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The Effect of the Pjb-HOTS learning model on cognitive learning, analytical thinking skills, creative thinking skills, and metacognitive skills of biology education students

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ABSTRACT
In this industrial revolution era, university-level education emphasises higher-order thinking skills). This research aims to analyse the effect of implementing the PjB-HOTS learning model on cognitive learning, creative thinking skills, analytical thinking skills, and metacognitive skills of the students studying osmoregulation concepts in Animal Physiology courses. The sample consisted of 61 fifth-semester students divided into two classes. An open-ended test was used to measure students' cognitive learning levels, creative thinking skills, analytical thinking skills, creative thinking skills, and metacognitive skills. The research data were analysed using the Analysis of Covariance (ANCOVA). The results of this research show that the learning model had a significant effect on the cognitive learning gains (0.000< α= 0.05), creative thinking skill (0.001< α= 0.05), analytical thinking skill (0.000< α= 0.05), and metacognitive skill (0.000< α= 0.05). These results indicate that the combined syntax of PjBL and HOTS can foster students' higher-order thinking skills and improve their cognitive learning gains. We recommend the PjB-HOTS learning model be used for other biological concepts at the university-level.

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Introduction

Education 4.0 is a part of Industrial Revolution (IR) 4.0 (Bonfield et al., 2020). It is a phenomenon that results from the necessity of the IR 4.0. For example, the curricula of primary schools, lower secondary schools and upper secondary schools are revised to prepare the pupils exiting the education system to compete in the IR 4.0 era. According to Venkatraman et al. (2022), the Education Framework 4.0 aims to support Industry 4.0 skills needs which include soft skills development and lifelong learning. Higher Order Thinking Skills (HOTS) are considered the most suitable skills for the 4.0 education era. Hartono and Pahlevi (2020) explain that HOTS focuses on critical thinking and creative thinking to solve problems. HOTS-based learning can help learners improve their problem-solving skills. HOTS integrated with learning strategies can be used to improve the learning process by promoting learners' creativity at all levels of education (Zohar & Dori, 2008; Chinedu et al., 2015; Zubaidah et al., 2017; Heong et al., 2019; Istiyono et al., 2020).

So far, HOTS has always been evaluated at the end of learning activities. Researchers have developed appropriate instruments to measure HOTS in learning (Serevina et al., 2019; Erfianti et al., 2019). Syafryadin et al. (2021) have integrated the HOTS principle during the English learning process, while Pius et al. (2019) applied the HOTS principle during History learning. This means that implementing HOTS integrated with a learning model can also be done in Biology learning. The Project-Based Learning (PjBL) learning model is an innovative learning model that emphasizes the investigation process by the students and produces artifacts like objects or documents. Rumahlatu and Sangur (2019) reported that implementing the PjBL learning model had a more significant effect on fostering students' metacognitive skills through the construction of cognitive and manage their learning than the conventional learning model. Syawaludin et al. (2022), Kortam et al. (2018), Maiasputri et al. (2018), Surahman et al. (2018), and Berchiolli et al. (2018) recommend that the PjBL learning model be implemented to improve students' higher-order thinking skills and active participation in learning. The PjBL learning model can be integrated with HOTS into an innovative learning model called the Project Based-Higher Other Thinking Skills Learning Model (PjB-HOTS learning model. Each stage of the PjBL learning model, which includes planning, creating, and presenting, will be integrated into a single unit with HOTS components such as creative, critical, and analytical thinking skills.

Budsankom et al. (2015) invoke HOTS in three abilities are analytical thinking, critical thinking, and creative thinking. Rumahlatu et al. (2020) and Saputri & Corebima (2020) state that in addition to critical thinking skills and creative thinking skills, metacognitive skills can also improve students' comprehension of the learning material. Fosters of metacognitive abilities have a positive relationship with creative thinking which is shown through original ideas and idea formation (Puente-Diaz et al., 2021; Suratno et al., 2019). Metacognitive skills can also affect students' critical thinking skills through a research-based learning process that fosters these two abilities (Kozikoğlu, 2019; Gurcay & Ferah, 2018; Mataniari et al., 2020).

Educators should prepare an innovative learning model to improve students' higher-order thinking skills. Retnawati et al. (2018) state that educators should provide challenging opportunities for students to train their higher-order thinking skills. With the implementation of an appropriate learning model, it is expected that students, as the young Indonesian generation, are prepared and ready to face the challenges of the 4.0 Industrial Revolution.

Most of the lecturers in the Biology Education Department in Pattimura University have implemented innovative cooperative learning models, such as STAD, PBL, PjBL, NHT, GI and many other models. The lecturers have also implemented learning evaluations with HOTS-based questions. This shows that they apply the HOTS learning and evaluation model separately/partially. However, they have not integrated HOTS with the learning models to improve the students' higher-order thinking skills. Lecturers need to design HOTS-based learning models to effectively and efficiently foster students' higher-order thinking skills so that learning and evaluation processes become one unit. Previous researchers have successfully integrated HOTS with learning models (Heong et al., 2019; Launuru et al., 2021). This study aims to conduct this research to investigate the implementation of the PjB-HOTS learning model on the fosters of students' cognitive learning gains, analytical thinking skills, creative thinking skills, and metacognitive skills in the Biology education department at Pattimura University, Ambon. The conduct of this research can offer an innovative biology learning climate at the university level.

