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

Saidil Mursali1,2, Utami Sri Hastuti1, Siti Zubaidah1, Fatchur Rohman1
1Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
2Department 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.

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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 UNDIIKMA 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

<table>
<thead>
<tr>
<th>Class</th>
<th>Pretest</th>
<th>Treatment</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>P1</td>
<td>O1</td>
<td>P2</td>
</tr>
<tr>
<td>Control 1</td>
<td>P3</td>
<td>O2</td>
<td>P4</td>
</tr>
<tr>
<td>Control 2</td>
<td>P5</td>
<td>O0</td>
<td>P6</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning activity (Pre-investigation)</th>
<th>Learning stages</th>
<th>GI-Moodle</th>
<th>Students’ activities (GI-WAG)</th>
<th>SI-WAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online (Pre-investigation)</td>
<td>Delivery of learning topic</td>
<td>The lecturer delivers the learning topic (Moodle)</td>
<td>The lecturer delivers the learning topic (WAG)</td>
<td>The lecturer delivers the learning topic (WAG)</td>
</tr>
<tr>
<td></td>
<td>Problem identification and asking the question</td>
<td>The lecturer submits the investigation question (Moodle)</td>
<td>The lecturer submits the investigation question (WAG)</td>
<td>The lecturer submits the investigation question (WAG)</td>
</tr>
<tr>
<td></td>
<td>Investigation design</td>
<td>Students compile and propose their investigation procedure (Moodle)</td>
<td>Students compile and propose their investigation procedure (WAG)</td>
<td>Students compile and propose their investigation procedure (WAG)</td>
</tr>
<tr>
<td>Offline (Investigation activity)</td>
<td>Data analysis and conclusion drawing</td>
<td>Students conduct an investigation based on the prepared procedures</td>
<td>Students conduct an investigation based on the scheduled procedures</td>
<td>Students conduct an investigation based on the prepared procedures</td>
</tr>
<tr>
<td></td>
<td>Communicate the results of the investigation</td>
<td>Students gather and analyze the data, then conclude their finding</td>
<td>Students collect and analyze the data, then conclude their finding</td>
<td>Students gather and analyze the data, then complete their finding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Students arrange and present their investigation</td>
<td>Students organize and submit their investigation report</td>
<td>Students arrange and present their investigation</td>
</tr>
</tbody>
</table>
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 Kolmogrov-Smirnov test, while homogeneity was tested using Levene’s test. The results of the data normality test are shown in
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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.

Table 3. Results of normality and homogeneity tests

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
<th>N</th>
<th>Sig. normality</th>
<th>Sig. homogeneity</th>
<th>α</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPS</td>
<td>Pretest</td>
<td>90</td>
<td>0.341</td>
<td>0.078</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>90</td>
<td>0.700</td>
<td>0.115</td>
<td>0.05</td>
</tr>
<tr>
<td>CU</td>
<td>Pretest</td>
<td>90</td>
<td>0.200</td>
<td>0.674</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>90</td>
<td>0.200</td>
<td>0.634</td>
<td>0.05</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig. (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning model</td>
<td>SPS</td>
<td>2</td>
<td>416.977</td>
<td>6.499</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>CU</td>
<td>2</td>
<td>327.488</td>
<td>10.762</td>
<td>0.000</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Variable</th>
<th>Class</th>
<th>Corrected average</th>
<th>LSD notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPS</td>
<td>GI-Moodle learning</td>
<td>55.76</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>GI-WAG learning</td>
<td>54.15</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>SI-WAG learning</td>
<td>48.17</td>
<td>b</td>
</tr>
<tr>
<td>CU</td>
<td>GI-Moodle learning</td>
<td>73.21</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>GI-WAG learning</td>
<td>69.71</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>SI-WAG learning</td>
<td>66.38</td>
<td>c</td>
</tr>
</tbody>
</table>

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
Guided inquiry with Moodle to improve students’ science process skills and conceptual understanding (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 scientific 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.

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Guided inquiry with Moodle to improve students’ science process skills and conceptual understanding. (Saidil Mursali)


**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.