Biosfer: Jurnal Pendidikan Biologi

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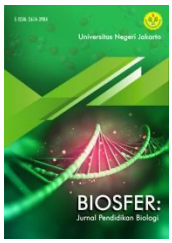

Problem-based instructional module on the excretory system: the impact on high school students' scientific process skills

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ARTICLE INFO

Article history
Received: 17 June 2025
Revised: 09 September 2025
Accepted: 15 September 2025

Keywords:
Excretory System
Module
Problem-Based Learning
Science Process Skills

ABSTRACT

This study investigates the teacher's and students' perception of problem-based instructional modules on biology learning and its effect on students' scientific process skills. The stages of development were analysis, design, development, implementation, and evaluation (ADDIE). This was quasi-experimental research with samples selected using cluster random sampling. Data were collected through needs analysis questionnaires, response questionnaires, and pretest-posttest of Science Process Skills (SPS). The module was validated by expert judgments. Data analysis used the Rasch model and paired t-test. Results indicate that the module effectively improves students' science process skills. Positive impressions were given by students and teachers regarding the use of the module. Rasch analysis shows the module helps stimulate students' understanding and involvement. The N-gain test showed increased scores, especially in the communication aspect. Meanwhile, planning experiments scored lowest, indicating challenges in students' experimental design skills. A significant difference was found in students' SPS before and after treatment, showing that PBL modules support better engagement and learning outcomes. Teachers observed students being more active, collaborative, and responsive in class discussions and problem-solving tasks. Students reported that the contextual problems enhanced their motivation, understanding, and critical thinking. The module also helped create a student-centered learning environment by promoting inquiry and exploration. Therefore, the PBL-based module for the excretory system is suitable, practical, and effective for improving high school students' science process skills, fostering scientific literacy, and enhancing overall biology learning experiences.

INTRODUCTION

The science process skill is important in learning science. Science Process Skills consist of six aspects, namely observation, classification, interpretation, applying concepts, planning experiments, and communicating (Rustaman, 2007). Science process skills (SPS) support students in the process of acquiring new knowledge (Fadillah, 2017; Senisum, 2021). Mahmudah et al. (2019), stated that SPS enables students to apply their knowledge, not just understand it. Science process skills can be developed while learning science.

The science process skills of Indonesian students need to be improved. Mahmudah et al. (2019), state that most Indonesian students lack proper mastery of SPS. The low level of students' SPS came from several factors, such as complex learning topics. Observations also show that students lack problem-solving skills. According to Abungu et al. (2014), it should be developed to help students gain a more long-term understanding, thus improving their problem-solving skills. Science process skills equip students with problem-solving abilities.

Science process skills can be realized with the support of proper learning media (Hartati et al., 2022; Sestiya et al., 2020). Various media can help students learn, one of which is a module (Audia et al., 2019). Scientific approach-based learning modules have the potential to fulfil the need for proper media, especially in Biology learning, and can stimulate students to learn (Akhri et al., 2018). Learning modules can increase students' knowledge about concepts and help teachers implement more innovative learning methods. Hasanah et al. (2018), stated that modules help students in learning and can be an alternative approach to solving students' learning problems.

According to Dwiningsih et al. (2018), the current young generation is very sensitive to technology, meaning they can easily utilize technology to develop knowledge. Apart from technology, proper stimuli are needed for students to learn through various contextual problems encountered by students in everyday life. Problem-Based Learning (PBL) can be an alternative solution to contextual learning (Mayanty et al., 2020). According to Wisic & Makiyah (2021), PBL can help improve students' problem-solving skills. Learning with PBL also stimulates students to actively build their knowledge and skills (Iriani et al., 2019).

Problem-based learning has a positive influence on students' science process skills (Hardianti et al., 2020). Sihafudin & Trimulyono (2020), stated that science process skills can be optimized through the PBL. According to Wahyudi et al. (2015), PBL has a very significant effect on students' science process skills. Learning using PBL can improve SPS because students are presented with contextual problems to be solved (Mayanty et al., 2020). Students build their conceptual understanding and skills by trying to solve the problem being presented (Sellavia et al., 2018). Along with SPS, PBL also helps to improve students' motivation and active participation during learning.