Methods

Table Representation

This research was of quasi-experimental design using a pretest-posttest nonequivalent group approach. The PjB-HOTS and PjBL learning models were used as the independent variables, while cognitive learning gains, creative thinking skills, analytical thinking skills, and metacognitive skills were used as the dependent variables. These two models were used in different classes to test the effect of the PjB-HOTS learning model on the dependent variable. Table 1 shows the quasi-experimental research design. The difference in learning from these two models can be seen in the Appendix.

Table 1

Research Design

Treatment Group	Pre-test	Post-test
PjB-HOTS learning model (X1)	Y1	Y2
PjBL learning model (X2)	Y1	Y2

Sample

The population of this research was the fifth-semester students taking the Animal Physiology course which consisted of three classes. The research samples involved two classes of students. Class A was taught using the PjB-HOTS learning model as the experimental class, and class B was taught using the PjBL learning model as the control class. The research samples were determined using the purposive sampling technique by considering several conditions: a heterogeneous class (gender and social background) and able to perform digital literacy.

Instruments

The instrument developed in this research was an open-ended test based on creative thinking skills, analytical thinking skills, and metacognitive skills. In addition, the instrument was also equipped with a scoring matrix for cognitive learning, creative thinking skills, analytical thinking skills, and metacognitive skills. Before being used, the instrument was initially tested for reliability and validity. Table 2 shows the validity analysis and the reliability analysis.

Table 2

Instrument Validity and Reliability

Question items	Question type	r_{xy}	Significant value	Interpretation	Cronbach's alpha Value	Interpretation
1	Smoothness	.187	= 0.05	Valid	.782	Good
2	Authenticity	.082		Valid		
3a	Flexibility	.080		Valid		
3b		.070		Valid		
4a	Develop	.285		Valid		
4b		.071		Valid		
5a	Rate	.370		Valid		
5b		.250		Valid		

5c	.066	Valid
5d	.056	Valid

Procedures

The learning activities in each class were carried out almost simultaneously and using different learning models (Table 4). The dependent variables (cognitive learning gains, creative thinking skill, analytical thinking skill, and metacognitive skill) were assessed using the same instrument. The research data were collected as follows. (1) The Pre-test was administered to both classes before the learning activities began. The pre-test results of the cognitive learning, creative thinking, analytical thinking, and metacognitive skills were used as covariates in the ANCOVA statistical analysis. (2) The experimental class was taught by using the PjB-HOTS learning model and the control class was taught using the PjBL learning model (Table 4). (3) Post-test was administered to measure students' cognitive learning gains, creative thinking skills, analytical thinking skills, and metacognitive skills.

Table 4

The Learning Syntax of the PJB-HOTS Learning Model

PjBL Stages for a control class	Explanation	HOTS Aspects	PjB-HOTS Integration for a experiment class	
Planning	1. Selecting a topic 2. Searching for information 3. Organising human resources in groups	• Creative Thinking • Analytical Thinking	Planning	1. Fostering students' analytical thinking about problems that can be used as the topics for osmoregulation investigation projects 2. Fostering students' analytical thinking to select relevant information to the concept of osmoregulation 3. Fostering students' creative thinking in dividing group tasks
Creating	4. Developing project stages 5. Implementing the project 6. Making a product (artefact) 7. Compiling project reports		Creating	4. Fostering students' creative thinking in arranging the stages of osmoregulation investigation projects 5. Fostering students' creative thinking in implementing the project 6. Fostering students' creative thinking in making a product 7. Fostering students' analytical thinking in compiling investigative data into project reports
Presenting	8. Presentation 9. Feedback		Presenting	8. Fostering students' creative thinking in doing presentations

Data Analysis

The research data were analysed using inferential statistics. The data were tested for normality and homogeneity using the One-Sample Kolmogorov-Smirnov Test and Leven's Test of Quality of Error Variances, respectively (Table 5). The Analysis of Covariance (ANCOVA) was used to analyse the effect of the implementation of the learning models on students' cognitive learning gains, creative thinking skills, analytical thinking skills, and metacognitive thinking skills. Furthermore, if the analysis results indicated that the implementation of the learning model had an effect, the post hoc least significant difference (LSD) would be performed to determine the average statistical significance difference. The data analyses were performed using the SPSS 18.0 program.

Table 5

The Data of the Normality and Homogeneity Analyses of the Dependent Variable

Variable	Description	Description
Cognitive Learning Gains	Homogeneous	Normal
Creative Thinking	Homogeneous	Normal
Analytical Thinking	Homogeneous	Normal
Metacognitive Thinking	Homogeneous	Normal

Findings

Several osmoregulation projects carried out by students are described in Figures 1-3.

