identical test given to the experimental and control groups. The purpose of the test was to assess students' understanding of the basic ideas of biology. The test consisted of five essay questions that had been approved by subject matter experts. Furthermore, the validity and reliability of the test instrument were checked. The test was given to students before the meeting (initial test) and after (final test). After data collection, the data were statistically analyzed using Kolmogorov-Smirnov normality test and t-test (Independent T-test).

The steps in this study are as follows: (1) Giving pretest to experimental and control groups. (2) Carry out learning by providing conventional learning models to the control class and PBL learning models to the experimental group through the virtual laboratory. (3) Giving post-test to experimental and control groups. (4) After the data is collected, the data is tested using SPSS 22.0 software.

RESULTS AND DISCUSSION

The research data was generated from tests conducted on the research sample. There were two tests used: pretest and posttest. The pretest was given to measure students' initial knowledge, while the PostTest, which used virtual laboratory media, measured students' knowledge after PBL learning. The average results of the pretest and posttest for the experimental and control classes are shown in Figure 1.

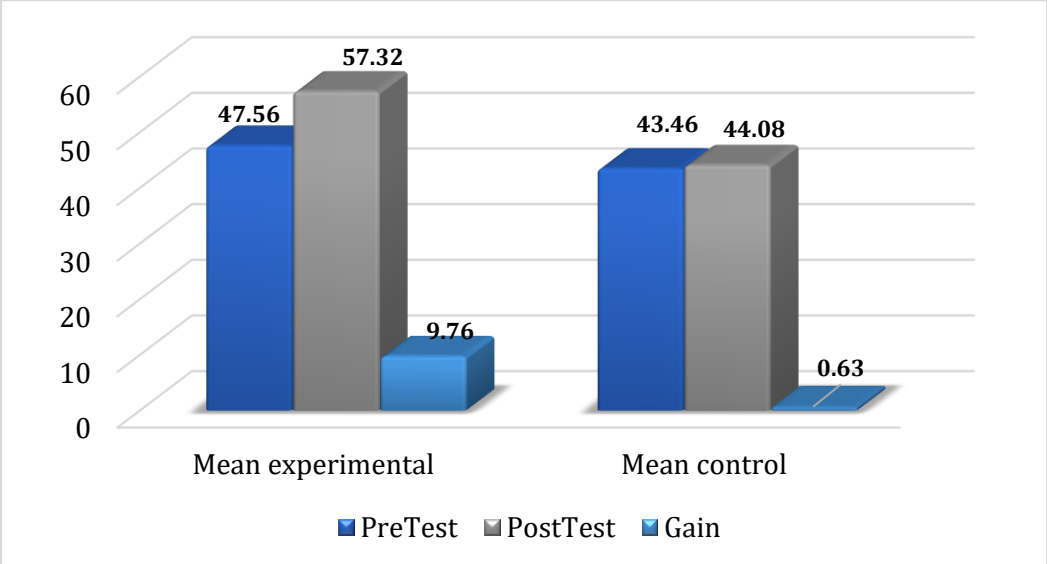

Fig. 1. Graph of mean score

Based on the collected data, the initial achievement of the experimental class was 47.56, with a minimum score of 38 and a maximum score of 57. Meanwhile, students in the experimental class completed the learning with an average of 57.32, ranging from 47 to 66 at the lowest and highest points. As a result, it has been proven that this improved the learning outcomes of the experimental class students. On the other hand, the first trial of the control group resulted in an average score of 43.46, with a minimum of 34 and a maximum of 50. On the other hand, students' final achievement scores ranged from a minimum of 38 to a maximum of 50, with an average of 44.08. In addition, a normality test was conducted to ensure the research data fell into the normal category or not after collecting information on students' skills in the experimental and control classes.

