International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 3, June 2024, pp. 1875~1884
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i3.27617

Guided inquiry with Moodle to improve students' science process skills and conceptual understanding

Saidil Mursali[1,2], Utami Sri Hastuti[1], Siti Zubaidah[1], Fatchur Rohman[1]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
[2]Department of Biology Education, Faculty of Applied Science and Engineering, Universitas Pendidikan Mandalika, Mataram, Indonesia

Article Info

Article history:

Received May 29, 2023
Revised Oct 29, 2023
Accepted Nov 17, 2023

Keywords:

Conceptual understanding
Guided inquiry
Hybrid learning
Moodle
Post-pandemic
Science process skills

ABSTRACT

This study aims to improve and describe science process skills (SPS) and conceptual understanding (CU) college students through guided inquiry learning with Moodle (GI-Moodle). This quasi-experimental study used a pretest-posttest non-equivalent control group design. College students taking general biology courses at Faculty of Applied Science and Engineering (FSTT), Universitas Pendidikan Mandalika (UNDIKMA) participated in this study. They were divided into three classes: the experiment, control 1, and control 2. Their SPS was measured using an essay test instrument containing 18 items, while the CU was examined using 50 items multiple choice test and 5 items essay test. The obtained data were analyzed using the analysis of covariance (ANCOVA) test. The analysis results identified different average students' SPS and CU before and after they attended the learning processes using GI-Moodle, guided inquiry with WhatsApp group (GI-WAG), and structured inquiry with WhatsApp group (SI-WAG). The experiment class attended learning using GI-Moodle presented a more significant increase of SPS and CU than the students attending the other two learning with GI-WAG and SI-WAG. Therefore, the GI with Moodle learning can be used to improve students' SPS and CU during post COVID-19 pandemic. Besides, further studies are suggested to use a more number and broader participants and identify the influence of GI-Moodle on other variables.

Corresponding Author:

Utami Sri Hastuti
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
Semarang street no. 5, Malang-65145, Indonesia
Email: utami.sri.fmipa@um.ac.id

1. INTRODUCTION

In this 21st century, science process skills (SPS) have become one of the fundamental skills for college students [1]. SPS represents someone's skills to learn while working in scientific activities, consisting of observation, asking a question, hypothesis construction, prediction, interpretation, and communicating the results [2]. It is one of the obligatory skills in the implementation of the scientific method, with crucial skills in the learning process [3]. Additionally, it aids individuals in accessing information as well as establishing the information. Consequently, it is important to train students' SPS throughout the learning activities [4]–[6].

In fostering students' SPS, a number of efforts have been carried out, but they present non-maximum results. Several previous studies show the students' SPS is still in the low category so that their SPS is not an optimal condition. Research at Universitas Negeri Yogyakarta reports that first and second-year students' SPS needs improvement because most students only master basic SPS [7]. Maison *et al.* [8] found that the SPS of science teacher candidates at Universitas Jambi was still relatively poor (49.68%). That study illustrates the need to accelerate students' SPS. Linearly, prospective teachers also have to enhance their SPS [9], [10]. Students who have good SPS will impact the students' understanding of concepts, both previously obtained and in understanding new concepts learned [3], [10], [11]. As described by Irwanto [1], SPS represents someone's skills in applying the scientific method to the thinking and problem-solving processes which further helps them form an understanding.

In addition, conceptual understanding (CU) is another fundamental competency for college students. It reflects a student's mastery of basic scientific concepts [12], [13] as well as their utilization in daily life [14], [15]. Other studies define CU as a combination of knowledge and cognitive process [16]. A great CU facilitates students implementing their knowledge on numerous tasks [14], remembering the previously learned ideas from a long time ago with ease, resulting in more meaningful learning [17]. Consequently, CU is highly essential for college students.

Sadly, the available studies presented that student CU has fallen short of expectations. For instance, the results of research at Universitas Bung Hatta Padang Indonesia in the Plant Physiology course stated that only 39% of Biology Education students had a good understanding of concepts, so this must be improved [18]. Another study described that the majority of college students experience misconceptions about science materials [12], [19]. Their misconception indicates the students' imperfect CU [12], [14].

As a consequence, a learning model is required to improve students' SPS and CU, one of them is guided inquiry (GI). GI is a learning model that greatly emphasizes students' learning participation through investigation activities [20]. The aspects of GI contain a formulation of the problem or hypothesis, design of investigation procedures, information collection, conclusion drawing, and results report [13], [21]. Meanwhile, the investigation activity establishes student-centered learning [20].

GI is one of the four types of inquiry learning, namely confirmatory inquiry, structured inquiry, guided inquiry, and open inquiry [21]. The fundamental difference between GI and other types of inquiry is that this learning requires students to design and develop investigative procedures independently based on the problems determined by the lecturer [13], [22]. GI learning begins with research questions (problems) provided by the lecturer, and then students are collaboratively responsible for designing procedures, carrying out investigations, to communicating their findings [20]. GI aims to provide students with basic investigation experience, so it is very appropriate for first-year students.

In GI learning, through the investigation activity, students are directed to do immediate observation, create a concept, and conclude the newly obtained knowledge [23]. Thus, aside from enhancing students' skills, GI also focuses on improving students' CU. This is consistent with the findings of previous research, which stated that GI learning carries a positive influence on students' learning results, primarily their SPS [2]. Previous study also uncovered that GI learning improves students' CU [24].