One of the essential topics in Biology is the excretory system, which many students struggle to understand because learning is often still conventional and requires them to study independently without adequate teacher support (Abram et al., 2022). To make learning more engaging and less monotonous, a suitable instructional model is needed (Devi et al., 2019). This condition makes the excretory system highly appropriate for the implementation of Problem-Based Learning (PBL), a student-centered approach that encourages learners to solve real-world problems and construct their own knowledge (Arrend, 2008). PBL has been shown to significantly enhance science process skills (Hardianti et al., 2020; Wati et al., 2016). Apart from the learning model, proper media is needed to ensure an optimal learning process (Agushinta R. & Satria, 2018). Thus, research on teachers' and students' perceptions of problem-based learning modules and their effects on students' science process skills should be conducted.

METHODS

Research Design

This was Research and Development (R&D). The module was developed using ADDIE (analysis, design, development, implementation, and evaluation) methods. This research aimed to develop a learning module about the Excretion System and assess user experience in using it. The quasi-experimental design was applied at the Implementation stage to test the effectiveness of the developed module. The samples were selected using cluster random sampling. This research used a one-group pretest-posttest design, in which students' science process skills were measured before and after learning with the module. The research was conducted in one experimental class without a comparison

or control class. This design was chosen to collect effective data after the module had been validated by experts and declared feasible for use. In addition, the Evaluation stage was carried out throughout the process to collect expert judgments, teacher and student responses, and suggestions for improvement at each phase of development.

Population and Samples

The populations were 395 high school students from Surakarta. The samples were 36 students who would study the Excretory System.

Instrument

The research instruments were teaching modules; Student worksheets, teacher response questionnaire grids, teachers' questionnaires, students' questionnaires, rubrics for students' and teachers' responses, pretest and post-test for SPS. and a rubric for SPS tests. SPS tests were given to determine changes in students' SPS. Teachers' and students' questionnaires were distributed to collect their responses to the learning module. All instruments have been validated using expert judgment. Content validity was employed, assessed by material experts, media experts, and education practitioners. The validation criteria included aspects of content accuracy, clarity of language, suitability of design, and alignment with learning objectives. Revisions were made based on the experts' feedback before the instruments were used in the study.

Procedure

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) as adapted from Branch (2009). The process began with a needs analysis to identify gaps in SPS mastery and limitations in existing learning resources. In the design stage, a learning matrix aligned with SPS components was created as a foundation for module development. The prototype was then constructed and underwent expert validation for content accuracy, instructional design, and visual communication. Following validation, the implementation stage was conducted using a one-group pretest-post-test design in a single experimental class without a control group. The researcher was actively present during the classroom sessions to observe the learning process and administer instruments such as pretests, posttests, and perception questionnaires. Data collection included documentation, testing, and structured questionnaires to obtain feedback from both students and teachers. The questionnaires consisted of 10 items for students and 10 items for teachers, covering aspects of content clarity, language, presentation, and usefulness of the module. These instruments were validated through expert judgment by material experts, media experts, and education practitioners to ensure content validity. Revisions were made based on their feedback before the questionnaires were administered. In the final evaluation stage, the effectiveness of the module was assessed based on improvements in SPS, analyzed using N-gain and paired t-tests, while teacher and student responses were examined using the Rasch model.

Data Analysis Techniques

Data were collected through documentation and tests. Documentation aims to obtain information in determining research subjects. Tests were used to obtain students' SPS data. Questionnaires were intended to obtain information on students' and teachers' opinions on learning modules. Normality tests and homogeneity tests were conducted before choosing samples. Students' science process skills were analyzed using the N-gain test to determine the improvement of students' process skills after learning. N-gain was chosen to avoid bias. Teachers' and students' questionnaires were analyzed using the Rasch model. The research hypothesis was tested using a paired t-test.

RESULTS AND DISCUSSION

Module Development

The need analysis, as the first stage, was conducted by observing the learning process and examining documentation. The analysis shows that textbooks were inadequate to train students' SPSs. This underlines the need for proper textbooks or modules to facilitate training students' SPSs. The need for proper and innovative learning modules arose for certain topics, such as the excretory system. The planning stage was done by mapping the matrix for problem-based learning. The matrix was used as a

foundation for creating the prototype module. The matrix and prototype were developed following the systematics of science process skills Rustaman (2007). The module was then tested and validated by experts. Media experts gave a rating of "highly suitable for use in learning" because the media was appropriate in terms of technique and visual communication. Expert validation of the material showed that it was highly suitable because it was appropriate in terms of grammar and content. The components of the developed instructional module, which support the implementation of problem-based learning and the development of science process skills, are presented in Figure 1.

