International Journal of Evaluation and Research in Education (IJERE)
Vol. 11, No. 4, December 2022, pp. 1704~1713
ISSN: 2252-8822, DOI: 10.11591/ijere.v11i4.22282

Enhancing students' nature of science understanding through project-based learning and mind mapping

Sri Sukaesih[1,2], Siti Zubaidah[1], Susriyati Mahanal[1], Dwi Listyorini[1]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia

Article Info

Article history:

Received Jun 9, 2021
Revised Jul 7, 2022
Accepted Aug 15, 2022

Keywords:

Conservation education
Mind mapping
Nature of science
Project-based learning

ABSTRACT

This study aimed to investigate students' understanding of the nature of science (NOS) in project-based learning combined with mind mapping (PjBL-MM), students' NOS understanding across gender, and PjBL-MM and gender interaction's effect on students' NOS understanding of conservation education. It employed a pretest-post-test non-equivalent group design. The research population consisted of first-year students at the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Central Java, Indonesia. Thus, the study consisted of 98 students (40 male and 58 female) selected randomly from three different classes. The students' NOS understanding was assessed using the views of NOS type B questionnaire. The learning models' effectiveness was tested using ANCOVA. The results showed a significant difference in students' NOS understanding, PjBL-MM group reported the highest NOS score among all treatment groups in the Conservation education course. There is a significant difference NOS understanding between male and female students. Females outperformed males in NOS understanding. However, PjBL-MM and gender interaction did not affect students' NOS understanding. This study is expected to encourage the implementation of PjBL-MM to improve the students' NOS understanding. The educators are also expected to empower NOS understanding through students' active participation in science by implementing project-based learning combined with mind mapping techniques.

Corresponding Author:

Siti Zubaidah
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
Semarang street no. 5, Malang 65145, Indonesia
Email: siti.zubaidah.fmipa@um.ac.id

1. INTRODUCTION

One of the global issues in science education is the development of nature of science (NOS) concepts [1], [2]. World organizations such as the American association for the advancement of science (AAAS) 1990, 1993, National research council (NRC) 1996, 2012 and Next generation science standard (NGSS) 2013 have recommended NOS to be one of the components of science education [3]. Science for all American has also stressed the urgency of broader scientific literacy while suggesting learning models in specific fields, such as NOS, including scientific perspectives, inquiry as a scientific method, and scientific endeavors. The understanding of NOS becomes one of the primary objectives for scientific education [4] as it is an essential component of scientific literacy [3], [5].

Nature of science (NOS) is the epistemology and axiology of science, encompassing the principles and beliefs inherent in science as well as its development [2], [6]. NOS describes what science is, how it works, how scientists work as a social group, and how society responds to scientific endeavors [7]. NOS has several aspects that characterize it: empirical science, observation, and inference in science, scientific theory and scientific law, creation and imagination as well as being subjective (full of theory), socially and culturally influenced, and tentative (not absolute) [6], [8].

Every individual needs to understand the NOS to become scientifically literate [9], [10]. Scientifically literate individuals possess scientific knowledge, grasp scientific processes, and apply scientific knowledge in their daily lives [5], [11]. NOS understanding is required to recognize the scientific community's standards, realize society's moral commitment, and promote a positive attitude toward science [12]. Individuals who understand NOS can comprehend their surroundings, make decisions, be knowledgeable about scientific, personal, and social issues [10], and solve everyday problems [11].

A survey conducted on 66 student respondents majoring in biology at Universitas Negeri Semarang, Indonesia. It suggests that the students' average comprehension of NOS was still poor (60.35) and needed to be optimized [13]. In addition, past studies show that students have a negative perception and interpretation of NOS [10]–[12]. Furthermore, research indicates that students' comprehension of NOS is still lacking [14]. The science learning process does not familiarize students with extracting information and connects science to the scientific method. In short, the NOS is often overlooked in science education [15].

Science education should present science as a process and product, with NOS as an essential component of learning [16]. The incorporation of NOS into learning will help individuals appreciate science and its role in their lives. All students are required to have positive experiences as a part of the science learning process. Every student has the right to learn science and take advantage of opportunities to develop in science [17]. Science education must be relatively open and beneficial to all pupils, male and female, regardless of gender.

Gender influences how humankind thinks, behaves, and perceives NOS. There is a strong correlation between interest in science and views on NOS [18]. Several studies reported on students' understanding of NOS based on gender. There are significant differences in the perception and knowledge of NOS between male and female students [19]. However, some experts contend that there is no large discrepancy in male and female students' understanding of NOS, even though women outperform men in physics and biology [20].

When it comes to brain anatomy, there are variations in the arrangement of men's and women's cerebral cortexes that can change how they perceive something [21]. The male brain's cortex area is more devoted to conducting spatial tasks and less to generating and reading sentences. The bundle of nerves linking the left and right sides of the male brain, known as the corpus callosum, is one-quarter less than women. Men use their right hemisphere more often than women, while women can maximize the use of both their right and left hemispheres to their benefit.