Table 1. Normality test results

	Kolmogorov-Smirnov[a]			
	Class	**Statistic**	**df**	**Sig.**
Learning outcomes	Pre-test Exsperimental (PBL)	0.152	25	0.140
	Post-test Exsperimental (PBL)	0.100	25	0.200
	Pre-test control (Konvensional)	0.129	24	0.200
	Post-test control (Konvensional)	0.156	24	0.135
	Gain-experimental	0.138	25	0.200
	Gain-control	0.175	24	0.055

From the results of Table 1, it is known that the Kolmogorov-Smirnov test produces a significance value (Sig) >0.05 for the data. Thus, it can be said that the data on student learning outcomes are normal.

Table 2. Homogeneity and t-test independent result

Data		**F**	**Sig.**	**t**	**df**	**P**	**Mean Difference**
Pre	Equal variances assumed	2.071	0.157	2.593	47	0.013	4.102
	Equal variances not assumed			2.608	44.372	0.12	4.102
Post	Equal variances assumed	0.203	0.655	10.451	47	0.000	13.237
	Equal variances not assumed			10.438	46.553	0.000	13.237
Gain	Equal variances assumed	20.608	0.000	6.467	47	0.000	9.135
	Equal variances not assumed			6.549	35.591	0.000	9.135

The findings of Table 2 show that the pretest, posttest, and gain are $p < 0.05$. It can be said that there is a difference between the average understanding of students' concepts in the experimental class and the control class. Determining differences in students'

understanding of concepts based on gain values. The use of gain values is because, from the prior (pretest), students' understanding of concepts has been different. Thus, students' conceptual understanding is significantly affected when using virtual laboratory media and problem-based learning to study biology.

The research data shows that students' learning outcomes have improved, and the learning model used had an impact on this improvement. Problem-based learning, as a student-centered learning style, requires students to take an active part in the learning process and be the main source of knowledge. Students' understanding of the material is affected by the traditional or lecture-based teaching strategies used in the control and experimental classes. By using virtual laboratory media as support, the problem-based learning approach was applied in learning activities in the experimental class. Nonetheless, compared to the control class, the experimental class experienced more improvement, and its posttest score had the highest average value.

After the application of the problem-based learning learning model, the average value of the experimental class was 57.32, while the average value of the control class was 44.08 after the application of the conventional learning model. Students' understanding of the subject matter will be influenced by their choice of learning approach (Siregar & Adlini, 2022). Problem-based learning is the right tool to involve students in the learning process by asking them to answer the questions given (Indriani et al., 2022).

Virtual laboratory which is a supporting media that is an integral part of PBL learning also has an impact on students' concept understanding. Research results Sugiharti and Sugandi (2020) show how virtual practice-based learning can improve students' understanding and ability in scientific procedures. Students who use virtual laboratory media can complete their practice faster because there are fewer supporting laboratory materials and equipment available. This is beneficial because practicum implementation is very important to improve students' understanding of biological material and the learning process.

Students can conduct experiments in virtual laboratories as well as with actual laboratory equipment. to accelerate and reduce the cost of learning biology while maintaining the expected results as a scientific process (Ekasari, 2023). Muliyono et al. (2019) claim that the use of virtual laboratories improves students' conceptual understanding through visualization. Virtual laboratory applications and learning resources can be used to complete online practice exercises (Safaria et al., 2023). Virtual laboratories can help visualize research that is difficult to do in a physical laboratory by providing simulation designs, animations, videos, and experimental equipment (Trihastuti et al., 2019).

Students show good enthusiasm in learning in PBL-based experimental classes that utilize virtual laboratory media. Thus, this affects how well students understand the subject matter (Hikmah et al., 2017). In contrast, students in the control group were less engaged in learning and less able to understand the subject matter. This group only used the traditional learning model with a lecture approach and textbook assistance. The students' average score is the proof.

In the problem-based learning stage, one of the syntaxes is the use of virtual laboratory media. This is the third step of the learning process. Students are divided into several study groups after understanding the material and asked to create a problem related

to the phenomenon that has been taught. In this group, they discuss the given problem and its solution. In addition, assistive media, especially virtual laboratory, supports the biology learning process by allowing practicum that is limited by tools and equipment to be carried out. Therefore, the use of problem0based learning assisted by virtual laboratory media affects students' concept understanding in learning biology, especially on excretory system material.