As we are currently in the post coronavirus disease 2019 (COVID-19) pandemic situation, the implementation of GI should be re-adjusted. In the post-pandemic, the incorporation of online and offline learning (hybrid) during GI learning is inevitable, so the learning needs to be assisted by a set of technology devices. The usage of technology in learning processes is necessary [25]–[27]. Accordingly, teachers are demanded to have great technological mastery since they have to guide students in using the learning platforms for a more meaningful learning atmosphere [28], [29]. Modular object-oriented dynamic learning environment (Moodle) is one of the available learning platforms in the form of an integrated system [30]–[32]. As Moodle uses student center learning, the students are encouraged to actively participate in the learning processes [33], [34]. Besides, Moodle is equipped with several practical features, such as the features of learning material, assignments, quizzes, discussion, and others [31], [35], that support hybrid learning [34], [36]. Moodle can cover the limitations of offline learning, which is limited by space and time because students and lecturers can interact anytime and from anywhere [27], [31], [37].

Therefore, in this research, we investigate the GI model with Moodle in facilitating hybrid learning. guided inquiry learning with Moodle (GI-Moodle) is carried out involving scientific research activities, so it can be implemented in the courses that support investigative activities. The initial curriculum observation on the Faculty of Applied Science and Engineering of Universitas Pendidikan Mandalika (UNDIKMA) Mataram, suggested that the General Biology course is one of the courses that can adopt GI-Moodle.

General Biology course is one of the compulsory courses for students in the Faculty of Engineering and Applied Sciences of UNDIKMA Mataram, Indonesia. The General Biology course and GI-Moodle present extremely close ties, as shown from one of the learning outcomes in the General Biology course that students are forecasted to master the basic Biology concept, principles, and procedures through scientific work. GI learning encourages students to achieve their learning objectives since the learning is carried out following problem identification, information collection, and conclusion drawing [13]. Meanwhile, Moodle will facilitate learning activities because it has full features and is safe to use [27]. It illustrates GI-Moodle's compatibility with General Biology courses. The novelty of this research is that the application of GI learning is carried out by combining online and offline (hybrid) learning with the help of Moodle, especially in General Biology lectures at UNDIKMA.

Therefore, GI-Moodle learning is believed to be capable of enhancing and increasing students' SPS and CU since the GI-Moodle improves students' active participation and independence in identifying information resources through investigative activities with the help of technology. The purpose of this study was to improve and investigate students' SPS and CU through GI-Moodle learning. Our hypothesis is that GI-Moodle learning can improve students' SPS and CU. Then, this research can be a reference for the enhancement of students' SPS and CU, as well as future studies in the relevant topics.

2. RESEARCH METHOD

2.1. Research design

This study used a quasi-experiment method with a pretest-posttest non-equivalent control group design [38], as summarized in Table 1. The independent variable of this study is the learning model for all treatment classes, namely GI-Moodle, guided inquiry with WhatsApp group (GI-WAG), and structured inquiry with WhatsApp group (SI-WAG). The dependent variables are SPS and CU. Apart from that, there were confounding variables that have the potential to influence the research results. Controlling confounding variables in this research was carried out by sample determination was carried out randomly, starting with an equality test and the use of appropriate data analysis techniques, namely the analysis of covariance (ANCOVA) test. Determining the sample (treatment classes) randomly can ensure that any differences in student abilities are distributed evenly across all classes, thereby reducing the impact of confounding variables. In addition, the use of the ANCOVA test in analyzing research data allows the addition of one covariate variable (pretest) to the analysis to control the impact of the covariate variable so that the influence of the independent variable can be assessed more accurately.

This research was carried out over three months, from October 2021 to January 2022, at UNDIKMA, Mataram, Indonesia. This study was conducted during the implementation of hybrid learning. The online learning was carried out in the first meeting with the pre-investigation activities. Then, in the second to the tenth meeting, the students carried out investigation activities using different topics through face-to-face learning. There were five main topics in this learning, namely cytology, reproduction, photosynthesis, ecosystems, and biodiversity. Through online learning, the lecturer guided students in solving issues relevant to those topics, deciding the tools and materials, as well as the procedures for the investigation. Further, in the face-to-face meeting, students carried out the investigative procedures. Students' activities during classroom learning are shown in Table 2.

Table 1. Pretest-posttest non-equivalent control group design

Class	Pretest	Treatment	Posttest
Experiment	P1	O1	P2
Control 1	P3	O2	P4
Control 2	P5	O0	P6

P1, P3, P5: pretest score; P2, P4, P6: posttest score; O1: GI-Moodle learning; O2: GI-WAG learning; O0: SI-WAG learning.

Table 2. Comparison of students' activities in three classes

Learning activity	Learning stages	Students' activities GI-Moodle	GI-WAG	SI-WAG
Online (Pre-investigation)	Delivery of learning topic	The lecturer delivers the learning topic (Moodle)	The lecturer delivers the learning topic (WAG)	The lecturer delivers the learning topic (WAG)
	Problem identification and asking the question	The lecturer submits the investigation question (Moodle)	The lecturer submits the investigation question (WAG)	The lecturer submits the investigation question (WAG)
	Investigation design	Students compile and propose their investigation procedure (Moodle)	Students compile and propose their investigation procedure (WAG)	The lecturer describes the investigation (WAG)
Offline (Investigation activity)	Investigation	Students conduct an investigation based on the prepared procedures	Students conduct an investigation based on the scheduled procedures	Students conduct an investigation based on the prepared procedures
	Data analysis and conclusion drawing	Students gather and analyze the data, then conclude their finding	Students collect and analyze the data, then conclude their finding	Students gather and analyze the data, then complete their finding
	Communicate the results of the investigation	Students arrange and present their investigation	Students organize and submit their investigation report	Students arrange and present their investigation

2.2. Research population and sample

The population of this research was all students taking the General Biology course in the Faculty of Applied Science and Engineering of UNDIKMA Mataram, in the 2021/2022 academic year. The sample was further selected using the cluster random sampling technique using the equivalence test (ANOVA) through the SPSS version 23.0. The classes with a significant value greater than 0.05 (0.701>0.05), suggesting their equal academic skills, were selected as our sample. Then, these classes were divided into the experiment, control 1, and control 2 classes. The experiment class (31 students) learned using the GI-Moodle model, while the control 1 class (32 students) used the GI-WAG model, and the control 2 class (27 students) used SI-WAG. The total sample in this research is 90 students. This number of samples has met the standards and is adequate for quasi-experimental research [15], [38], [39].