Figure 1. Module Components

The module consists of a cover, procedural flow of learning, PBL syntax, guiding questions to deepen students' understanding, QR codes for accessing additional resources, and tasks designed to train science process skills such as observation, classification, interpretation, planning, application, and communication. Each component is structured to facilitate student-centered learning and stimulate inquiry through contextual problem-solving. The implementation stage was done by using the validated module in the learning process. This stage was done to test the effectiveness of the products. The module was implemented in the selected experimental classes.

Teachers' and Students' Perceptions of the Module

Students' and teacher's perceptions and feedback were collected using questionnaires. The responses were analyzed using the Rasch Model. The student questionnaire consisted of 10 items, while the teacher questionnaire also consisted of 10 items. The items covered several aspects, including content accuracy and clarity, appropriateness of language, presentation and attractiveness of the design, ease of use, and usefulness of the module for both independent study and classroom implementation. All questionnaire items were validated by material experts, media experts, and education practitioners before use to ensure content validity and clarity. Results of Rasch's analysis of teachers' and students' responses were presented in Figure 2 and Figure 3 respectively.

Person: REAL SEP.: .00 REL.: .00 ... Item: REAL SEP.: .99 REL.: .49

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
10	8	3	1.07	.40	2.08	1.59	2.23	1.72	-.95	.13	.0	18.1	A10
20	8	3	1.07	.40	2.08	1.59	2.23	1.72	-.95	.13	.0	18.1	A20
1	9	3	.89	.44	1.44	.75	1.60	.89	-.95	.12	.0	21.8	A1
11	9	3	.89	.44	1.44	.75	1.60	.89	-.95	.12	.0	21.8	A11
12	9	3	.89	.44	.56	-.41	.59	-.32	-.98	.12	33.3	21.8	A12
21	9	3	.89	.44	1.44	.75	1.60	.89	-.95	.12	.0	21.8	A21
2	10	3	.67	.52	.90	.27	1.02	.39	-.95	.10	.0	20.9	A2
13	10	3	.67	.52	.21	-.74	.22	-.68	-.21	.10	66.7	20.9	A13
22	10	3	.67	.52	.90	.27	1.02	.39	-.95	.10	.0	20.9	A22
3	11	3	.32	.68	.39	-.09	.43	-.05	-.95	.08	66.7	71.1	A3
4	11	3	.32	.68	.25	-.32	.23	-.35	.74	.08	66.7	71.1	A4
23	11	3	.32	.68	.39	-.09	.43	-.05	-.95	.08	66.7	71.1	A23
5	12	3	-.22	.71	.91	.41	.88	.38	.67	.08	33.3	77.5	A5
14	12	3	-.22	.71	.01	-1.26	.01	-1.27	.00	.08	100.0	77.5	A14
24	12	3	-.22	.71	.01	-1.26	.01	-1.27	.00	.08	100.0	77.5	A24
25	12	3	-.22	.71	.87	.37	.86	.37	.98	.08	33.3	77.5	A25
6	13	3	-.58	.50	.94	.43	.92	.41	1.00	.11	33.3	52.5	A6
15	13	3	-.58	.50	.09	-.70	.08	-.73	.95	.11	100.0	52.5	A15
16	13	3	-.58	.50	.94	.43	.92	.41	1.00	.11	33.3	52.5	A16
7	15	3	-.91	.34	.46	-.53	.42	-.54	.95	.16	.0	7.4	A7
17	15	3	-.91	.34	.46	-.53	.42	-.54	.95	.16	.0	7.4	A17
8	16	3	-1.01	.31	.72	-.26	.67	-.32	.95	.18	.0	7.5	A8
18	16	3	-1.01	.31	.72	-.26	.67	-.32	.95	.18	.0	7.5	A18
9	17	3	-1.11	.30	1.05	.27	1.00	.18	.95	.19	.0	7.5	A9
19	17	3	-1.11	.30	1.05	.27	1.00	.18	.95	.19	.0	7.5	A19
MEAN	11.9	3.0	.00	.50	.81	.07	.84	.10			29.3	36.5	
P.SD	2.7	.0	.76	.14	.56	.72	.61	.76			35.7	27.1	

Figure 2. Results of Rasch's analysis of Teachers' responses

Logit values, or measures, are ordered from highest to lowest. Figure 2 shows that statement 10 (S10) was the most difficult item for respondents to agree with because it has the highest item logit (+1.07). However, S19 has the lowest, (-1.11), which indicates that most of the respondents agree with the statement. The highest participant logit is 1.07 and the lowest is -1.11, which indicates that the respondent has low science process skills mastery. S10 states that the learning materials in the module are easy to understand. S19 states that the module has proper typography. The average logit value is 0.76, indicating that respondents tend to always answer statements about various items.