CONCLUSION

Based on the research results, the average value of the experimental class is greater than the control class. Therefore, the use of problem-based learning method with the help of virtual laboratory media affects students' concept understanding in biology class. Students' concept understanding can be improved by using problem-based learning learning techniques with virtual laboratory media to facilitate the learning process and enable practical activities. It is clear that problem-based learning using a combination of textbook and lecture methods is a more effective learning process than traditional learning models. After conducting investigations, data analysis, and discussions, the researcher provides several recommendations, among others: 1) Biology teachers should use virtual laboratory media and PBL approach in conducting learning. 2) To facilitate learning for students, teachers should use more varied learning models. 3) To ensure the findings are more comprehensive and widely applicable, it is recommended for future researchers to investigate the impact of virtual laboratory-assisted PBL on students' conceptual understanding or in terms of other characteristics.

REFERENCES

Alfiah, S., & Dwikoranto, D. (2022). Penerapan model problem based learning berbantuan laboratorium virtual PhET untuk meningkatkan HOTs siswa SMA. *Jurnal Penelitian Pembelajaran Fisika*, *13*(1), 9–18. https://doi.org/10.26877/jp2f.v13i1.11494

Apriyani, N. D., & Alberida, H. (2023). Pengaruh model problem based learning (PBL) terhadap keterampilan argumentasi peserta didik pada pembelajaran biologi: literature review. *Jurnal Biochepy: Journal of Science Education*, *03*(1), 40–48. https://doi.org/10.52562/biochephy.v3i1.531

Aristawati, N. K., Sadia, I. W., & Sudiatmika, A. A. I. A. R. (2018). Pengaruh model problem based learning terhadap pemahaman konsep belajar fisika siswa SMA. *Jurnal Pendidikan Fisika Undiksha*, *8*(1), 1–11. https://doi.org/10.23887/jjpf.v8i1.20573

Aswanti, N. H., & Isnaeni, W. (2023). Analysis of critical thinking skills, cognitive learning outcomes, and student activities in learning the human excretory system using an interactive flipbook. *REID (Research and Evaluation in Education)*, *9*(1), 37–48. https://doi.org/10.21831/reid.v9i1.53126

Damopolii, I., & Kurniadi, B. (2019). The development of android-based mobile learning supported by problem-based learning strategy for students' learning success. *International Journal of Scientific and Technology*, *8*(7), 190–193. https://www.ijstr.org/final-print/july2019/The-Development-Of-Android-based-Mobile-Learning-Supported-By-Problem-based-Learning-Strategy-For-Students-Learning-Success.pdf

Ekasari, A. (2023). Increasing concept mastery by applying problem based learning (PBL)

Assisted To PHET Simulation. *Journal of Biology Education Research*, *4*(1), 1–8. https://doi.org/10.32332/al-jahiz.v4i1.6292

Faiza, C. R., Idris, S., & Ginting, F. W. (2023). Pengaruh model problem based learning (PBL) berbantuan video youtube terhadap pemahaman konsep siswa. *OPTIKA: Jurnal Pendidikan Fisika*, *7*(1), 72–79. https://doi.org/10.37478/optika.v7i1.2696

Hikmah, N., Saridewi, N., & Agung, S. (2017). Penerapan laboratorium virtual untuk meningkatkan pemahaman konsep siswa. *EduChemia (Jurnal Kimia Dan Pendidikan)*, *2*(2), 186. https://doi.org/10.30870/educhemia.v2i2.1608

Indriani, L., Haryanto, H., & Gularso, D. (2022). Dampak model pembelajaran problem based learning berbantuan media Quizizz terhadap kemampuan berpikir kritis mahasiswa. *Jurnal Penelitian Dan Pengembangan Pendidikan*, *6*(2), 214–222. https://doi.org/10.23887/jppp.v6i2.48139

Kern, J. (1990). Implementation of new technology—The regulator's perspective. *SAE Technical Papers*, *7*, 5–9. https://doi.org/10.4271/902340

