KnE Social Sciences

IJESAS
International Joint Seminar on Education, Social Science and Applied Science
Volume 2024

Research Article

Blended Learning in Science Classroom: Its Impact on Preservice Teachers' Science Process Skills

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Published: 3 July 2024

Publishing services provided by Knowledge E

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Selection and Peer-review under the responsibility of the IJESAS Conference Committee.

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Abstract.
Blended learning is an approach to foster science process skills (SPSs). However, current studies of blended learning showed inconsistent results about the effectiveness of the learning approach. Therefore, this study aimed to investigate the impact of blended learning implementation on the SPs of preservice science teachers. Using a case study design, this study collected quantitative and qualitative data from 20 preservice science teachers at a university in Surabaya, Indonesia. This study utilized an SPS test, a questionnaire, and interviews to gather relevant information. The findings of this study indicated the positive impacts of blended learning on SPSs of preservice science teachers, especially on skills of identifying and controlling variables and graphing and interpreting data. However, the effect of this learning approach could have been more optimal. The main factors that hinder the achievement of the optimum impact of blended learning implementation on preservice science teachers' SPSs were their insufficient prior knowledge, inadequate self-regulation, and personality aspects. These three factors need to be considered when blended learning is implemented.

Keywords: blended learning, flipped classroom, learning management system, science process skills, preservice teachers, science education

1. INTRODUCTION

Due to its nature, science learning cannot be separated from scientific activities and investigations [1] . This is because scientists discover knowledge about natural phenomena through scientific studies. John Dewey's statement also recommended that science learning should reflect the activities carried out by scientists [2]. Therefore, science learning should not only focus on understanding existing theories and concepts, but also provide students with opportunities to develop relevant skills, namely Science Process Skills (SPSs) [3].

Popularised by the curriculum project called Science - A Process Approach (SAPA), SPSs are defined as a set of skills that can be taught, used in many scientific disciplines, and reflect the behaviour of scientists [4]. These skills are classified as basic and integrated SPSs. Basic (simpler) SPSs provide a basis for studying integrated (more complex) SPSs. Basic SPSs include observing, inferring, measuring, communicating, classifying, and predicting, whereas integrated SPSs consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models. In addition to helping students' understanding of science concepts [5], SPSs also facilitate students in developing critical thinking [6–8] and problem-solving skill [4]. Thus, SPSs are crucial for students in the 21st century [9]

However, preservice science teachers' SPSs are inadequate, as found in Turkey [10, 11], Malaysia and Indonesia [6, 12]. The lack of preservice science teachers' SPSs will negatively impact students' scientific attitudes [13] and understanding of science concepts [4]. Furthermore, without adequate SPSs, preservice science teachers will not be interested in these skills and, therefore, less likely to teach these skills to their future students [5], thus adversely affecting the development of SPSs of the new generation. Therefore, prospective teachers must develop SPSs at the expected level through the learning process.

Blended learning is one of the learning approaches currently recommended for optimizing the development of SPSs [11, 14]. The combination of face-to-face and online learning modes in blended learning [15] allows students to develop SPSs at their own pace without sacrificing social interaction [16, 17], which is crucial for developing these skills [18, 19]. Integrating technology in this learning approach also allows students to improve their ability in SPSs by facilitating students to explore as many learning resources as possible, such as videos and animations, before joining the physical classroom. Watching videos before experimentation positively impacted SPSs [20, 21], especially in identifying and stating hypotheses and defining operationally [11]. Accessing learning resources outside of the classroom supports students in building prior knowledge and understanding [11, 22]. Therefore, teachers' feedback is crucial for facilitating students in constructing accurate conceptions [11, 23]. Blended learning enables students to receive face-to-face and virtual feedback (Zhu et al., 2021).

However, the research findings about blended learning are inconclusive [24–26]. While some studies found positive impacts of blended learning [11, 14, 27], others revealed the ineffectiveness of this learning approach [16, 25, 28]. Furthermore, despite the importance of SPSs, only some studies explained how SPSs are affected by the learning approach [11], resulting in the minimal information available for designing appropriate blended learning. Therefore, the current study explored in depth the blended learning implementation in a particular study program where the learning approach is implemented to support the development of SPSs.

2. METHOD

A case study design was implemented in this study to collect in-depth information on the impacts of blended learning implementation on the preservice science teachers' SPs in a particular study program [29, 30]. A test, a survey, and interviews were adopted in this study to gain a holistic picture of this study's focus [31] without making generalizations of the research results [29]. These quantitative and qualitative data were gathered to triangulate this study's findings.

This study involved a classroom of 20 preservice science teachers from the Science Education Study Program at the Universitas Negeri Surabaya to collect relevant information. The selected class was superior compared to the other existing classes. The participants were 18 female and two male preservice teachers in the third semester when this study was conducted. In this study program, the preservice science teachers were facilitated to develop SPSs since the first semester directly through the Science Basics Course or indirectly through the learning activities in different science-related courses. The preservice science teachers learned primarily the integrated SPSs, including identifying and controlling variables, formulating hypotheses, operationally defining, designing investigations, and graphing and interpreting data [11].