Figure 1

One of the Osmoregulation Projects Was Carried Out By A Student Titled "Measurement Of Water Volume In Comet Fish By Using Water Variations". Through This Project, The Student Found Creative Ideas To Observe The Osmoregulation Ability Of Comet Fish In Water Variations That Are Different From Their Natural Habitat, Namely Freshwater. Analytical And Metacognitive Abilities Are Needed To Explain Why The Volume Of Boiled Water Decreases Faster Than Refilled Water And Pure Water

Measurement of Water Volume in Comet Fish by Using Water Variations

Date	Water Volume	Water Type			Observation Result		
		Pure Water	Water Gallon	Boiled Water	Pure Water	Water Gallon	Boiled Water
Monday, October 05, 2020	500 ml	500 ml	500 ml	500 ml			
Tuesday, October 06, 2020	500 ml	495 ml	492 ml	490 ml			
Wednesday, October 07, 2020	500 ml	490 ml	484 ml	480 ml			
Thursday, October 08, 2020	500 ml	485 ml	475 ml	470 ml			

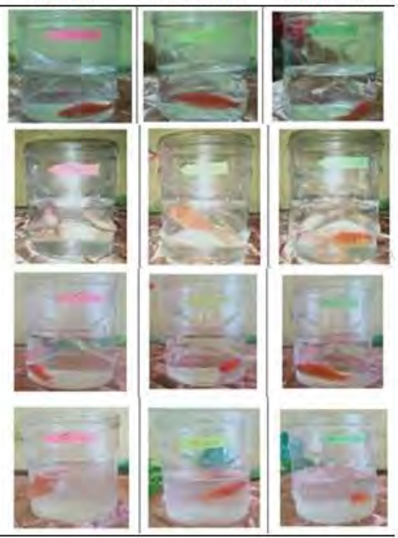

Figure 2

The Next Osmoregulation Project Is "The Effect Of Water Salinity On Tilapia And Survival Ability" In This Project, The Student Found Creative Ideas To Observe The Differences In The Survival Abilities Of Tilapia In Seawater And Freshwater. Through This Project, the Student Will Analyse the Osmoregulation Ability Of Freshwater Fish That Live In Seawater, Also Find And Evaluate A Suitable Concept To Explain The Osmoregulation Ability (Metacognitive Ability)

The Effect of Water Salinity on Tilapia (*Oreochromis niloticus*) and Survival Ability

Time	Observation Result		Documentation
	Freshwater	Seawater	
0 minute	The fish stay alive and active	The fish stay alive and active	
15 Minute	The fish stay alive and active	The fish are still alive but the movement is starting to weak	
30 Menit	The fish stay alive and active	The fish are still alive but the movement is very weak	

Figure 3

a) *The Students Is Carrying Out An Osmoregulation Project With The Title "Observation Of The Osmoregulation Of Earthworms (Lumbricus Terrestris)*
b) *Students Think Creatively To Arrange The Stages Of Observing The Osmoregulation Of Earthworms In Freshwater And Salt Solutions Based On Indicators Of Weight, Colour, Surface, And Fluids Released By The Worm's Body. Meanwhile, Analytical And Metacognitive Skills Are Needed To Compile A Final Report That Explains The Concept Of Osmoregulation Of Earthworms In Two Different Habitats*

Observation of the Osmoregulation of Earthworms (*Lumbricus terrestris*)

Prepare tools and materials | Weigh earthworm's body | Make a salt solution | Soaking earthworms in fresh and salt water | Worms in fresh and salt water

(a)

Observation Results

Indicator	Freshwater				Salt Solution			
	Beginning	10 Minute	20 Minute	30 Minute	Beginning	10 Minute	20 Minute	30 Minute
Weigh of body	5.1 gr	5.15 gr	5.15 gr	5.15 gr	4.3 gr	3.9 gr	3.2 gr	2.8 gr
Colour of body	Pinky	Shiny red	Shiny red	Shiny red	Pinky	Pale red	Pale red	Pale white
Surface of body	Slick	More slick	More slick	More slick	Slick	Less sticky	Sticky	More sticky
Fluids released of body	Nothing	Nothing	Nothing	Nothing	Nothing	White liquid	Nothing	Nothing

(b)

The results of the ANCOVA analysis on the effect of the learning models on the students' cognitive learning gains of osmoregulation concepts are presented in Table 6.

Table 6

The Results of ANCOVA analysis

Variable	Learning Model
Cognitive Learning Gains	*
Creative Thinking Skill	*
Analytical Thinking Skill	*
Metacognitive skill	*

Note: (*) has a significant effect on α= 0.05 (The results of statistical analysis can be seen in the Appendix)

The results of the ANCOVA analysis show that the learning model had a significance value of 0.00 0 <α=0.05. This indicates that the implementation of the learning models significantly affected the student's cognitive learning gains, creative thinking skills, analytical thinking skills, and metacognitive skills in learning osmoregulation concepts. The implemented learning models were the PjB-HOTS and the PjBL learning models. Moreover, to find out which learning model had a more significant effect on the improvement of students, a post hoc LSD test was performed (Table 7).