Kurniawan, B., Dwikoranto, D., & Marsini, M. (2023). Implementasi problem based learning untuk meningkatkan pemahaman konsep siswa: Studi pustaka. *Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan*, *2*(1), 27–36. https://doi.org/10.58362/hafecspost.v2i1.28

Kurniawan, I. K., Parmiti, D., & Kusmariyatni, N. (2020). Pembelajaran IPA dengan model problem based learning berbantuan media audio visual meningkatkan pemahaman konsep siswa. *Jurnal Edutech Undiksha*, *8*(2), 80. https://doi.org/10.23887/jeu.v8i2.28959

Marianus, M., Umboh, S. I., & Umacina, N. D. P. (2020). Efektivitas model PBL berbantuan media PhET terhadap proses dan hasil belajar siswa. *CHARM SAINS: Jurnal Pendidikan Fisika UNIMA*, *1*(2), 39–43. https://doi.org/10.53682/charmsains.v1i2.15

Muliyono, M. R., Suyanto, T., & Turhan Yani, M. (2019). The effect of problem based learning model on understanding concepts and problem solving skill in social sciences in grade IV students of SDN 1 Mulung Driyorejo Gresik. *International Journal of Scientific and Research Publications (IJSRP)*, *9*(7), p9156. https://doi.org/10.29322/ijsrp.9.07.2019.p9156

Nasir, N. I. R. F., Arifin, S., & Damopolii, I. (2023). The analysis of primary school student's motivation toward science learning. *Journal of Research in Instructional*, *3*(2), 258–270. https://doi.org/10.30862/jri.v3i2.281

Nasir, N. I. R. F., Damopolii, I., & Nunaki, J. H. (2020). Pengaruh pembelajaran inkuiri terhadap level berpikir siswa SMA. *Bioilmi: Jurnal Pendidikan*, *6*(2), 112–119. https://doi.org/10.19109/bioilmi.v6i2.6948

Nasir, N. I. R. F., Mahanal, S., Ekawati, R., Damopolii, I., Supriyono, S., & Rahayuningsih, S. (2024). Primary school students' knowledge about animal life cycle material: The survey study. *Journal of Research in Instructional*, *4*(1), 253–262. https://doi.org/10.30862/jri.v4i1.320

Olumorin, C. O., Babalola, E. O., & Ayoola, D. A. (2022). Design and Development of Human Excretory System Model to Teach A Biology Concept in Ilorin, Nigeria. *Indonesian Journal of Teaching in Science*, *2*(2), 107–116. https://doi.org/10.17509/ijotis.v2i2.45782

Pratiwi, S. N., Cari, C., Aminah, N. S., & Affandy, H. (2019). Problem-based learning with argumentation skills to improve students' concept understanding. *Journal of Physics: Conference Series*, *1155*(1), 012065. https://doi.org/10.1088/1742-6596/1155/1/012065

Rahmadani, H., & Acesta, A. (2017). Pengaruh penerapan model pembelajaran problem based learning terhadap pemahaman konsep siswa. *Jurnal Sekolah Dasar, 2*(1) 1–9. https://journal.ubpkarawang.ac.id/index.php/PGSD/article/view/203

Rahayu, R. D., & Prayitno, E. (2020). Minat dan pemahaman konsep siswa dalam pembelajaran berbasis problem based learning berbantuan media video. *JIPVA (Jurnal Pendidikan IPA Veteran)*, *4*(1), 69–80. https://doi.org/10.31331/jipva.v4i1.1064

Rihi, S. P. P., & Bano, V. O. (2022). Pengaruh laboratorium virtual terhadap hasil belajar siswa kelas XI pada materi sistem pencernaan makanan. *Quagga: Jurnal Pendidikan Dan Biologi*, *14*(2), 183–188. https://doi.org/10.25134/quagga.v14i2.5753

Rindah, M. A. K., Dwiastuti, S., & Rinanto, Y. (2019). Excretory system learning in senior high school: Comparative analysis of students' problem solving skills. *Biosfer*, *12*(2), 249–257. https://doi.org/10.21009/biosferjpb.v12n2.249-257