2.3. Instruments for data collection

The participants' science process skills were measured using an essay test instrument containing 18 items. This test was constructed following the indicators of basic and integrated process skills. The indicators from basic process skills consisted of observation, prediction, proposing the question, and drawing a conclusion, while the indicators from integrated process skills were constructing a hypothesis, identifying variables, defining a variable, designing an investigation, and interpreting data [1], [2]. For scoring SPS, we used 0 to 4 scales. In addition, the CU was calculated using a five items essay and 50 items multiple choice test. This test was made based on six categories of cognitive dimensions, namely remembering (C1), understanding (C2), Applying (C3), analyzing (C4), evaluating (C5), and creating (C6). For the multiple-choice items, the participants' answers were scored 1 if the answer was correct and 0 if it was incorrect, while the essay answers were scored using a scoring rubric with 0-4 ranges of a score.

Both the SPS and CU tests had undergone validity and reliability tests, signifying that the tests were valid and reliable. The average r_{count} for the SPS test was between 0.354-0.752 with r_{table} 0.3388 (r_{count}>r_{table}), showing that the items were valid, while its Cronbach's alpha was 0.857, in the extremely high category. For the CU test, we obtained an r_{count} ranging from 0.344 to 0.691, greater than the r_{table} 0.3388, so the test items were valid, with Cronbach's alpha of 0.581 in the very high category. The tests were administered before the learning process was started (pretest) to identify the participants' initial knowledge prior to the learning process. Then, the test was also given at the end of the learning process (posttest) to know their final knowledge after attending the learning.

2.4. Data analysis

The garnered data, showing the participants' science process skills and conceptual understanding, were analyzed using descriptive and parametric statistics. The descriptive statistic analysis was conducted based on the participants' average scores from both the pretest and posttest. Meanwhile, the parametric statistic analysis was carried out to test the hypothesis using analysis of covariance (ANCOVA). Before the ANCOVA analysis, the prerequisite test was first carried out, the normality (one sample Kolmogrov Smirnov) and homogeneity tests (Levene's test of equality of error variances). Further, if the ANCOVA test results showed differences, then the post hoc least significance different (LSD) test was to examine if the three-learning model produced significantly different learning results. The parametric statistic tests were completed at 0.05 (5%) significance using the SPSS program.

3. RESULTS

From the data collection processes, we garnered pretest and posttest data from three classes which were analyzed to find the participants' SPS and CU. The SPS test results suggested that all participants have increasing SPS, as shown by their average pretest and posttest scores. The GI-Moodle class presents the highest increase (56.29%), followed by the GI-WAG class (54.94%). Then, the SI-WAG had the lowest increase of 46.32%, as illustrated in Figure 1.

Similarly, all participants' CU average scores from the pretest and posttest also signify an increase, as presented in Figure 2. The figure compares participants' CU scores in the three treatment classes: GI-Moodle, GI-WAG, and SI-WAG. The GI-Moodle class experienced the highest increase (52.02%). The GI-WAG class had an improvement (49.85%) better than the SI-WAG class. The SI-WAG class experienced the lowest increase (44.12%). These results show that learning activities positively impact learning outcomes, namely CU.

In addition, to test the hypothesis, the obtained participants' SPS and CU scores were analyzed using the parametric statistic carried out using ANCOVA. Before that analysis, we conducted the prerequisite tests, namely the normality and homogeneity tests. Normality was examined using the Kolmogorov-Smirnov test, while homogeneity was tested using Levene's test. The results of the data normality test are shown in

Table 3, indicating that all of the pretest and posttest data were normally distributed. Meanwhile, the pretest and posttest data were also homogeneous, as presented in Table 3.