Table 7

The Results of LSD Analysis

Learning models	Cognitive Learning Gains	Creative Thinking Skill	Analytical Thinking Skill	Metacognitive skill
PjB _HOTS	81.1081[a]	25.5405[a]	26.0000[a]	69.7027[a]
PjBL	74.3750[b]	24.0833[b]	24.0833[b]	63.4028[b]

The results of the LSD analysis show that there is a difference in LSD notation between the PjB-HOTS learning class and the PjBL learning class. Using the PjB-HOTS learning model, the class taught had a higher average score than the class taught using the PjBL class.

Discussion

Cognitive Learning Gains

This research's cognitive learning gains are related to the students' ability to understand osmoregulation concepts using their thinking ability. Inferential analysis using the ANCOVA showed that the implementation of the learning models affected students' cognitive learning gains (p=.000 <α=0.05) (Table 6). Moreover, the Post Hoc LSD test results showed that implementing the PjB-HOTS learning model in the experimental class had more significant effects in improving students' cognitive learning gains than implementing the PjBL learning model in the control class (Table 7). The difference in the improvement of the students' cognitive learning gains between the experimental and control classes are affected by the learning activities in the learning model, which can develop the student's cognitive structure.

The learning activities in the PjBL learning model and the PjB-HOTS learning model focus on finding information, formulating problems, and completing projects through investigations. However, there are several differences between the two learning models. In the PjB-HOTS learning model, the lecturers direct and train the students' critical thinking, analytical thinking, and creative thinking skills in the learning activities. For example, the students are asked to analyse problems and information related to osmoregulation and then determine the topic of investigation and critically arrange the stages of the investigation. Through these learning stages, students' cognitive structures can be formed. Wang and Ruhe (2007) explain that one of the cognitive processes is making decisions on one or several choices from a certain set of alternatives.

The next learning stage of the PjB-HOTS learning model that can shape students' cognitive structure better than the control class is critical and creative in implementing projects and discussions with group members to make products and investigation reports. The integration of the PjB-HOTS learning model has a unified PjBL stage that is integrated with HOTS. Students are trained to plan projects using analytical and critical thinking skills, implement projects by fostering creative and analytical thinking skills, and prepare final products, reports, and presentations by fostering critical and creative thinking skills. When the students have already trained their critical thinking and discussed arranging the stages of the project, they already comprehend the osmoregulation concepts. Therefore, they can better prepare reports and make products than the students in the control class Lin et al. (2013) explain that the good cognitive abilities of students can be used to discuss other problems. Vukic et al. (2020) explain that good cognitive formation can build a strong understanding of the basis for understanding the principles for a more comprehensive understanding.

Freeman and Dale (2013) added two phenomena for cognitive formation, namely through single and multiple processes. Implementing projects based on the development of higher-order thinking skills is an important stage in forming students' cognitive processes in studying osmoregulation concepts. This can be explained through the concept of multiple cognitive formations. The multiple cognitive systems are formed through students' cognitive development, perception, direct practice, discussion involvement, and focus of attention on the given task, and is induced by skills and stimuli (seeing, feeling, hearing, and kinaesthetic), as well as student interactions with other students (Barsalou, 2017; Dale & Duran, 2011; Frixione & Lieto, 2014).

After participating in the series of learning stages, a HOTS-based final test is given at the end of the lesson. According to Ansori (2020) and Suprapto et al. (2020), cognitive abilities can be related to HOTS if the test items are based on interesting and contextual stimuli, the test items measure students' reasoning skills (knowledge transfer, processing and application of information, finding the relationship of various information, using the information to solve problems, and examining ideas and information critically). In order to answer these HOTS-based test items, students should already accustomed to developing HOTS in the learning activities using the PjB-HOTS learning model. Students who learn to use the PjBL learning model are also given a HOTS-based test. However, students who are taught using the PjB-HOTS and PjBL learning models have different abilities in answering HOTS-based test.

Creative Thinking Skill

HOTS is very important to train the students to foster their creative thinking skills in the learning process and to answer HOTS-based test items. The results of the ANCOVA inferential analysis showed that the implementation of learning models affected students' creative thinking ($p=.001 < \alpha=0.05$) (Table 8). Moreover, the results of the LSD test showed that the PjB-HOTS learning model implemented in the experimental class had a more significant effect on the improvement of students' creative thinking skills than the implementation of the PjBL learning model in the control class (Table 9). These results indicate that students taught using the PjB-HOTS learning model could foster their creative thinking skills to learn osmoregulation concepts better than those taught using the PjBL model. Both the PjBL learning model and the PjB-HOTS learning model emphasize investigation activities and producing scientific products. However, the PjB-HOTS learning model fosters students' creative thinking skills in each PjBL learning stage. As a result, the students can provide alternative ideas from the information they obtain from the internet. Creative thinking skill is the ability to generate images, new ideas, alternative hypotheses, and evaluation capabilities (Kampylis, Berki & Saariluoma, 2009). In addition, Hidayati, Fitriani, Saputri & Ferazona

(2023) and Mufida, Sigit & Ristanto (2020) state that investigation activities can encourage students to find new and unique ideas.