Safaria, S. A., Agus, I., & Hadi, A. La. (2023). Pengaruh pembelajaran berbasis masalah berbantu aplikasi geogebra terhadap pemahaman konsep siswa. *Math Educa Journal, 7*(2), 111–120. https://doi.org/10.15548/mej.v7i2.6760

Saharsa, U., Qaddafi, M., & Baharuddin. (2018). Efektivitas penerapan model pembelajaran problem based learning berbantuan video based laboratory terhadap peningkatan pemahaman konsep fisika. *Jurnal Pendidikan Fisika*, *6*(2), 57–64. https://doi.org/10.24252/jpf.v6i2.5725

Saputri, A. R., Patonah S., & Mudzatun, M. (2023). Efektivitas pembelajaran tema selalu berhemat energi bermuatan sustainability menggunakan model problem based learning terhadap pemahaman konsep. *Janacitta*, *6*(1), 28–37. https://doi.org/10.35473/jnctt.v6i1.2266

Sayekti, Y. (2020). Pengaruh problem based learning dengan strategi "MURDER" terhadap kemampuan pemahaman konsep matematis siswa. *AlphaMath : Journal of Mathematics Education*, *5*(1), 24. https://doi.org/10.30595/alphamath.v5i1.7348

Septiana, K. G., & Ikhsan, J. (2017). Pengaruh penerapan multiple intelligences dengan model pbl terhadap pemahaman konsep dan kemampuan berpikir kreatif. *Jurnal Edukasi Matematika Dan Sains*, *5*(1), 43. https://doi.org/10.25273/jems.v5i1.1785

Silahooy, P. V., Nunaki, J. H., Jeni, J., Wambrauw, H. L., Nasir, N. I. R. F., Damopolii, I., Siregar, N. N., & Budirianto, H. J. (2024). Papuan local wisdom and problem-based learning: Integrated into student books and its effect on students' conservation attitudes. *Inornatus: Biology Education Journal*, *4*(1), 57–68. https://doi.org/10.30862/inornatus.v4i1.568

Siregar, H. H., & Adlini, M. N. (2022). Discovery learning assisted by audiovisual learning media: its effect on student biology learning outcomes. *Jurnal Pembelajaran Dan Biologi Nukleus*, *8*(2), 284–292. https://doi.org/10.36987/jpbn.v8i2.2885

Siswono, H., Wartono, W., & Koes H, S. (2014). Pengaruh problem based learning berbantuan virtual laboratory terhadap ketrampilan proses sains dan penguasaan konsep siswa di SMA. *Prosiding Seminar Nasional Fisika* (*E-Journal*), *3*, 22–26.