TABLE 13.1 F:\#PBIO SEM 8\SIAPKAN!\PENELITIAN\#S ZOU937WS.TXT Jun 06 2024 21:29
INPUT: 36 Person 16 Item REPORTED: 36 Person 16 Item 3 CATS MINISTEP 5.7.2.0

Person: REAL SEP.: 2.13 REL.: .82 ... Item: REAL SEP.: .36 REL.: .11

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
6	107	36	1.56	.45	1.63	1.76	1.71	1.75	.61	.66	77.1	83.2	A6
10	112	36	.47	.48	1.49	1.35	1.51	1.13	.44	.67	80.0	84.2	A10
14	112	36	.47	.48	.88	-.24	.76	-.44	.79	.67	85.7	84.2	A14
1	113	36	.24	.47	1.01	.14	1.05	.27	.68	.67	80.0	83.6	A1
3	113	36	.24	.47	.83	-.44	.86	-.16	.63	.67	91.4	83.6	A3
5	114	36	.02	.47	1.91	2.36	1.74	1.48	.37	.67	80.0	82.9	A5
7	114	36	.02	.47	1.11	.44	1.02	.19	.73	.67	77.1	82.9	A7
13	114	36	.02	.47	.88	-.28	.85	-.20	.64	.67	88.6	82.9	A13
9	115	36	-.20	.46	.56	-1.61	.45	-1.40	.71	.66	94.3	82.2	A9
11	115	36	-.20	.46	1.48	1.45	1.40	.94	.66	.66	71.4	82.2	A11
12	115	36	-.20	.46	.59	-1.48	.46	-1.35	.70	.66	88.6	82.2	A12
15	115	36	-.20	.46	.84	-.43	.67	-.68	.79	.66	82.9	82.2	A15
2	116	36	-.41	.46	.65	-1.25	.49	-1.28	.78	.65	88.6	81.4	A2
8	116	36	-.41	.46	.42	-2.43	.26	-2.33	.78	.65	94.3	81.4	A8
4	117	36	-.61	.45	.72	-.99	.52	-1.21	.77	.65	82.9	80.7	A4
16	118	36	-.81	.44	.92	-.18	.82	-.31	.60	.64	80.0	80.3	A16
MEAN	114.1	36.0	.00	.46	.99	-.11	.91	-.22			83.9	82.5	
P.SD	2.4	.0	.53	.01	.41	1.28	.45	1.11			6.4	1.1	

Figure 3. Results of Rasch's analysis of students' responses

Figure 3 shows that the S6 has the highest item logit (+1.56), indicating that this statement was the most difficult for respondents to agree with. The lowest item logit was gained by S16, -0.81, indicating that this statement was the easiest for respondents to agree with. The highest person logit was 1.56 and the lowest was -0.81. These results show that these respondents have the lowest level of science process skills. S6 concerns the perception of whether the excretory system is a difficult topic to be mastered. S16 probed whether participants think that learning this topic is useful or not. S19 states that the module has proper typography. The average logit value is 0.53, indicating that respondents tend to always answer questions about various items.

Effect of Problem-Based Learning Modules on Students' Science Process Skills

The implementation of the PBL-based learning module about excretory system material increased students' SPS scores. The average score for each aspect before and after treatment is shown in Figure 4.