The indicators of creative thinking shown in the learning process are that students can express their project ideas well, identify and solve problems through project activities. Ersoy and Baser (2014); Hasan, Lukitasari, Utami & Anizar (2019) explain that the improvement of creative thinking can last in a long process through investigation activities, both information investigation and experiment investigation. Eragamreddy (2013) adds that creative thinking is based on the awareness to increase their thinking to do information searching to their comprehension of a concept.

Meanwhile, Yudiarti and Lantu (2017) explained that creative thinking skills are formed through simultaneous convergent and divergent thinking so that students can create innovative products. This can happen because, during the PjB-HOTS learning activities, the students are accustomed to divergent thinking to find ideas for solving animal osmoregulation investigation projects. The problem-solving activity is continued to produce scientific products in the form of scientific reports that can be used as material for scientific presentations in the lecturing activities. In this case, Ichsan, Sigit, Miarsyah, Ali & Suwandi (2020) and Chasanah, Kaniawati & Hermani (2017) argue that classes that foster HOT skills during the learning activities have high problem-solving skills. Students who learn the concept of osmoregulation using the PjBL learning model also carry out problem solving activities at each stage of PjBL, but the problem-solving activities carried out by students in the PjB-HOTS class have been trained with creative and analytical thinking skills.

Analytical Thinking Skill

Analytical thinking skill is one of the skills described in the higher-order thinking skills (HOTS). In Bloom's taxonomy, analytical thinking skill is in the C4 domain. The results of the ANCOVA inferential analysis showed that the implementation of learning models affected the students' analytical thinking skills ($p=.000<\alpha=0.05$) (Table 10). Moreover, the Post Hoc LSD test results showed that implementing the PjB-HOTS learning model in the experimental class had more significant effects in improving students' analytical thinking skills than implementing the PjBL learning model in the control class (Table 11). These results indicate that the students taught using the PjB-HOTS learning model could foster their analytical thinking skills in studying the concepts of osmoregulation better than the students taught by using the PjBL learning model. In the learning stages of the PjB-HOTS learning model, students are trained to think analytically about using the information found, analyzing the data from the investigation results into tables or graphs, and thinking analytically to structure the implementation of projects correctly. Participating in the learning activities of the PJB-HOTS learning model, the students can link the concepts of osmoregulation and understand and synthesize the concepts of osmoregulation. According to Ramos, Dolipas & Villamor (2013); Irwanto (2017); Irwanto, Roheti, Widjajanti & Suyanto (2017), analytical skill is an understanding of the relationship between the whole concepts and the sub-components of the concept; connecting the causes and effects, distinguishing and categorizing, and interpreting information from charts, graphs, or diagrams.

PjBL learning also provides a learning environment for conducting investigations and analyzing the investigations into tables and graphs. However, the PjB-HOTS learning model is more than that because the lecturer fosters students' analytical thinking skills in every PjBL learning activity. This is one of the differences between PjBL learning and PjB-HOTS learning models. According to Yusuf and Widyaningsih (2019); Warmadewi, Agustini & Wedhanti (2019); Supriyatin, Rahayu, Ristanto & Ichsan (2019), such learning strategies train students to use their higher-order thinking skills, to analyze and to evaluate contextual problems, and to use a variety of questions. In addition, they also state that supportive learning environments can foster thinking skills for reasoning, evaluation, problem-solving, decision making, and problem analysis.

At the implementation of the PjB-HOTS learning model, lecturers also foster students' thinking skills with questions to stimulate students' analytical thinking skills to analyze and evaluate problems related to the concepts of osmoregulation. Similarly, in their research, Abidinsyah, Ramdiah & Royani (2019) state that the most commonly used cognitive abilities to improve students' HOTS skills are applying, analyzing, decision making, and implementing.

Metacognitive Skill

Metacognitive skill is one part of the higher-order thinking skills (HOTS) which assesses one's awareness of their learning process, using learning strategies, evaluating the learning process, and the learning results. The results of the ANCOVA Inferential analysis showed that the implementation of the learning model affected students' metacognitive skills ($p=.000<\alpha= 0.05$) (Table 12). Moreover, the post hoc LSD test results indicate that implementing the PjB-HOTS learning model in the experimental class had a more significant improvement in students' metacognitive skills than implementing the PjBL learning model in the control class (Table 13).

Project-based research leads students to pose research problems related to osmoregulation independently. In implementing the PjBL learning model, the lecturer guides students to do the projects according to the learning stages. During the project learning stage, the students' learning values are independence in seeking information, planning, making decisions, implementing projects and making conclusions, and curiosity.