Nature of science needs to be integrated into the science curriculum [2], [22]. The development of students' views on NOS is one of the essential goals of science education [22]. If NOS is not involved in science curriculum and science implementation, science instruction will fail to instill the philosophy of science education in students [23]. Therefore, we need a learning approach that can inspire NOS in students [11]. The current study was intended to combine project-based learning and mind mapping (PjBL-MM) to develop students' understanding of NOS. The PjBL-MM learning model was built on the principles of constructivism that are useful to promote NOS in students [24].

In PjBL-MM, students are viewed as active learning subjects. PjBL helps students build knowledge through a series of systematically structured projects. PjBL makes knowledge construction more meaningful and stimulates students' constructive thinking [25]. Students can solve real problems because knowledge construction is carried out in an authentic context. PjBL engages students in in-depth inquiry to build knowledge supported by method and technique that help students complete assignments independently [26].

One of the characteristics of PjBL includes providing students with opportunities to explore, make assessments, interpret, and synthesize information in meaningful ways. PjBL allows students to investigate phenomena, facts, or problems more realistically. PjBL also presents various ways for students to demonstrate their knowledge by providing many alternative answers. Exploring, interpreting, and synthesizing information in investigations are the stages of scientific work through which aspects of NOS are learned. Investigative activities through observation and inference prove that science is empirically based on producing scientific theories and laws. NOS is also empowered when students are allowed to present knowledge with many alternative answers. This activity encourages students to use their imagination and creativity in solving problems.

PjBL has both benefits and drawbacks. PjBL requires much time to apply because students need to solve complex problems [27]. Besides, students who have no experience working in groups may have difficulty negotiating and compromising. It would be incredibly challenging for students if the topics assigned to each group varied widely. Mind mapping will help improve PjBL's weaknesses because it can be combined with constructivist learning methods [28].

Mind mapping is a creative and effective way to record and map thoughts [29]. It is perhaps the most convenient way to access and extract information from the brain. Mind mapping, which Tony Buzan developed as a note-taking technique, is an application that has the power to uncover the brain's thoughts about a subject from different viewpoints and activate the right and left lobes of the brain together as an alternative to linear thinking [30]. Mind maps have an important place as a lifelong learning tool nowadays when the constructivist approach is used as a base in the learning process [30]. Mind mapping applied in science learning significantly improves students' creative thinking skills [28]. Implementing multiple intelligence with mind mapping improved the students' creative thinking and achievement in learning science [31]. PjBL-MM in this study is expected to optimize students' NOS understanding. This study aimed to describe students' understanding of NOS in PjBL-MM, examine students' understanding of NOS based on gender, and investigate the effect of PjBL-MM and gender interaction on students' understanding of NOS.

2. RESEARCH METHOD

2.1. Research design

This study was designed as a quasi-experimental study that employed the pretest-posttest non-equivalent group design [32]. This study's independent, moderator, and dependent variables consisted of learning model, gender, and understanding of NOS. This study involved three treatment groups: PjBL-MM, PjBL, and control (discussions and assignments). Table 1 depicts the research design.

Table 1. Adapting the research design of the pretest-posttest non-equivalent group design [32]

Pretest	Group	Post-test
O_1	X_1-M	O_2
O_1	X_1-F	O_2
O_1	X_2-M	O_2
O_1	X_2-F	O_2
O_1	C-M	O_2
O_1	C-F	O_2

O_1: Pretest, O_2: Post-test, X_1: PjBL-MM, X_2: PjBL, C: control, M: male, F: female

2.2. Research subjects

The research population consisted of first-year students enrolled in the Conservation education at the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Central Java, Indonesia. The grade-point average of the students was used to assess data homogeneity. The significance value for the homogeneity test was 0.463>0.05, meaning that there was no significant difference in the students' GPAs. The testing group was chosen at random based on the results of the test. Thus, the study consisted of 98 students (40 males and 58 females) selected randomly from three different classes.

2.3. Research instrument

The instruments used in this study consisted of semester learning plans, course units, worksheets, and NOS assessment instruments. The instruments were previously tested for validity by two education and learning experts. Each component of the validation sheet has a score range of 1-5 (1=invalid, 2=less valid, 3=quite valid, 4=valid, 5=highly valid). The validity test showed a value of 4.83 for the Semester Learning Plans (valid), 4.87 for the Course Units (valid), 4.89 for the worksheets (valid), and 4.92 for the V-NOS form B (highly valid). The V-NOS form B reliability was tested and scored 0.57 (fairly reliable). The instrument V-NOS B form was tested on 30 students of the Biology Department at the Faculty of Mathematics and Natural Science of Universitas Negeri Semarang.

The students' understanding of NOS was assessed using the NOS assessment instrument, views of nature of science (VNOS) B form [33]. There were seven indicators of NOS measured in this study. They include: i) Science is tentative; ii) Science results from inferences; iii) There is a difference in theory and law of science; iv) Science is influenced by social and cultural contexts; v) Science involves creativity and imagination; vi) Science is empirically based; vii) Science is subjective (theory-based). The NOS evaluation rubric was used to test the participants' responses.