https://journal.unj.ac.id/unj/index.php/prosidingsnf/article/view/5435
Sogen, T. W. B., Damopolii, I., & Kilmaskossu, J. P. (2018). Problem-based learning in teaching excretory system materials: Does it affect student learning outcomes? *Inornatus: Biology Education Journal*, *1*(2), 89–94. https://doi.org/10.30862/inornatus.v1i2.254
Sugiharti, S., & Sugandi, M. K. (2020). Laboratorium virtual: Media praktikum online untuk meningkatkan pemahaman siswa di masa pandemi. *Prosiding Seminar Nasional Pendidikan, 2*, 45-51. https://prosiding.unma.ac.id/index.php/semnasfkip/article/view/299
Syahril, H. M. (2019). Efektifitas model pembelajaran problem based learning berbantukan multimedia terhadap kemampuan pemecahan masalah siswa. *Journal of The Indonesian Society of Integrated Chemistry, 11*(2), 43–48. https://doi.org/10.22437/jisic.v11i2.7433
Swandi, A., Nurul Hidayah, S., & Irsan, L. J. (2015). Pengembangan Media Pembelajaran Laboratorium Virtual untuk Mengatasi Miskonsepsi Pada Materi Fisika Inti di SMAN 1 Binamu, Jeneponto (Halaman 20 s.d. 24). *Jurnal Fisika Indonesia*, *18*(52), 20–24. https://doi.org/10.22146/jfi.24399
Trihastuti, I., Sundaygara, C., & Pratiwi, H. Y. (2019). Dampak penerapan model problem based learning (PBL) terhadap penguasaan konsep dan kerja ilmiah siswa SMP pada materi tekanan zat cair. *RAINSTEK : Jurnal Terapan Sains & Teknologi*, *1*(2), 73–81. https://doi.org/10.21067/jtst.v1i2.3550
Damopolii, I., & Kurniadi, B. (2019). The development of android-based mobile learning supported by problem-based learning strategy for students' learning success. *International Journal of Scientific and Technology*, *8*(7), 190–193. https://www.ijstr.org/final-print/july2019/The-Development-Of-Android-based-Mobile-Learning-Supported-By-Problem-based-Learning-Strategy-For-Students-Learning-Success.pdf
Nasir, N. I. R. F., Arifin, S., & Damopolii, I. (2023). The analysis of primary school student's motivation toward science learning. *Journal of Research in Instructional*, *3*(2), 258–270. https://doi.org/10.30862/jri.v3i2.281
Nasir, N. I. R. F., Damopolii, I., & Nunaki, J. H. (2020). Pengaruh pembelajaran inkuiri terhadap level berpikir siswa SMA. *Bioilmi: Jurnal Pendidikan*, *6*(2), 112–119. https://doi.org/10.19109/bioilmi.v6i2.6948
Nasir, N. I. R. F., Mahanal, S., Ekawati, R., Damopolii, I., Supriyono, S., & Rahayuningsih, S. (2024). Primary school students' knowledge about animal life cycle material: The survey study. *Journal of Research in Instructional*, *4*(1), 253–262. https://doi.org/10.30862/jri.v4i1.320
Olumorin, C. O., Babalola, E. O., & Ayoola, D. A. (2022). Design and Development of Human Excretory System Model to Teach A Biology Concept in Ilorin, Nigeria. *Indonesian Journal of Teaching in Science*, *2*(2), 107–116. https://doi.org/10.17509/ijotis.v2i2.45782
Silahooy, P. V., Nunaki, J. H., Jeni, J., Wambrauw, H. L., Nasir, N. I. R. F., Damopolii, I., Siregar, N. N., & Budirianto, H. J. (2024). Papuan local wisdom and problem-based learning: Integrated into student books and its effect on students' conservation attitudes.

Inornatus: Biology Education Journal, *4*(1), 57–68. https://doi.org/10.30862/inornatus.v4i1.568

Sogen, T. W. B., Damopolii, I., & Kilmaskossu, J. P. (2018). Problem-based learning in teaching excretory system materials: Does it affect student learning outcomes? *Inornatus: Biology Education Journal*, *1*(2), 89–94. https://doi.org/10.30862/inornatus.v1i2.254

Yomaki, E. K., Nunaki, J. H., Jeni, J., Mergwar, S. D. I., & Damopolii, I. (2023). Flipbook based on problem-based learning: Its development to bolster student critical thinking skills. *AIP Conference Proceedings*, *2614*(1), 020022. https://doi.org/10.1063/5.0126212

Zannah, N. L., Damopolii, I., Iwan, I., & Rahman, S. R. (2022). Examining student learning outcomes on the topic of invertebrates through problem-based learning. *Inornatus: Biology Education Journal*, *1*(2), 69–74. https://doi.org/10.30862/inornatus.v1i2.251

Zhang, C. (2023). Influences of Problem-Based Online Learning on the Learning Outcomes of Learners. *International Journal of Emerging Technologies in Learning (iJET)*, *18*(01), 152–163. https://doi.org/10.3991/ijet.v18i01.36705

Zhao, W., He, L., Deng, W., Zhu, J., Su, A., & Zhang, Y. (2020). The effectiveness of the combined problem-based learning (PBL) and case-based learning (CBL) teaching method in the clinical practical teaching of thyroid disease. *BMC Medical Education*, *20*(1), 381. https://doi.org/10.1186/s12909-020-02306-y