Meanwhile, at implementing the PjB-HOTS learning model, the lecturer guides the students based on the HOTS-based PjBL learning stage. Each learning stage is integrated with critical thinking, creative thinking, and analytical thinking skills. During the learning activities, the lecturer familiarizes the students to think critically, analytically and creatively; even during independent learning, the students are critical in asking questions and creative in making products. The learning process begins with online learning using zoom meetings. At that time, students did project planning with lecturers. Lecturers familiarize students with practicing critical, analytical, and creative thinking skills by setting problems according to the osmoregulation concept, seeking information, and making project implementation stages. After that, students experience independent learning to carry out projects and make products. However, students and lecturers continue to ask questions using the WhatsApp application to control the students' independent learning process. The same result was also conveyed by Samsudin, Jamali, Zain & Ebrahim (2020) that the integration of STEM with PjBL fosters students to carry out projects using their independence to design techniques, produce research procedures, and divide work into groups to make simple pulleys. Rahardjanto, Husamah & Fauzi (2019) apply Hybrid-PjBL learning and report that although learning is done online, Hybrid-PjBL learning is able to stimulate critical thinking, creativity, and self-regulation skills through project implementation.

Moreover, Saido, Siraj, Bin-Nordin & Al-Amedy (2015); Ichsan, Rahmayanti, Purwanto, Sigit, Singh & Babu (2020); Husamah, Fatmawati & Setyawan (2018); explain that higher-order thinking skills (HOTS) can be fostered if the students are engaged with problems, uncertainty and questions. In addition, an innovative learning model can foster students' higher-order thinking skills (HOTS) to give explanations, make the decision, understand facts, change from not knowing to know, and from unable to able. Those statements indicate that implementing the PjB-HOTS learning model can foster students' metacognitive skills better than the PjBL learning model. Students who are taught using the PjB-HOTS learning model have a different learning experience from the PjBL learning model. Although both of these learning models focus on project implementation. However, the PjB-HOTS learning model has several stages that are integrated with the HOTS component so that it improves students' metacognitive abilities better than the PjBL learning model in the control class.

The PjBL learning model is also an innovative learning model, but in this RI 4.0 era, PjBL should be developed or modified in other stages. Hsu, Van-Dyke & Smith (2014) argue that project-based learning integrated with graph-oriented computers is more effective in improving scientific understanding, scientific argumentation skills, and a dynamic learning environment. Meanwhile, the integration of STEM in PjBL learning is very beneficial for forming thinking structures such as clarifying problems, establishing ideas, and making products; improving cooperation and communication in groups; increasing creativity and imaginativeness; caring about actual issues in society; and fostering digital literacy technology capabilities (Lin, Wu, Hsu & Williams, 2021; Baran, Baran, Karakoyun & Maskan, 2021).

Metacognitive skill is a higher-order thinking skill that combines the students' soft skills and cognitive skills. The students' soft skills include planning, monitoring, and evaluating their learning processes. Furthermore, cognitive skills are used to process thoughts to understand, analyze, synthesize new information, and learn. Therefore, it is essential to train metacognitive skills in learning. According to Rahmat and Chanunan (2018); Antonio and Prudente (2021), metacognitive skills include the ability to control one's resources to regulate their cognition through student-centred learning, and a strategy that fosters the student to investigate and make scientific conclusions.

Conclusion and Implications

The implementation of the PjB-HOTS learning model affected students' cognitive learning gains in studying the concepts of osmoregulation. Moreover, it can also be used to foster students' higher-order thinking skills including creative thinking skills, analytical thinking skills, and metacognitive thinking skills.

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Appendix 1

LESSON PLAN EXPERIMENT CLASS (PjB-HOTS LEARNING)

Study programme	**Biology Education**
Course code	**PBN-503**
Course/Semester	**Animal Physiology / V**
Meeting time	**150 minutes**
Meeting	**9th**
Programme Learning Outcome (PLO)	1. Students will be able to understand and apply the fundamental concepts and principles of biology, including cell and molecular biology, physiology, genetics, structure and development, biosystematics, evolution, and ecology in their roles as professional educators. 2. Student capable of conducting scientific research and acquiring knowledge in the field of Biology, utilizing the research findings to perform a critical evaluation of their own learning process, while proposing alternative measures for continual enhancement.
Course Learning Outcome (CLO)	To be able to identify the mechanisms of osmoregulation and excretion in aquatic and terrestrial animals, together with the organs involved.
Learning Materials	1. The mechanisms of osmoregulation and excretion in aquatic animals and the corresponding organs are discussed in this section. 2. Mechanisms of osmoregulation and excretion, as well as the associated organs, in tertiary animals are discussed in this paper.
Learning Model	PjB-HOTS Learning
Learning Strategy	Active student/Student centre learning
Learning Methods	Experiments, Projects, and Varied discussions

Learning Activities

PjB-HOTS Learning Integration		**Week**	**Lecturer Activity**	**Student Activity**
Planning	✓ Fostering students' analytical thinking about problems that can be used as the topics for osmoregulation investigation projects ✓ Fostering students' analytical thinking to select relevant information to the concept of osmoregulation ✓ Fostering students' creative thinking in dividing group tasks	I (using Zoom Cloud Meeting)	✓ Direct students to analyse the phenomenon of osmoregulation in animals living in marine, freshwater, brackish, and terrestrial environments ✓ Direct students to find information and then analyse the information into an investigation topic.	✓ Students analyse the phenomenon of osmoregulation in animals living in marine, freshwater, brackish, and terrestrial environments ✓ Students search for information then analyse the information into an investigation topic.
Creating	✓ Fostering students' creative thinking in arranging the stages of osmoregulation investigation projects ✓ Fostering students' creative thinking in implementing the project ✓ Fostering students' creative thinking in	II (using Zoom Cloud Meeting) III (Using Zoom Cloud Meeting to independently	✓ Direct students to analyse scientific articles to find the stages of project implementation ✓ Directing students to be critical in reading scientific articles to develop project stages ✓ Directing students to be	✓ Students Analyse scientific articles to find the stages of project implementation ✓ Students are critical in reading scientific articles to develop project stages ✓ Students are creative in