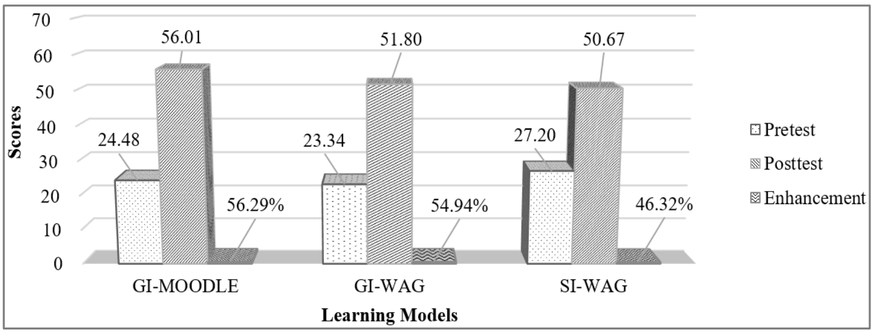

Figure 1. Average science process skills scores of participants

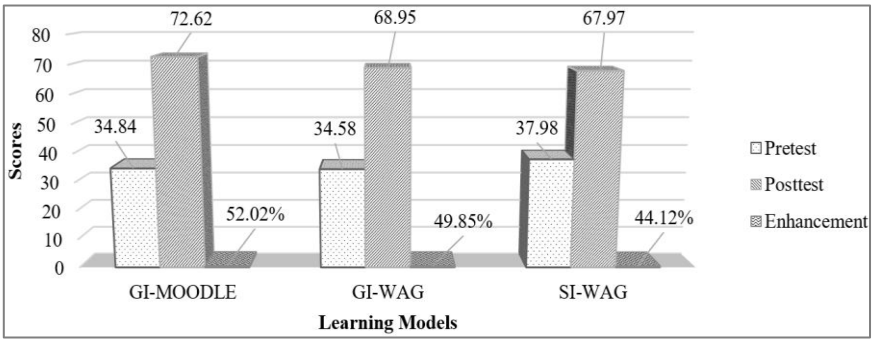

Figure 2. Average conceptual understanding pretest and posttest scores of the participants

Table 3. Results of normality and homogeneity tests

Data		N	Sig. normality	Sig. homogeneity	α
SPS	Pretest	90	0.341	0.078	0.05
	Posttest	90	0.700	0.115	0.05
CU	Pretest	90	0.200	0.674	0.05
	Posttest	90	0.200	0.634	0.05

In addition, to test the hypothesis, the obtained participants' SPS and CU scores were analyzed using the parametric statistic carried out using ANCOVA. Before that analysis, we conducted the prerequisite tests, namely the normality and homogeneity tests. Normality was examined using the Kolmogorov-Smirnov test, while homogeneity was tested using Levene's test. The results of the data normality test are shown in Table 3, indicating that all of the pretest and posttest data were normally distributed. Meanwhile, the pretest and posttest data were also homogeneous, as presented in Table 3.

As the normality and homogeneity tests suggested that the data had normal distribution and were homogeneous, then the data were further analyzed using ANCOVA. This test was conducted to see the participants' different learning results (SPS and CU) before and after they attended the learning. The results of the ANCOVA test in Table 4 stated that the SPS attained a greater F count (6.499) than the p-value (0.002), while the CU obtained an F count of 10.762 and a p of 0.000. This finding signifies that the p SPS and PM are lower than the alpha (0.05), showing average differences of SPS and CU from students attending learning GI-Moodle, GI-WAG, and SI-WAG. Further, the results also suggested that the GI-Moodle, GI-WAG, and SI-WAG are capable of improving college students' SPS and CU.

Table 4. Results of the ANCOVA test

Source	Variable	df	Mean square	F	Sig. (p)
Learning model	SPS	2	416.977	6.499	0.002
	CU	2	327.488	10.762	0.000

Then, we carried out an LSD test at a 5% significance level to determine which learning model presents the most significant influence on the students' SPS and CU. As shown in Table 5, the highest corrected average value for SPS is from the GI-Moodle (55.76), followed by GI-WAG (54.15) and SI-WAG (48.17). The GI-Moodle presented the same notification as the GI-WAG but different from the SI-WAG. Therefore, between the GI-Moodle and GI-WAG, the participants' SPS are not significantly different, but they present significantly distinct SPS in the SI-WAG classroom. Additionally, the results of the LSD test also indicate that the highest CU is from GI-Moodle (73.21), followed by GI-WAG (69.71) and SI-WAG (66.38). Thus, the CU of participants attending GI-Moodle classes is significantly different from the CU of participants from GI-WAG and SI-WAG, as shown from the notation from the three classes. The results of the LSD test are shown in Table 5.

Table 5. Significant difference of SPS and CU average scores based on the LSD test

Variable	Class	Corrected average	LSD notation
KPS	GI-Moodle learning	55.76	a
	GI-WAG learning	54.15	a
	SI-WAG learning	48.17	b
CU	GI-Moodle learning	73.21	a
	GI-WAG learning	69.71	b
	SI-WAG learning	66.38	c

4. DISCUSSION

The results showed that the GI learning model using Moodle (GI-Moodle) is capable of enhancing the science process skills (SPS) and the conceptual understanding (CU) of college students. Specifically, our ANCOVA test results clearly describe different average SPS and CU scores between students attending the GI-Moodle, GI-WAG, and SI-WAG learning. Although all participants in the three classes present an increase in average SPS and CU scores from the pretest and posttest, their increase of scores varies, with the highest increase shown from the participants attending GI-Moodle learning, followed by the participants from GI-WAG class and finally the students in SI-WAG. Our findings are linear with the finding of previous studies reporting that GI learning and Moodle carry a positive impact on participants' SPS and CU. The study by Ekici and Erdem [2] discovered that GI effectively increases college students' SPS. Meanwhile, other studies uncovered that college students' CU is enhanced after they join GI learning [24] and learning with Moodle [36].

The increase of SPS and CU in students is observed after they learn using inquiry learning. Specifically, they use GI-Moodle, GI-WAG, and SI-WAG learning. Inquiry learning is carried out using the procedures of scientific investigation [13] focusing on the skills to conduct research, interpret meaning, and attain new knowledge [13], [40]. Investigation activities promote students' independence to be actively and responsibly involved in the learning process [41] since these activities are students centered [20]. Additionally, inquiry learning supports students' collaboration [42], enabling them to establish knowledge and skills together in a group [10], [11]. Along with the lecturer's guidance, these investigation activities develop students' skills, primarily in designing and conducting scientific investigations (SPS and CU).