2.4. Research procedure

This study was started by a preliminary study on biology students, followed by formulating the problems and solutions. The next steps were preparing the learning and research instruments and then validating them. The study was conducted from March to July 2020.

At the beginning of the lesson, the pretest was carried out to obtain initial data on students' NOS understanding from all treatment groups, while the post-test was carried out at the end of the lesson. The learning model implementation was carried out for 14 meetings for two projects, where one project was completed in seven sessions. This study was conducted in the Conservation education course. The Conservation education course aims to equip students with logical, critical, systematic, and innovative thinking in developing or applying knowledge to solve problems contextually. The Conservation education encourages students to be sensitive to environmental problems and social issues around them.

Students can learn about the environment and learn in the environment to gain a solid knowledge of NOS. The following are the topics covered in the Conservation education course during the implementation of Project I: i) Environmental paradigm and ethics; ii) Conservation values, character, and behavior; iii) Disasters and disaster awareness. Meanwhile, the topics discussed in the second project included: i) Conservation of arts and culture; ii) Natural, non-biological and biodiversity resources; iii) Green architecture; iv) Waste and paperless treatment.

The control class' learning was started with a group presentation on the topic discussed and followed by discussions and assignments. In the PjBL class, the learning activities were conducted according to The George lucas educational foundation. The learning stages carried out by the PjBL students consisted of: i) start with the essential question; ii) design a plan for the project; iii) create a schedule; iv) monitor the students and the progress of the project; v) assess the outcome; vi) evaluate the experience. The PjBL-MM group applied was similar to PjBL syntax with mind mapping at the projects' beginning and end. The learning process in the PjBL-MM class was executed through the stages: i) start with the essential question and mind mapping; ii) design a plan for the project; iii) create a schedule; iv) monitor the students and the progress of the project v) assess the outcome and mind mapping; vi) evaluate the experience. The evaluation stage was performed by creating a reflection journal. During the last stage, the analysis and interpretation of research data were conducted.

2.5. Data analysis

Statistics prerequisites (normality and homogeneity) were completed by conducting Kolmogorov-Smirnov's test and Levene's test. Inferential statistics were used to test the hypotheses; thus, ANCOVA at a significance level of 5% was run. Then, the Least significance difference (LSD) test was performed. The inferential statistics analysis was assisted with SPSS version 21.

3. RESULTS

The prerequisite tests of the students' pretest and post-test scores showed that the data were distributed normally, and the groups had homogeneous variants as shown in Table 2. The results of ANCOVA on the application of the learning model showed F=26,427 with a significance value of 0.000 (p<0.05). This result means that there were differences in students' understanding of NOS due to the implementation of different learning models. Gender, as the moderator variable, obtained F=4.040 with a significance value of 0.047 (p<0.05). These figures indicate that male and female students differed in NOS understanding. Meanwhile, the interaction between the learning model and gender was not significantly different, with F=0.147 and a significance value of 0.864 as shown in Table 3.

Table 2. Summary of the normality and homogeneity tests of students' NOS understanding

Data group	Normality		Homogeneity
	N	Sig.	Sig.
Pretest of NOS	98	0.062	0.698
Post-test of NOS	98	0.058	0.091

Table 3. Summary of the ANCOVA test results

Source	Df	Mean square	F	Sig.
Corrected model	6	1191.811	10.282	0.000
Intercept	1	15867.985	136.903	0.000
Pretest NOS	1	269.181	2.322	0.131
Learning models	2	3063.071	26.427	0.000
Gender	1	468.227	4.040	0.047
Learning models*Gender	2	17.025	0.147	0.864
Error	91	115.907		
Total	98			
Corrected total	97			

The LSD test results showed significance in the students' NOS understanding scores as presented in Table 4. The mean score reported by the female students (78.10) was higher than that of the male students (73.64). Qualitative analysis was also performed to examine students' NOS understanding. The NOS mean score obtained by the PjBL-MM group (85.12) was higher than that of the PjBL (77.78) and control (66.00) classes as revealed in Table 5.

Table 4. The results of the LSD test based on learning models

No	Group	Mean score		Average mean score	Increase	LSD notation
		Pretest	Post-test			
1.	PjBL-MM	57.738	85.119	84.638	47.42 %	a
2.	PjBL	58.412	77.777	77.492	33.15 %	b
3.	Control	57.142	66.005	65.479	15.51 %	c

Table 5. Students' understanding of NOS on each indicator

No	Indicator of NOS	Students' understanding of NOS after the implementation (%)		
		PjBL-MM	PjBL	Control
1	Science is tentative	84.38	80.00	63.89
2	Science results from inferences	90.63	84.44	70.37
3	There is a difference between scientific theory and scientific law	80.21	77.78	61.11
4	Science is influenced by social and cultural contexts	91.67	84.44	73.15
5	Science involves creativity and imagination	89.58	78.89	79.63
6	Science is empirically based	90.63	83.33	66.67
7	Science is subjective (theory-based)	68.75	55.56	47.22
	Mean score	85.12	77.78	66.00

The following is an example of the PjBL-MM, PjBL, and control students' answers to the first NOS indicator, namely science is tentative.