	making a product ✓ Fostering students' analytical thinking in compiling investigative data into project reports	research and coordinate with the course instructor)	creative to carry out project activities ✓ Directing students to be critical in carrying out projects ✓ Directing students to creatively create products in the form of scientific writing in the form of articles, posters, etc. ✓ Directing students to conduct data analysis according to the correct data analysis technique ✓ Directing students to analyse relevant literature to develop project reports ✓ Directing students to be creative in compiling reports according to the rules in scientific reports	carrying out project activities ✓ Critical students in carrying out the project ✓ Creative students make products in the form of scientific writing in the form of articles, posters, etc. ✓ Students perform data analysis according to the correct data analysis technique ✓ Students analyse relevant literature to develop project reports ✓ Students are creative in preparing reports according to the rules in scientific reports
Presenting	✓ Fostering students' creative thinking in doing presentations	IV (using *Zoom Cloud Meeting*)	✓ Directing students to be critical when listening to other groups making presentations ✓ Directing students to be creative in asking questions to groups that are presenting	✓ Students are critical when listening to other groups making presentations ✓ Students are creative in asking questions to the group that is presenting

Instrument

Non-Test: Scientific product assessment instruments
Tests: cognitive, analytical thinking, creative thinking, and metacognitive

Reference

- Campbell at, 2000, Biology. Printed by PT Gelora Aksara Pratama. Jakarta (In Indonesian)
- Isnaeni, W. 2006. Animal Physiology. Yogyakarta: Kanisius (In Indonesian)
- Scientific articles

Appendix 2

LESSON PLAN CONTROL CLASS (PjBL)

Study programme	**Biology Education**
Course code	**PBN-503**
Course/Semester	**Animal Physiology / V**
Meeting time	**150 minutes**
Meeting	**9th**
Programme Learning Outcome (PLO)	1. Students will be able to understand and apply the fundamental concepts and principles of biology, including cell and molecular biology, physiology, genetics, structure and development, biosystematics, evolution, and ecology in their roles as professional educators. 2. Student capable of conducting scientific research and acquiring knowledge in the field of Biology, utilizing the research findings to perform a critical evaluation of their own learning process, while proposing alternative measures for continual enhancement.
Course Learning Outcome (CLO)	To be able to identify the mechanisms of osmoregulation and excretion in aquatic and terrestrial animals, together with the organs involved.
Learning Materials	1. The mechanisms of osmoregulation and excretion in aquatic animals and the corresponding organs are discussed in this section. 2. Mechanisms of osmoregulation and excretion, as well as the associated organs, in tertiary animals are discussed in this paper.
Learning Model	PjBL
Learning Strategy	Active student/Student centre learning
Learning Methods	Experiments, Projects, and Varied discussions

Learning Activities

PjBL	Week	Lecturer Activity	Student Activity
Planning	I (using Zoom Cloud Meeting)	✓ Direct students to determine project topics on osmoregulation in animals living in marine, freshwater, brackish, and terrestrial environments. ✓ Direct students to find and collect information about osmoregulation that supports the implementation of the project	✓ Students determine the topic of osmoregulation in animals living in marine, freshwater, brackish, and terrestrial environments. ✓ Students search for and collect information on osmoregulation
Creating	II (using Zoom Cloud Meeting) III (Using Zoom Cloud Meeting to independently research and coordinate with the course instructor)	✓ Direct students to formulate the stages of project implementation ✓ Directing students to carry out project activities ✓ Directing students to make products in the form of scientific writing in the form of articles, posters, etc. ✓ Directing students to conduct data analysis according to the correct data analysis technique	✓ Students formulate the stages of project implementation ✓ Students carry out project activities ✓ Students create products in the form of scientific writing in the form of articles, posters, etc. ✓ Students analyse data according to the correct data analysis technique

		✓ Directing students to compile reports according to the rules in scientific reports	✓ Students compile reports according to the rules in scientific reports
Presenting	IV (using *Zoom Cloud Meeting*)	✓ Directing students to listen to other groups making presentations ✓ Directing students to ask questions to the presenting group.	✓ Students listen to other groups presenting ✓ Students ask questions to the group that is presenting