Our data analysis results also suggested that GI-Moodle and GI-WAG present no significant different influence on enhancing students' SPS. However, the two learning models are significantly different compared to the SI-WAG learning model in improving student SPS. GI-Moodle and GI-WAG facilitate a more effective learning experience for students than the SI-WAG. In GI, students are demanded to formulate hypothesis and design procedures of investigation independently, while in SI, the hypothesis and investigation procedures have been determined by the lecturer [22], [43]. Consequently, students can have greater participation and liability during the investigation activities in the GI-Moodle and GI-WAG learning than in SI-WAG. Through this greater cooperation and responsibility in GI-Moodle and GI-WAG, students are highly motivated to collaborate and attempt to solve their assignments. The responsibility given to students in designing investigation procedures encourages them to discuss actively and cooperate in completing the assignments. Besides, greater participation and liability also increases students' concern, collaboration, and motivation, affecting their process skills [44].

In GI-Moodle and GI-WAG, the learning is started through pre-investigative activity (online), in which the lecturer delivers the investigation topics and problems. Then, the students are allowed to collaboratively formulate a hypothesis and design the procedures [13]. In this activity, students attain the fundamental information for building the hypothesis and investigation procedures. Then, these students search for and gather additional information through active discussion to generate the hypothesis and procedures [1], [22]. Further, the designed procedures are consulted by the lecturer to ensure their accuracy [40]. Further, the students are also demanded to identify and define the investigation variables based on their hypothesis. This pre-investigative activity develops and expands students' SPS, specifically the skills of proposing the question, forecasting, formulating a hypothesis, controlling variables, defining variables, and designing research.

The investigation activities in the GI-Moodle and GI-WAG contain data collection, data analysis, conclusion drawing, and results presentation [13], [40]. During these activities, students conduct the investigation to test their hypothesis, where they have to find, observe, analyze, and resolve the issues based on the information they have attained previously [15]. Then, they are asked to present their findings. Aside from those activities, students should organize their findings in the form of tables and diagrams for greater data presentation [13]. This set of activities facilitates students to develop their SPS, primarily their skills in observing, predicting, concluding, and interpreting data.

In GI-Moodle and GI-WAG, the lecturers provide guidance and motivation for students in exploring concepts, conducting an investigation, and concluding findings based on the data [11]. In other words, the lecturers act as facilitators, while the students have to conduct the investigation actively and collaboratively [20]. Therefore, GI-Moodle and GI-WAG are research-based learning models that require students to solve issues enthusiastically and cooperatively [24]. Accordingly, both GI-Moodle and GI-WAG present a positive influence on students' SPS in comparison to the SI-WAG.

Additionally, GI-Moodle learning is observed to present significantly different effects on enhancing college students' CU than the GI-WAG and SI-WAG. This finding is possibly caused by the distinct inquiry level practiced using the Moodle. GI-Moodle learning accentuates the search for information in designing investigation procedures and concluding the research findings. In this learning, students are habituated to gathering information from relevant sources, such as textbooks and research articles [45]. The process of information searching advances students' skills in identifying, evaluating, and using information [45] which further becomes the fundamentals for designing research procedures [13]. Also, this activity expands students' skills in deciding the accurate information, which later influences their conceptual understanding. A previous study confirmed that GI learning is more effective in improving students' SPS [22] and scientific reasoning [43] than SI learning.

Students' active participation throughout the GI-Moodle learning also aids them in finding knowledge and understanding from the discussed concept. Tornee *et al.* [23] described GI as a learning model that offers a direct problem-solving experience through investigation activities. This investigation directs students to observe, construct a concept, and conclude the new knowledge [42]. Thus, aside from expanding students' skills, GI-Moodle also focuses on enhancing students' conceptual understanding. Linearly, research reported positive impacts on GI learning on increasing students' CU [13], [24].

Meanwhile, Moodle has also been reported to be capable of supporting students' learning activities [27], [34], [46]. The adoption of technology in online learning is necessary to realize a student-centered atmosphere [28], [29]. The utilization of technology in learning increases students' thinking skills significantly [47]. Thus, the adoption of Moodle also assists the implementation of GI learning, primarily in expanding students' interaction with the learning material, facilitating students-lecturers and student-student discussion, as well as providing feedback and facilitating collaboration [30]. Thus, the use of Moodle also affects the efficiency of learning [31] and increase of students' CU [36].

Our data analysis results also suggested that students attending SI-WAG learning have the lowest increase of SPS and CU compared to those participating in GI-Moodle and GI-WAG learning. SI learning uses the lowest level of inquiry compared to the GI-Moodle and GI-WAG [21], [43]. In SI-WAG learning, the students are not asked to construct investigation procedures independently, but they are provided with the procedures by the lecturers. However, the students can conduct the investigation easily in the SI-WAG learning, so they can focus on the lecturers' guidelines and instructions. Further, the investigation process in this learning is relatively shorter and more efficient than the other two learning models. Consequently, the SI-WAG is suitable for lower education levels, where the students have no experience in conducting an investigation [22].

It is important to note that the science teachers (Biology teachers) have to focus on expanding and training students' SPS and CU, even starting from the beginning of the learning. SPS and CU are the fundamental competencies for students as they influence their future success in learning and professional career. The implementation of GI-Moodle in the learning process can be the alternative for post-pandemic 21st-century learning since it facilitates the enhancement of students' process skills, as well as their conceptual understanding of science material. In the end, we conclude that GI-Moodle is effective in improving students' SPS and CU.