> "*Theories change and continue to develop according to the development of science and technology based on research results. They are taught (to students) to respect scientists, as a source of knowledge, a reference for the development of existing theories, and a basis for further research.*" (PjBL-MM)
> "*Theories change with the development of technology and adapt to the ever-evolving human thinking. Scientific theories are taught (to students) as a basis for developing theories through new research, and as a basis for future theory use*." (PjBL)
> "*Some theories may change, but they haven't changed at all. Scientific theories are still being taught (to students) to find out how these changes occur and the factors that drive these changes.*" (Control)

The following section contains the PjBL-MM, PjBL, and control students' responses to "science are subjective."

> "*Conclusion varies from one scientific study to another because scientists have different perspectives, research methods, and research periods.*" (PjBL-MM)
> "*Scientists can draw different conclusions because research is greatly influenced by the perspective (thinking), creativity and imagination of the scientist.*" (PjBL)
> "*Scientists collect the same data but have different ways of studying the data which can lead to different conclusions.*" (Control)

PjBL-MM students were able to respond appropriately to the NOS predictor "science is tentative." In the preceding case, the PjBL-MM student offered 1-4 rational reasons to support his claim that scientific theory would alter and evolve. Meanwhile, the PjBL student claimed that "science theory will change" by presenting 1-2 rational explanations for why scientific theory should be taught. Students in the control group expressed skepticism that "some theories may change" and stated that "they haven't changed at all," demonstrating the inaccuracy of the response.

According to PjBL-MM students, subjectivity in science could be affected by various factors such as scientists' perspectives, techniques used, and study times. The PjBL class correctly identified two factors that contribute to subjectivity in research. According to the control group, "Scientists collect the same data but have different ways of studying the data." This solution is less accurate since scientists' observations or conclusions are not always consistent as they could be affected by various variables. These examples of student responses reflected the depth and breadth of their NOS comprehension. Students in the PjBL-MM class would typically express their opinions on NOS using extensive, complex, and rational reasoning.

4. DISCUSSION

4.1. The effect of PjBL-MM on students' understanding of NOS

The results of previous research showed that project-based learning positively affects learning outcomes [34]–[37]. PjBL implemented through investigation significantly affects students' creative thinking [34]. PjBL also develops scientific processing and scientific literacy with substantial advancement compared to conventional learning [35] while considerably improving the biology department students' higher-order thinking skills [36]. Besides, PjBL combined with Mind Mapping applied during the science learning process positively impacts students' creative thinking development and learning outcomes [37]. In this research, PjBL combined with Mind Mapping was applied to Conservation education, and its effect on the students' scientific understanding was analyzed.

The findings indicated that implementing PjBL-MM had a beneficial impact on students' comprehension of NOS. Since NOS indicators were learned from the beginning to the end of the lesson, the PjBL-MM stage improved NOS comprehension. Students recognized environmental and social issues in their environments during the first stage of PjBL-MM, starting with the essential question combined with mind mapping. Socio-scientific topics should be used to educate students about NOS when they become crucial contextual issues [8]. Students engaged in a variety of exercises to develop the critical problems that would be addressed in a project. Students made interpretations of phenomena and evidence surrounding them, drew conclusions, and used scientific theories and laws as a framework for their thoughts. At the start of the project, students created a mind map of the subjects to be explored. Mind mapping encourages pupils to use their imagination and ingenuity. Environmental topics and social problems learned in class put students closer to understanding how society and culture affect science.

The second stage of PjBL-MM is to design a plan for the project. The practice of creating project plans encourages students to use their creativity and imagination to solve problems. Students used empirical theories and law to establish a research structure and theoretical base. Students were advised to identify and choose different problem-solving alternatives and choose suitable testing methods.

At the third stage, create a schedule. Students used their creativity and imagination to solve project challenges and compile a list of the equipment, resources, and instruments required for the project. In the fourth phase, monitor the students and the project's progress; students obtained empirical data through observation and investigation. Students were prepared to compile a report on the project's progress based on the observational data, using creativity and imagination before and after data collection.

The fifth and sixth stages of PjBL-MM consist of assessing the outcome combined with mind mapping and evaluating the experience. Students viewed the findings of their project work in the form of objects and compiled a mind map at this time. They were advised to use their imagination and creativity to design artifacts and plan mind maps. Mind mapping allows students to gather as much knowledge and relevant ideas as possible during project work. The collection of mind maps directs students to think flexibly and systematically. Students selected a prominent theme and created a mapping of the relationships between the selected theme's concepts.

This study focused on environmental concerns and social challenges learned in the Conservation education course. Students arranged their information in the form of key ideas from the start to the finish of a project. Students outlined key ideas to gain more substantial experience. Mind mapping created after students complete the assignment allows them to articulate themselves visually by applying their expertise [38]. As a result, students' interpretation of NOS becomes more profoundly rooted. Students reflect on the learning process at the evaluation stage by keeping a reflection log. Reflection exercises could help students have a better understanding of NOS [16].