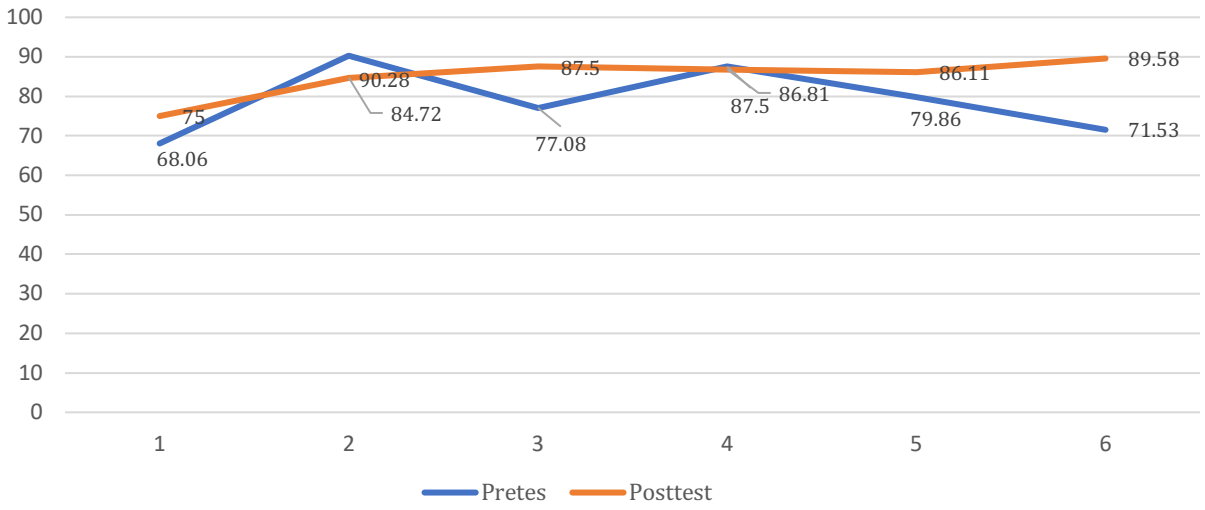

Figure 4. Average results of students' SPS scores in the pretest and post-test (Notations: 1) Observation, 2) classification, 3) interpretation, 4) planning concepts, 5) planning learning, 6) communicating).

Figure 4 shows that the average students' SPS scores have increased. The results indicated that the learning module can improve students' SPS mastery. Apart from that, presenting contextual problems during learning helps students to better master the topic. The N-gain for each aspect of science process skills is presented in Figure 5.

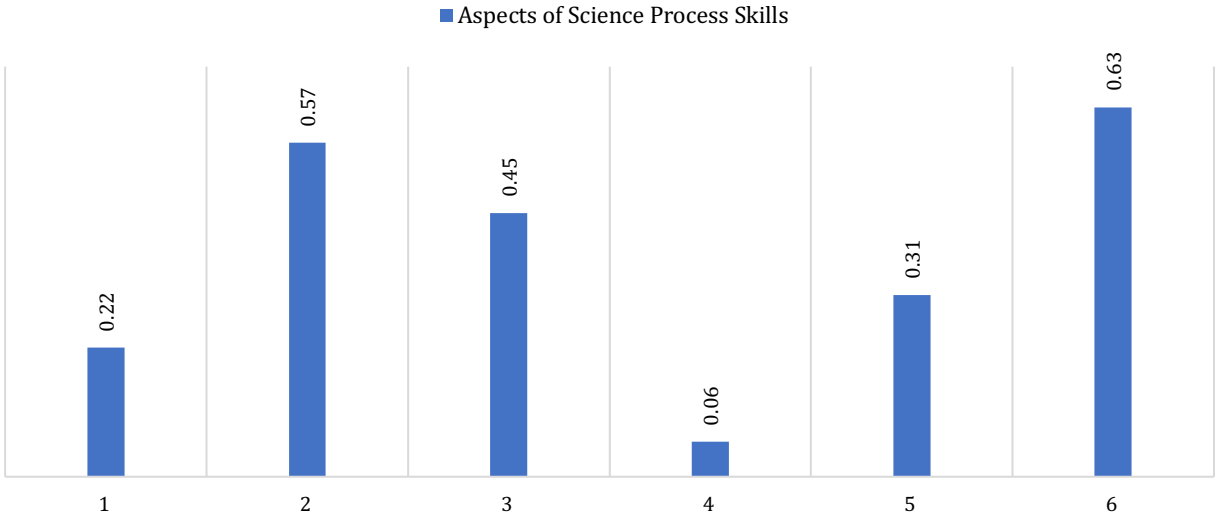

Figure 5. N-Gain of Students' Science Process Skills Aspects (Description: 1) Observation, 2) classification, 3) interpretation, 4) planning concepts, 5) planning learning, 6) communicating)

Figure 5 shows that the planning experiment has the lowest N-gains. According to Rustaman (2005), experiments are activities using the mind such as planning experiments, determining variables, determining the procedures, and choosing proper tools and materials. According to (Rahmasiwi et al., 2015), students tend to have poor mastery of this skill because they are rarely involved in experimental design activities including determining materials, variables, and procedures.