5. CONCLUSION

Guided inquiry learning with Moodle (GI-Moodle) combines online and offline learning using technology devices. This learning is suitable for post-COVID-19 learning. GI-Moodle directs students to directly participate in the investigation activities, which contain problem formulation, investigation procedures formulation, data or information collection, conclusion drawing, and results presentation. Besides, GI-Moodle also helps students access information relevant to their learning material easily. Further, this learning also facilitates students to sharpen their process skills, improving their understanding of the science topic being discussed. Then, GI-Moodle also promotes students' active involvement during the problem-solving processes and improved performance in the investigation activities. Therefore, the GI-Moodle can improve college students' science process skills (SPS) and conceptual understanding (CU). Thus, this GI-Moodle learning is recommended to be applied to learning that aims to improve students' conceptual comprehension and processing skills.

This study has a number of limitations. First, we only used 90 freshman students, divided into three classes, as our research subject and sample. This sample size is adjusted to the number of students who contract the General Biology course in the three classes that have been selected in the sampling technique. Second, in this study, we only used general biology courses, focusing only on the students' SPS and CU. From these limitations, future studies are required to better understand the effects of GI-Moodle on the increase of SPS and CU, primarily on secondary school students or college students in different courses. Besides, future research is also recommended to explore the influence of GI-Moodle learning on other variables to facilitate the fulfilment of students' needs during learning. Thus, we can have competent human resources capable of facing 21st-century challenges.

ACKNOWLEDGEMENTS

The authors would like to thank the *Lembaga Pengelola Dana Penelitian/LPDP* (Indonesia Endowment Fund for Education), Ministry of Finance, Republic of Indonesia, which has provided scholarships for doctoral studies at the Universitas Negeri Malang, Indonesia.

REFERENCES

[1] Irwanto, "Improving preservice chemistry teachers' critical thinking and science process skills using research-oriented collaborative inquiry learning," *Journal of Technology and Science Education*, vol. 13, no. 1, pp. 23–35, Jan. 2023, doi: 10.3926/jotse.1796.

[2] M. Ekici and M. Erdem, "Developing science process skills through mobile scientific inquiry," *Thinking Skills and Creativity*, vol. 36, Jun. 2020, doi: 10.1016/j.tsc.2020.100658.

[3] R. M. Tan, R. T. Yangco, and E. N. Que, "Students' conceptual understanding and science process skills in an inquiry-based flipped classroom environment," *Malaysian Journal of Learning and Instruction*, vol. 17, 2020, doi: 10.32890/mjli2020.17.1.7.

[4] Khotimah, U. S. Hastuti, I. Ibrohim, and S. Suhadi, "Developing microbiology digital handout as teaching material to improve the student's science process skills and cognitive learning outcomes," *Eurasian Journal of Educational Research*, vol. 2021, no. 95, Sep. 2021, doi: 10.14689/ejer.2021.95.5.

[5] S. Saidawati, Z. A. I. Supardi, F. Rachmadiarti, E. Hariyono, A. Sholahuddin, and B. K. Prahani, "Profile of students' science process skills on substance pressure material," in *Proceedings of the Eighth Southeast Asia Design Research (SEA-DR) and the Second Science, Technology, Education, Arts, Culture, and Humanity (STEACH) International Conference (SEADR-STEACH 2021)*, 2022, vol. 627, doi: 10.2991/assehr.k.211229.031.

[6] M. Asy'ari, H. Fitriani, S. Zubaidah, and S. Mahanal, "The science process skills of prospective biology teachers in plant cell material based on gender," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 14, no. 19, Oct. 2019, doi: 10.3991/ijet.v14i19.11208.

[7] I. Irwanto, E. Rohaeti, and A. K. Prodjosantoso, "Undergraduate students' science process skills in terms of some variables: a perspective from Indonesia," *Journal of Baltic Science Education*, vol. 17, no. 5, pp. 751–764, Oct. 2018, doi: 10.33225/jbse/18.17.751.

[8] Maison, Darmaji, Astalini, D. A. Kurniawan, and P. S. Indrawati, "Science process skills and motivation," *Humanities and Social Sciences Reviews*, vol. 7, no. 5, pp. 48–56, Sep. 2019, doi: 10.18510/hssr.2019.756.

[9] D. Maison *et al.*, "Science process skill in science program higher education," *Universal Journal of Educational Research*, vol. 8, no. 2, pp. 652–661, Feb. 2020, doi: 10.13189/ujer.2020.080238.

[10] C. Valls-Bautista, A. Solé-LLussà, and M. Casanoves, "Pre-service teachers' acquisition of scientific knowledge and scientific skills through inquiry-based laboratory activity," *Higher Education, Skills and Work-Based Learning*, vol. 11, no. 5, pp. 1160–1179, Oct. 2021, doi: 10.1108/HESWBL-07-2020-0161.

[11] S. Ibrahim and S. N. D. Mahmud, "Inquiry-based science teaching: knowledge and skills among science teachers," *Humanities and Social Sciences Reviews*, vol. 8, no. 4, pp. 110–120, Jul. 2020, doi: 10.18510/hssr.2020.8413.

[12] T. Hadinugrahaningsih, Y. Rahmawati, and E. Suryani, "An analysis of preservice Chemistry teachers' misconceptions of reduction-oxidation reaction concepts," *Journal of Technology and Science Education*, vol. 12, no. 2, Jul. 2022, doi: 10.3926/jotse.1566.

[13] S. Flegr, J. Kuhn, and K. Scheiter, "When the whole is greater than the sum of its parts: Combining real and virtual experiments in science education," *Computers and Education*, vol. 197, May 2023, doi: 10.1016/j.compedu.2023.104745.