Figure 1 displays the mind map. It illustrates that students could map their ideas related to concepts they learned during the Conservation education class. They could also establish good connections between environmental issues. Students decide the central theme (Conservation education) and develop a theme for each branch in fundamental concepts, paradigms, conservation pillars, environmental ethics, and conservation values. Each branch is defined or given notes. Students formulate the project's main issue that becomes the central part of the mind map very well, which is "a campaign to solve toxic components problem in landfills and its effects to the environment." To solve this issue, students learn its science and context in society by applying theory, looking for empirical data in the field, and using their imagination and creativity during the project. The scientific processes conducted through project works and mind map creation are expected to empower students' scientific understanding.

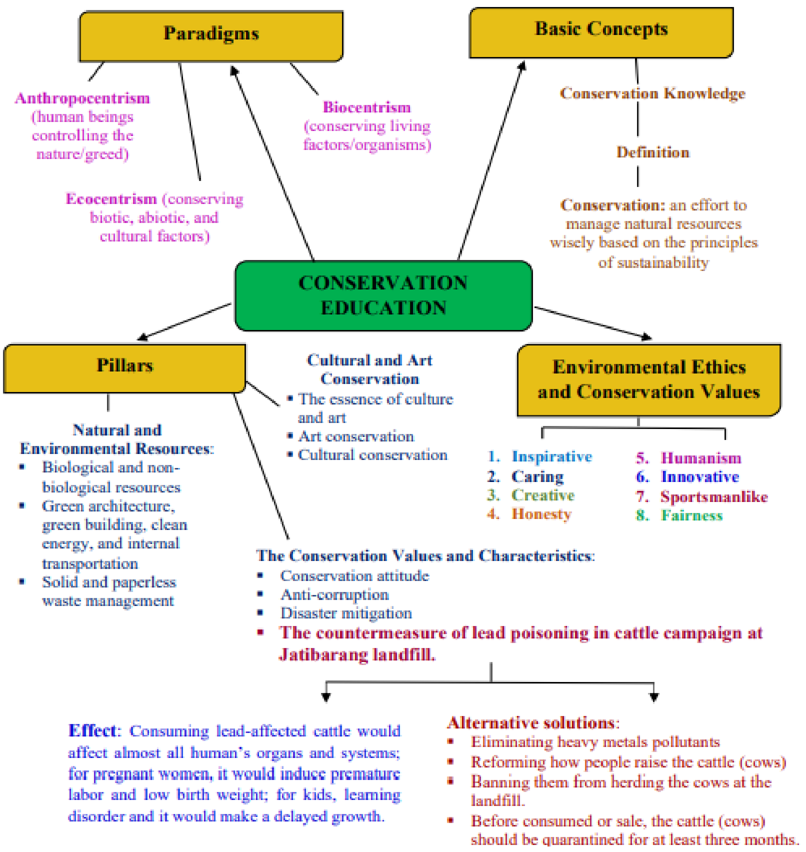

Figure 1. Mind mapping of the Conservation education (Group 7)

4.2. The effect of gender on students' understanding of NOS

The findings revealed that male and female students had different understandings of NOS. Female students outperformed male students in terms of NOS comprehension. This result is believed to be attributed to female students' greater interest in science (biology). Understanding NOS is influenced and directly proportional to one's interest in science. This phenomenon is consistent with the findings of [18], who found a clear association between scientific curiosity and NOS attitudes. According to the study's findings, women are more optimistic about science than men [39].

Differences in NOS comprehension between male and female students can also be attributed to differences in brain development between males and women. The brain's anatomy and brain structure complexity influence thought habits and human brain function, revealing physical distinctions between men and women [40]. Humans and their brains are composed of unique mosaics of female and male features [41]. Women have a larger anterior cingulate cortex (ACC) than males. The ACC has a part in making choices and decisions. Women have a larger prefrontal cortex (PFC) than men, responsible for impulse regulation, regular and systemic thoughts. The ACC and PFC are the fundamental capital in behaving and reasoning with care and prudence and making the right choices. Furthermore, this section encourages women to think systematically, which is needed in scientific thought processes. The scientific mindset includes the nature of diligence, thoroughness, and making accurate and systematic decisions. This process is believed to aid in the growth of female students' NOS comprehension.

The male brain's cortex area is more devoted to conducting spatial tasks and less devoted to generating and reading sentences [21]. The collection of nerves that link the left and right sides of the male brain, known as the corpus callosum, is one-quarter smaller than that of women. Women's language abilities are better than men's since the brain areas involved with language function work differently in women. Language is a medium for communicating ideas. The ability to use words effectively is a good predictor of one's ability to think critically. The ability to think at a higher level is needed to comprehend the features of science fully. This fact may be linked to women's superior capacity to absorb and remember knowledge, implying that women have a greater comprehension of NOS.

4.3. The effect of PjBL-MM and gender interaction on students' understanding of nature of science

The findings revealed that the interaction of learning models and gender had no impact on students' comprehension of NOS. Although there is no correlation between the learning model and gender, it should be noticed that the mean NOS comprehension score in the PjBL-MM class was higher than in the PjBL class and the control class (Table 5). The PjBL-MM class (male and female students) had a greater capacity than the other two classes to empower students' NOS comprehension.