The science process skill that emerged with the highest N-gain was communication. Students' communication skills can be improved by various methods. According to Malik (2014), good communication can be improved by conditioning the classroom for conducive learning. Proper

triggering and probing questions from teachers also help develop students' communication skills. Contextualized learning using PBL also fosters communication skills by allowing students to be involved in dialogues, debates, or discussions during the learning process.

Table 1.
Results of paired t-test

Data	Sig.	Conclusion
Pretest and Post-test	0,000	There is a significant difference

Statistical differences in students' science process skills can be measured using a paired t-test. The results show that there is a significant difference between students' science process skills before and after being treated with a PBL-based learning module. In other words, problem-based learning modules can improve students' science process skills.

Effect of Problem-Based Learning Modules on Students' Science Process Skills

This research evaluates the feasibility of PBL-based learning about excretory systems to improve students' science process skills. The results show that the module is feasible and suitable. The validation results show that the module can link excretory system concepts to real situations faced by students, thereby improving their understanding. The problem-based modules also facilitate students' active involvement in the learning process, which can be seen from their increased participation in learning discussions (Rachmawati & Nugraha, 2019). This is in line with Hardianti et al. (2020) what was found, which found that PBL can improve students' science process skills because it requires them to actively construct knowledge through problem-solving. Similarly, Wahyudi et al. (2015) emphasize that PBL enhances observation, experimentation, and communication skills. The use of contextual problems in the module was also effective in stimulating students' higher-order thinking (Mayanty et al., 2020) and motivating them to apply scientific concepts in daily life (Sellavia et al., 2018). In addition, integrating PBL into modules allows students to engage in systematic investigations, fostering both independence and collaboration (Sihafudin & Trimulyono, 2020). The module has proven effective in improving students' science process skills (Suryani, 2021).

Feedback from teachers and students shows that the module is easy to use and understand. The module makes learning more interesting and interactive (Kusumawati & Hartono, 2018). This finding is also supported by Hasanah et al. (2018) those who argue that learning modules help students focus on key concepts and encourage self-directed learning. Therefore, the module is considered feasible and effective for use in improving students' science process skills.

Teachers' and Students' Perceptions of the Module

The module has received a positive response from teachers and students. The module is effective in increasing students' involvement in the learning process. Teachers noted that students became more active and involved in the learning process when using the module, which was reflected in their participation during group discussions and experimental activities. This, in turn improves the learning quality (Rachmawati & Nugraha, 2019). This is consistent with Iriani et al. (2019), who reported that PBL increases student participation and motivation.

Students' responses to the module were also positive. Students stated that their learning motivations were increased, and they gained a deeper understanding of the excretory system. Students enjoy the opportunity to work in groups, discuss, and find solutions to the problems given in the module. However, the results also highlight several challenges in implementing a PBL-based learning module. Some teachers may experience difficulties in adapting to the new learning method, especially in terms of planning and organizing time. Meanwhile, some students may need time to adapt to a more active and independent learning approach.

Differences in Students' Science Process Skills Before and After the Treatment

The learning module has positive impacts on students' SPSs. This is because PBL helps students to become more independent in learning. PBL also encourages them to develop knowledge through observation. Hartati et al. (2022) They have reported that learning with PBL can improve students' SPSs. Problem-based learning can improve students' SPSs. This is because the PBL is based on scientific methodology. PBL trains students to carry out investigations to identify problems, formulate questions, find solutions, or test temporary answers (Yusmanidar et al., 2017). The result is to be communicated both orally and in writing. In this study, students were guided through the PBL stages presented in the module. At the problem orientation stage, students observed contextual cases of excretory system

disorders, which trained their observation and classification skills. During the problem analysis and discussion stage, students formulated questions and exchanged ideas in groups, fostering their interpretation and communication skills. In the experiment and data collection activities, students planned and carried out simple investigations, thereby strengthening their ability to apply concepts and design experiments. Finally, in the presentation and reflection stage, students communicated their findings both orally and in writing, which further enhanced their science process skills. These processes in turn, foster students' SPS (Hou, 2014).

CONCLUSION

The E-module for the Excretory System has been declared suitable based on expert judgments and empirical testing. Positive responses from teachers and students show high practicality values of the module. The application of problem-based learning modules in the learning process can improve students' science process skills.

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