[14] H. S. Finbråten, H. K. Grønlien, K. S. Pettersen, C. Foss, and Ø. Guttersrud, "Nursing students' experiences with concept cartoons as an active learning strategy for developing conceptual understanding in anatomy and physiology: A mixed-method study," *Nurse Education in Practice*, vol. 65, Nov. 2022, doi: 10.1016/j.nepr.2022.103493.

[15] N. Yakob, K. Kaliun, A. M. Ahmad, R.-A. A. Rashid, and A. Abdullah, "The effect of coupled inquiry-5E in enhancing the understanding of Meiosis concept," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 1, pp. 129–137, Mar. 2020, doi: 10.11591/ijere.v9i1.20393.

[16] S. L. Zorluoğlu and Ç. Güven, "Analysis of 5th grade science learning outcomes and exam questions according to revised bloom taxonomy," *Journal of Educational Issues*, vol. 6, no. 1, Mar. 2020, doi: 10.5296/jei.v6i1.16197.

[17] Y. Rahmawati, Z. Zulhipri, O. Hartanto, I. Falani, and D. Iriyadi, "Students' conceptual understanding in chemistry learning using PhET interactive simulations," *Journal of Technology and Science Education*, vol. 12, no. 2, Jun. 2022, doi: 10.3926/jotse.1597.

[18] R. Redo and A. Sundaryono, "Establishment of learning module based on research of solid lipid nanoparticles to improve biology understanding," *Bencoolen Journal of Science Education and Technology*, vol. 1, no. 1, pp. 13–18, Jun. 2020, doi: 10.33369/bjset.v1i1.11186.

[19] A. Andariana, S. Zubaidah, S. Mahanal, and E. Suarsini, "Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test," *Journal for the Education of Gifted Young Scientists*, vol. 8, no. 3, pp. 1071–1085, Sep. 2020, doi: 10.17478/jegys.752438.

[20] D. Maknun, Z. K. Prasetyo, and D. Djukri, "Guided inquiry laboratory to improve research skills of prospective biology teachers," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 11, no. 4, pp. 2122–2128, Dec. 2022, doi: 10.11591/ijere.v11i4.22104.

[21] G. Orosz, V. Németh, L. Kovács, Z. Somogyi, and E. Korom, "Guided inquiry-based learning in secondary-school chemistry classes: a case study," *Chemistry Education Research and Practice*, vol. 24, no. 1, pp. 50–70, 2023, doi: 10.1039/D2RP00110A.

[22] I. P. Artayasa, H. Susilo, U. Lestari, and S. E. Indriwati, "The effect of three levels of inquiry on the improvement of science concept understanding of elementary school teacher candidates," *International Journal of Instruction*, vol. 11, no. 2, pp. 235–248, Apr. 2018, doi: 10.12973/iji.2018.11216a.

[23] N. Tornee, T. Bunterm, K. Lee, and S. Muchimapura, "Examining the effectiveness of guided inquiry with problem-solving process and cognitive function training in a high school chemistry course," *Pedagogies: An International Journal*, vol. 14, no. 2, pp. 126–149, Apr. 2019, doi: 10.1080/1554480X.2019.1597722.

[24] N. A. Sholikhan, I. N. S. Degeng, P. Setyosari, and S. K. Handayanto, "Understanding the physics concept between guided inquiry or open inquiry," *International Journal of Learning and Change*, vol. 12, no. 2, 2020, doi: 10.1504/IJLC.2020.106784.

[25] P. Sothayapetch and J. Lavonen, "Technological pedagogical content knowledge of primary school science teachers during the COVID-19 in Thailand and Finland," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 18, no. 7, May 2022, doi: 10.29333/ejmste/12118.

[26] E. Angraini, S. Zubaidah, H. Susanto, and N. Omar, "Enhancing creativity in genetics using three teaching strategies-based TPACK model," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 18, no. 12, Dec. 2022, doi: 10.29333/ejmste/12697.

[27] E. Mulyatiningsih, S. Palupi, P. Ekawatiningsih, A. R. Firdausa, and Z. Nuryana, "The enjoyable online learning model for vocational students during COVID-19 pandemic," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 1, pp. 106–113, Mar. 2023, doi: 10.11591/ijere.v12i1.23122.

[28] R. J. Robillos, "Impact of LoiLooNote digital mapping on University Students' oral presentation skills and critical thinking dispositions," *International Journal of Instruction*, vol. 15, no. 2, pp. 501–518, Apr. 2022, doi: 10.29333/iji.2022.15228a.

[29] E. Bekteshi, B. Gollopeni, and E. Avdiu, "The challenges of conducting online inquiry-based learning among tertiary level education," *Journal of Technology and Science Education*, vol. 13, no. 1, Jan. 2023, doi: 10.3926/jotse.1700.

[30] T. Y. Aikina and L. M. Bolsunovskaya, "Moodle-based learning: motivating and demotivating factors," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 2, pp. 239–248, Jan. 2020, doi: 10.3991/ijet.v15i02.11297.

[31] M. Amin, A. M. Sibuea, and B. Mustaqim, "The effectiveness of Moodle among engineering education college students in Indonesia," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 1, pp. 1–8, Mar. 2023, doi: 10.11591/ijere.v12i1.23325.

[32] C. B. Mpungose, "Is Moodle or WhatsApp the preferred e-learning platform at a South African university? First-year students' experiences," *Education and Information Technologies*, vol. 25, no. 2, pp. 927–941, Mar. 2020, doi: 10.1007/s10639-019-10005-5.

[33] N. Almusharraf and S. Khahro, "Students satisfaction with online learning experiences during the COVID-19 pandemic," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 21, Nov. 2020, doi: 10.3991/ijet.v15i21.15647.