The PjBL-MM model is more effective in empowering NOS for the following reasons. To begin, PjBL-MM is a constructivist-based learning model. Students in PjBL-MM can solve real-world challenges, and awareness creation happens in an authentic context [26]. Project initiatives include evident accomplishments for acquiring more lasting and comprehensive information in interpreting NOS [42] and can be an alternative to solve the problems of creative thinking skills [43]. Second, the PjBL-MM stage encourages students to engage in research regularly. Active involvement in the form of experimental work contributes to the empowerment of NOS. Third, explicitly and reflectively integrating NOS through project practice empowers students' awareness of NOS [16].

Previous experiments yielded separate findings where gender (men and women) and interpretation of NOS were considered. Men and women did not have significantly different understandings of NOS in physics and biology [20], [44]. Meanwhile, previous study [19] recorded substantial gaps in students' views and comprehension of NOS in science learning. However, men and women have equal opportunities to pursue research and contribute to the world of science and technology [44].

5. CONCLUSION

In conclusion, PjBL-MM positively impacts students' comprehension of the NOS. The interpretation of NOS differs between male and female students, but the interaction between the PjBL-MM model and gender has no significant effect on students' understanding of NOS. PjBL-MM can be used to help students learn without making gender distinctions.

The findings imply that the PjBL-MM model can increase students' comprehension of NOS. NOS understanding is trained through the model stages specifically constructed by incorporating NOS. PjBL-MM helps students grasp ideas, perform scientific processes, and acquire experience through project work and mind mapping. In the Conservation education classes, the PjBL-MM model can be seen as an approach to teaching NOS. The educators are expected to empower the NOS understanding through students' active participation in science by implementing project-based learning and mind mapping techniques. Integrating NOS to the PjBL-MM learning model is expected to develop students' NOS understanding during the Conservation education course.

There are some drawbacks to this research. First, research participants are restricted to science (Biology) students. Second, the study was limited to a single subject, Conservation Education. Third, data processing was limited to one semester. Further studies may be conducted to investigate the comprehension of NOS in students of various majors or to assess the progress of students' NOS understanding in the early or final years after completing university courses.

ACKNOWLEDGEMENTS

Gratitude and appreciation are expressed to the Indonesia Endowment Fund of Education of the Indonesian Ministry of Finance (*Lembaga Pengelola Dana Pendidikan*/LPDP) for providing scholarship funds during the doctoral program study reference number KET-1489/LPDP.3/2018, December 14, 2018.

REFERENCE

[1] R. Gunstone, *Encyclopedia of Science Education*. Springer Dordrecht, 2015, doi: 10.1007/978-94-007-2150-0.

[2] N. G. Lederman and J. S. Lederman, "Teaching and learning nature of scientific knowledge: Is it Déjà vu all over again?" *Disciplinary and Interdisciplinary Science Education Research*, vol. 1, no. 1, pp. 1–9, 2019, doi: 10.1186/s43031-019-0002-0.

[3] R. Summers and F. Abd-El-Khalick, "Examining the representations of NOS in educational resources," *Science & Education*, vol. 28, no. 3–5, pp. 269–289, Jul. 2019, doi: 10.1007/s11191-018-0018-4.

[4] N. G. Lederman, "Contextualizing the Relationship Between Nature of Scientific Knowledge and Scientific Inquiry: Implications for Curriculum and Classroom Practice," *Science and Education*, vol. 28, no. 3–5, pp. 249–267, 2019, doi: 10.1007/s11191-019-00030-8.

[5] A. Al Sultan, H. Henson, and D. Lickteig, "Assessing preservice elementary teachers' conceptual understanding of scientific literacy," *Teaching and Teacher Education*, vol. 102, p. 103327, 2021, doi: 10.1016/j.tate.2021.103327.

[6] N. G. Lederman, J. S. Lederman, and A. Antink, "Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy," *International Journal of Education in Mathematics, Science and Technology*, vol. 1, no. 3, 2013.

[7] S. Aydin, "A science faculty's transformation of nature of science understanding into his teaching graduate level chemistry course," *Chemistry Education Research and Practice*, vol. 16, no. 1, pp. 133–142, 2015, doi: 10.1039/c4rp00212a.

[8] N. G. Lederman, A. Antink, and S. Bartos, "Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry," *Science and Education*, vol. 23, no. 2, pp. 285–302, 2014, doi: 10.1007/s11191-012-9503-3.

[9] J. Torres and C. Vasconcelos, "Nature of science and models: Comparing portuguese prospective teachers' views," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 11, no. 6, pp. 1473–1494, 2015, doi: 10.12973/eurasia.2015.1407a.

[10] S. Y. Yoon, J. K. Suh, and S. Park, "Korean students' perceptions of scientific practices and understanding of nature of science," *International Journal of Science Education*, vol. 36, no. 16, pp. 2666–2693, 2014, doi: 10.1080/09500693.2014.928834.