Instrument

Non-Test: Scientific product assessment instruments

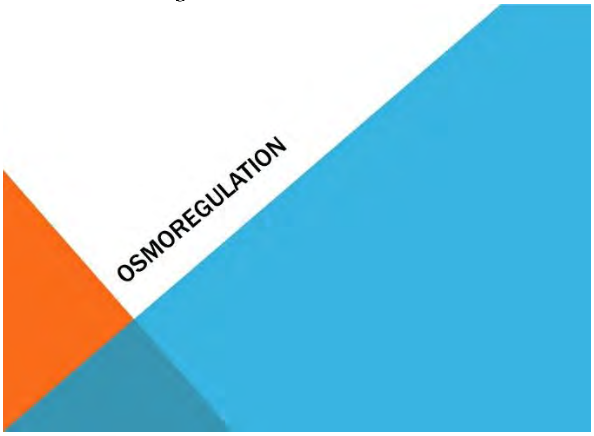
Tests: cognitive, analytical thinking, creative thinking, and metacognitive

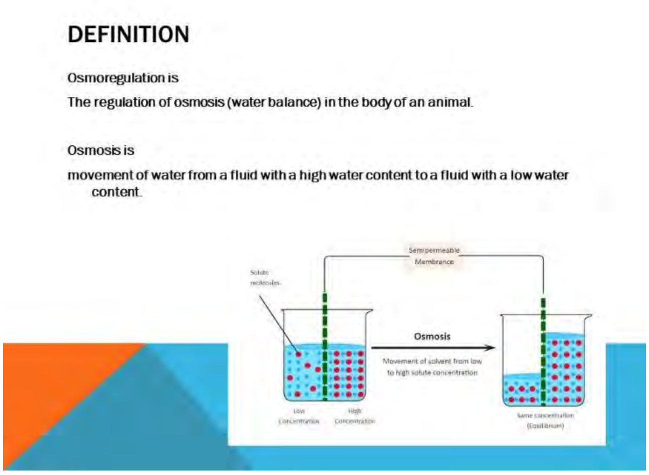
Reference

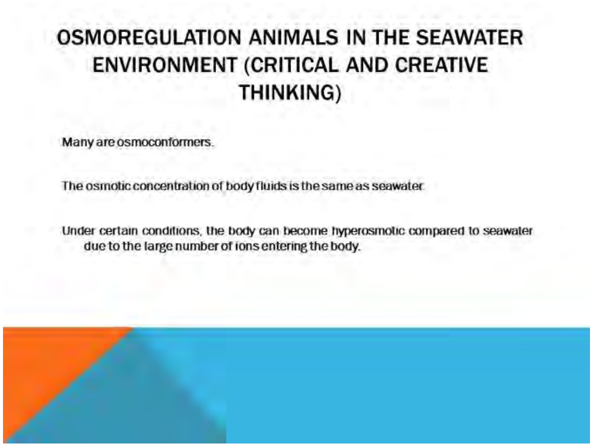
- Campbell at, 2000, Biology. Printed by PT Gelora Aksara Pratama. Jakarta (In Indonesian)
- Isnaeni, W. 2006. Animal Physiology. Yogyakarta: Kanisius (In Indonesian)
- Scientific articles

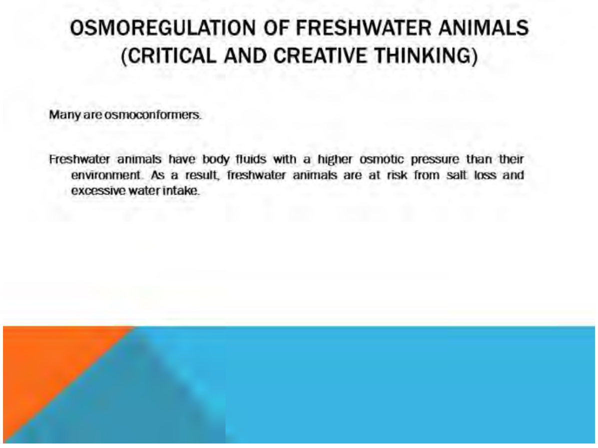
Appendix 3

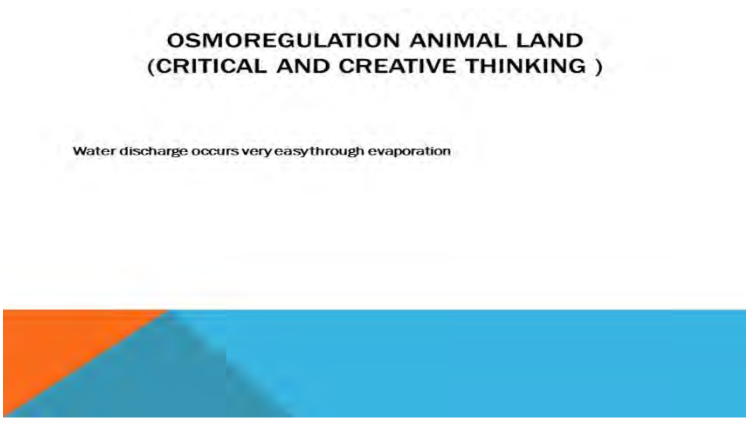
The following are learning materials to direct students to analyse the phenomenon of osmoregulation in animals living in marine, freshwater, brackish water and terrestrial environments.











Notes:
the learning material presented is the same between the control and experimental classes, the difference is that the experimental class adds fosterment of critical, analytical, and creative thinking skills in learning process.