[34] I. Makruf, A. A. Rifa'i, and Y. Triana, "Moodle-based online learning management in higher education," *International Journal of Instruction*, vol. 15, no. 1, pp. 135–152, Jan. 2022, doi: 10.29333/iji.2022.1518a.

[35] S. Sumarwati, H. Fitriyani, F. M. A. Setiaji, M. H. Amiruddin, and S. A. Jalil, "Developing mathematics learning media based on e-learning using Moodle on geometry subject to improve students' higher order thinking skills," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 4, Mar. 2020, doi: 10.3991/ijim.v14i04.12731.

[36] C. Schettini, D. Amendola, I. Borsini, and R. Galassi, "A blended learning approach for general chemistry modules using a moodle platform for first year academic students," *Journal of E-Learning and Knowledge Society*, vol. 16, no. 2, pp. 61–72, 2020, doi: 10.20368/1971-8829/1135197.

[37] I. Al-Kindi, Z. Al-Khanjari, and Y. Jamoussi, "Extracting student patterns from log file Moodle course: A case study," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 11, no. 2, pp. 917–926, Jun. 2022, doi: 10.11591/ijere.v11i2.23242.

[38] L. Cohen, L. Manion, and K. Morrison, *Research methods in education*, 8th ed. Routledge, 2017.

[39] D. H. Tong, B. P. Uyen, and L. K. Ngan, "The effectiveness of blended learning on students' academic achievement, self-study skills and learning attitudes: A quasi-experiment study in teaching the conventions for coordinates in the plane," *Heliyon*, vol. 8, no. 12, Dec. 2022, doi: 10.1016/j.heliyon.2022.e12657.

[40] A. Sutiani, M. Situmorang, and A. Silalahi, "Implementation of an inquiry learning model with science literacy to improve student critical thinking skills," *International Journal of Instruction*, vol. 14, no. 2, pp. 117–138, Apr. 2021, doi: 10.29333/iji.2021.1428a.

[41] S. Syahwin, T. Hardianti, and S. Fitriana, "The effect of guided inquiry learning by virtual laboratory assistance in physics learning in Indonesian Senior High Schools: a meta-analysis," *International Journal of Instruction*, vol. 15, no. 4, pp. 101–114, Oct. 2022, doi: 10.29333/iji.2022.1546a.

[42] T. de Jong et al., "Let's talk evidence-The case for combining inquiry-based and direct instruction," *Educational Research Review*, vol. 39, May 2023, doi: 10.1016/j.edurev.2023.100536.

[43] B. E. Yanto, B. Subali, and S. Suyanto, “Improving students’ scientific reasoning skills through the three levels of inquiry,” *International Journal of Instruction*, vol. 12, no. 4, pp. 689–704, Oct. 2019, doi: 10.29333/iji.2019.12444a.

[44] R. Rusmini, S. Suyono, and R. Agustini, “Analysis of science process skills of chemical education students through self project based learning (SjBL) in the pandemic COVID 19 era,” *Journal of Technology and Science Education*, vol. 11, no. 2, pp. 371–387, Jun. 2021, doi: 10.3926/jotse.1288.

[45] E. Rosba, S. Zubaidah, S. Mahanal, and S. Sulisetijono, “Digital mind map assisted group investigation learning for college students’ creativity,” *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 5, pp. 4–23, Mar. 2021, doi: 10.3991/ijim.v15i05.18703.

[46] C. Kaensar and W. Wongnin, “Analysis and prediction of student performance based on Moodle log data using machine learning techniques,” *International Journal of Emerging Technologies in Learning (iJET)*, vol. 18, no. 10, pp. 184–203, May 2023, doi: 10.3991/ijet.v18i10.35841.

[47] S. Chootongchai and N. Songkram, “Design and development of SECI and Moodle online learning systems to enhance thinking and innovation skills for higher education learners,” *International Journal of Emerging Technologies in Learning (iJET)*, vol. 13, no. 3, Mar. 2018, doi: 10.3991/ijet.v13i03.7991.

BIOGRAPHIES OF AUTHORS

Saidil Mursali is Doctoral Student of Biology Education Postgraduate Program, FMIPA, Universitas Negeri Malang, Indonesia. In addition, he is a lecturer at the Department of Biology Education, FSTT, Universitas Pendidikan Mandalika (UNDIKMA) Mataram, Indonesia. His research focuses on biology e-learning, biology teaching and learning, 21st century skills, science process skills, critical thinking, conceptual understanding. He can be contacted at email: saidilmursali@undikma.ac.id.

Utami Sri Hastuti is a professor at the Department of Biology, FMIPA, Universitas Negeri Malang, Indonesia. Senior lecturer and researcher in the fields of biology teaching and learning, learning evaluation, digital handout, science process skills, cognitive learning outcomes, educational philosophy, and microbiology. She can be contacted at email: utami.sri.fmipa@um.ac.id.

Siti Zubaidah is a professor and lecturer at the Department of Biology, FMIPA, Universitas Negeri Malang, Indonesia. Apart from teaching, she is also a senior researcher in the fields of biology learning model development, biology teaching and learning, learning evaluation, metacognition, critical thinking, 21st century skills, molecular biology analysis techniques, and genetics. She can be contacted at email: siti.zubaidah.fmipa@um.ac.id.

Fatchur Rohman is a professor and lecturer at the Department of Biology, FMIPA, Universitas Negeri Malang, Indonesia. He is a senior researcher who is concerned in the fields of: learning model development, biology teaching and learning, blended learning, critical thinking, problem solving skills, and ecology. He can be contacted at email: fatchur.rohman.fmipa@um.ac.id.