[11] İ. Ocak, "The Relationship between Teacher Candidates' Views of the Nature of Science and Their Problem Solving Skills," *International Journal of Instruction*, vol. 11, no. 3, pp. 419–432, Jul. 2018, doi: 10.12973/iji.2018.11329a.

[12] A. C. Pratiwi, S. Kijkuakul, and P. Sangin, "The development of students' nature of science views in cellular respiration context," *Journal of Physics: Conference Series*, vol. 1028, no. 1, 2018, doi: 10.1088/1742-6596/1028/1/012012.

[13] S. Sukaesih, S. Zubaidah, S. Mahanal, and D. Listyorini, "Biology student's understanding of nature of science (NOS) and metacognitive awareness at higher education," *Journal of Physics: Conference Series*, vol. 1567, no. 2, 2020, doi: 10.1088/1742-6596/1567/2/022053.

[14] H. Cofré, P. Núñez, D. Santibáñez, J. M. Pavez, M. Valencia, and C. Vergara, "A critical review of students' and teachers' understandings of nature of science," *Science and Education*, vol. 28, no. 3–5, pp. 205–248, 2019, doi: 10.1007/s11191-019-00051-3.

[15] W. F. McComas, "The nature of Science: The next generation of biology education," *The American Biology Teacher*, vol. 77, no. 7, pp. 485–491, 2015, doi: 10.1525/abt.2015.77.7.2.

[16] W. McComas, "Understanding how science works: UnderstaThe nature of science as the foundation for science teaching and learning," *School Science Review*, vol. 98, no. 365, pp. 71–76, 2017.

[17] P. Vincent-Ruz and C. D. Schunn, "The nature of science identity and its role as the driver of student choices," *International Journal of STEM Education*, vol. 5, no. 1, 2018, doi: 10.1186/s40594-018-0140-5.

[18] R. A. L. F. van Griethuijsen *et al.*, "Global patterns in students' views of science and interest in science," *Research in Science Education*, vol. 45, no. 4, pp. 581–603, 2015, doi: 10.1007/s11165-014-9438-6.

[19] N. A. Samara, "Understanding of the 'nature of science' among undergraduate students at Mutah university in Jordan," *European Scientific Journal*, vol. 11, no. 8, pp. 1857–7881, 2015, doi: 10.13140/RG.2.1.3768.7763.

[20] Ö. Acar, A. Büber, and Z. Tola, "The effect of gender and socio-economic status of students on their physics conceptual knowledge, scientific reasoning, and nature of science understanding," *Procedia - Social and Behavioral Sciences*, vol. 174, pp. 2753–2756, 2015, doi: 10.1016/j.sbspro.2015.01.962.

[21] R. Silberstein, D. A. Camfield, G. Nield, and C. Stough, "Gender differences in parieto-frontal brain functional connectivity correlates of creativity," *Brain and Behavior*, vol. 9, no. 2, pp. 1–10, 2019, doi: 10.1002/brb3.1196.

[22] S. A. Bartos and N. G. Lederman, "Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice," *Journal of Research in Science Teaching*, vol. 51, no. 9, pp. 1150–1184, 2014, doi: 10.1002/tea.21168.

[23] V. Prachagool and P. Nuangchalerm, "Investigating the nature of science: An empirical report on the teacher development program in Thailand," *Jurnal Pendidikan IPA Indonesia*, vol. 8, no. 1, pp. 32–38, 2019, doi: 10.15294/jpii.v8i1.17275.

[24] J. Torres and C. Vasconcelos, "Prospective science teachers' views of nature of science: data from an intervention programme," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 16, no. 1, pp. 1–19, 2019, doi: 10.29333/ejmste/110783.

[25] A. M. Mahasneh and A. F. Alwan, "The effect of project-based learning on student teacher self-efficacy and achievement," *International Journal of Instruction*, vol. 11, no. 3, pp. 511–524, 2018, doi: 10.12973/iji.2018.11335a.

[26] P. Guo, N. Saab, L. S. Post, and W. Admiraal, "A review of project-based learning in higher education: Student outcomes and measures," *International Journal of Educational Research*, vol. 102, no. April, p. 101586, 2020, doi: 10.1016/j.ijer.2020.101586.

[27] S. R. Tamim and M. M. Grant, "Definitions and sses: Case study of teachers implementing project-based learning," *Interdisciplinary Journal of Problem-Based Learning*, vol. 7, no. 2, pp. 5–16, 2013, doi: 10.7771/1541-5015.1323.

[28] S. Zubaidah, N. M. Fuad, S. Mahanal, and E. Suarsini, "Improving creative thinking skills of students through Differentiated Science Inquiry integrated with mind map," *Journal of Turkish Science Education*, vol. 14, no. 4, pp. 77–91, 2017, doi: 10.12973/tused.10214a.

[29] J. Rye, R. Landenberger, and T. A. Warner, "Incorporating Concept Mapping in Project-Based Learning: Lessons from Watershed Investigations," *Journal of Science Education and Technology*, vol. 22, no. 3, pp. 379–392, 2013, doi: 10.1007/s10956-012-9400-1.

[30] A. Erdem, "Mind maps as a lifelong learning tool," *Universal Journal of Educational Research*, vol. 5, no. 12A, pp. 1–7, 2017, doi: 10.13189/ujer.2017.051301.

[31] I. W. Widiana, N. Jampel, and I. N. Jampel, "Improving students' creative thinking and achievement through the implementation of multiple intelligence approach with mind mapping," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 5, no. 3, pp. 246–254, 2016, doi: 10.11591/ijere.v5i3.4546.

[32] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*, 8th ed. New York: Routledge, 2018.

[33] E. E. Peters-Burton, J. C. Parrish, and B. K. Mulvey, "Extending the Utility of the Views of Nature of Science Assessment through Epistemic Network Analysis," *Science and Education*, vol. 28, no. 9–10, pp. 1027–1053, 2019, doi: 10.1007/s11191-019-00081-x.

[34] S. B. Albar and J. E. Southcott, "Problem and project-based learning through an investigation lesson: Significant gains in creative thinking behaviour within the Australian foundation (preparatory) classroom," *Thinking Skills and Creativity*, vol. 41, no. June, p. 100853, 2021, doi: 10.1016/j.tsc.2021.100853.

[35] I. W. U. Tias and S. Octaviani, "The effect of using the project based learning model on process skills and science literation skills," *JHSS (Journal Of Humanities And Social Studies)*, vol. 2, no. 2, pp. 25–30, Sep. 2018, doi: 10.33751/jhss.v2i2.905.

[36] H. Husna, Hasruddin, and T. Gultom, "The effect of project-based learning and problem-based learning in the order of contextual learning in microbiology lectures on the high order thinking skills of biology students in FMIPA UNIMED," *Proceedings of the 4th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2019)*, vol. 384, 2020, pp. 188–191, doi: 10.2991/aisteel-19.2019.40.

[37] R. W. Daulay, S. Tarigan, and I. S. Jahro, "The influence of teaching models to provide concept change (M3PK) and project based learning (PjBL) assisted mind mapping media with creative thinking about student learning result in koloid sistem material of class XI MAN," *IOSR Journal*, vol. 7, no. 4, pp. 74–80, 2017, doi: 10.9790/1959-0902044652.

[38] A. Habok, "Implementation of a project-based concept mapping developmental programme to facilitate children's experiential reasoning and comprehension of relations," *European Early Childhood Education Research Journal*, vol. 23, no. 1, pp. 129–142, 2015, doi: 10.1080/1350293X.2014.991100.

[39] M. Metin, S. Acisli, and A. Kolomuc, "Attitude of elementary prospective teachers towards science teaching," *Procedia - Social and Behavioral Sciences*, vol. 46, pp. 2004–2008, 2012, doi: 10.1016/j.sbspro.2012.05.418.

[40] J. Xin, Y. Zhang, Y. Tang, and Y. Yang, "Brain differences between men and women: Evidence from deep learning," *Frontiers in Neuroscience*, vol. 13, no. March, Mar. 2019, doi: 10.3389/fnins.2019.00185.

[41] D. Joel and L. Vikhanshi, *Gender mosaic: Beyond the myth of the male and female brain*. New York Boston London: Little, Brown Spark, 2019.

[42] A. S. Çıbık, "The effect of project-based history and nature of science practices on the change of nature of scientific knowledge," *International Journal of Environmental and Science Education*, vol. 11, no. 4, pp. 453–472, 2016, doi: 10.12973/ijese.2016.331a.

[43] J. Jumadi, R. Perdana, R. Riwayani, and D. Rosana, "The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 10, no. 1, pp. 16–23, Mar. 2021, doi: 10.11591/ijere.v10i1.20593.

[44] G. Shannon *et al.*, "Gender equality in science, medicine, and global health: where are we at and why does it matter?" *The Lancet*, vol. 393, no. 10171, pp. 560–569, 2019, doi: 10.1016/S0140-6736(18)33135-0.

BIOGRAPHIES OF AUTHORS

Sri Sukaesih is a postgraduate student doctoral at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Her research interests include: Biology Education, Nature of science (NOS), Thinking Skills, and Environmental Attitudes. She is a lecturer at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia. She can be contacted at e-mail: sri_sukaesih@mail.unnes.ac.id.

Siti Zubaidah is a professor at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Her research areas: Biology Education, Critical and Creative Thinking Skills, Metacognitive Skills, 21st Century Learning. She can be contacted at e-mail: siti.zubaidah.fmipa@um.ac.id.

Susriyati Mahanal is a professor at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Her research areas: Biology Education, Critical and Creative Thinking Skills, Environmental Education, Development of Biology Learning Tools. She can be contacted at e-mail: susriyati.mahanal.fmipa@um.ac.id.

Dwi Listyorini is assistant professor in Developmental Biology at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Her research areas: Genetic Regulation in Development, Cancer Regulation by Wnt5a Gene, Biotechnology, Genetic Conservation of Raptors, Biology Education. She can be contacted at e-mail: listyorini.aljabari@um.ac.id.