In this research, the preservice science teachers developed SPSs through blended learning. The blended learning in the form of a flipped classroom was implemented in two topics of the Human Anatomy and Physiology Course, namely Osmosis and Photosynthesis. The inquiry learning model was adopted in the two topics. The online learning mode was facilitated by a learning management system provided by the university called Vinesa. At the beginning of the semester, lecturers uploaded all teaching materials and learning media, such as books, PPTs, and videos, in the Vinesa to support students' learning outside the classroom anytime and anywhere. Assignments, quizzes, and tests were also attached to the Vinesa for easy grading and to support a paperless policy. The learning outline for each topic was conveyed clearly through the LMS. Students were required to access the LMS and complete the provided assignments before joining the face-to-face classes. The face-to-face meetings were held to conduct pre-laboratory activities, experiments, and discussions. Lecturers or practicum assistants facilitated these face-to-face learning activities to provide direct lecturer-student and student-student interactions.

Quantitative and qualitative data were collected in this study during the blended learning implementation to gain a holistic understanding of the preservice science teachers' SPSs. Pretest, posttest, and survey were administered to the participants to collect quantitative data, whereas interviews were conducted to gather qualitative information about the focus of this study. Pretest and posttest were performed using an SPS test developed by Monica. The content validity of the test was 0.98, and the internal reliability was 0.81, indicating that the test instrument was valid and reliable [32]. The test contains 30 multiple-choice questions that measure integrated SPSs, including identifying and controlling variables, stating hypotheses, designing experiments, graphing and interpreting data, and operational definitions. To assess perceptions, a survey was conducted at the end of blended learning using an instrument in the form of Google Form, which was developed by adapting a questionnaire created by Bouilheres et al [16]. The developed questionnaire contained 18 items that inquired about participants' identities and perceptions of the teaching and learning processes. Each item has four response options ranging from strongly disagree to agree strongly. Semi-structured interviews were also run one week after the questionnaire administration by involving six participants who indicated positive and negative perceptions in the survey.

Descriptive statistics were used in this study for analysing quantitative data. Means (M), standard deviations (SD), mean differences and Cohen's d (effect size) were calculated for analysing the results of the SPS test. The effect size (ES) values, then, were interpreted as follows: 0.0 to 0.2 was categorised as low, more than 0.2 to 0.5 as a medium, and above 0.5 as significant [32]. Percentages were also calculated to analyse perceptions collected from the survey [16]. Qualitative data collected from interviews were analysed using the six-step thematic analysis, including familiarising the data, generating initial codes, identifying, reviewing, comparing and compiling themes, and writing the report [31, 33].

3. RESULTS AND DISCUSSIONS

3.1. The Results of the SPs Test

The SPS test was administered to the participants at the beginning (pretest) and the end (posttest) of the blended learning to understand the effectiveness of this approach on their integrated SPSs. Descriptive statistics for the results of the SPS test are presented in Table 1.

Table 1 shows that the mean of pretest and posttest are different overall. Except for stating hypotheses, the means of posttest results are higher than pretest values, indicating the positive impacts of blended learning on the preservice science teachers' SPSs. However, the effect size values for each integrated SPS range from 0 to 0.24, with

Table 1: Descriptive statisctics for the sps test results.

Integrated SPSs	Mpretest	Mpostest	Mpostes-Mpretes	SDpretest	SDpostest	ES
Identifying and controlling variables	0.864	0.900	0.036	0.344	0.301	0.111
Stating hypotheses	0.492	0.492	0.000	0.502	0.502	0.000
Operational definitions	0.617	0.667	0.050	0.488	0.473	0.104
Graphing and interpreting data	0.875	0.944	0.069	0.332	0.231	0.241
Designing investigations	0.650	0.700	0.050	0.481	0.462	0.106

most skills having values less than 0.2. These findings indicate that the effectiveness of blended learning on the preservice science teachers' integrated SPSs is relatively low. Even the effect size value for formulating a hypothesis is zero, meaning blended learning had no impact on this skill. Nevertheless, graphing and interpreting data are the skills with the highest effect size value (0.241). This result indicates the moderate impact of blended learning only on this skill.

3.2. The Results of the Questionnaire

The preservice teachers' perceptions toward the blended learning implementation were also explored to find the reasons behind the ineffectiveness of this approach on their SPSs. Thus, the blended learning questionnaire was administered to the preservice teachers at the end of the implementation of this approach. The results of the questionnaire are visually presented in Figure 1.

Figure 1 shows that most preservice science teachers perceived positively (choosing Agree or Strongly Agree responses) blended learning they had experienced. This finding is supported by the percentage of negative responses ranging from 5% to 40%, indicating that more than 50% of the respondents gave positive answers to each questionnaire item. Furthermore, most respondents selected positive responses, Agree compared to Strongly Agree, indicating that they did not perceive the optimum benefit of blended learning implementations.

Figure 1 also indicates blended learning aspects that received more positive or negative responses. Learning flexibility (Items 9 and 10) and interaction quality (Item 12) are learning aspects that received higher percentages of Strongly Agree from the respondents. It means that most preservice teachers perceived the flexibility of blended learning, especially when interacting with online learning materials. They also perceived quality interactions during blended learning implementations. This fact is supported by the higher percentages of Agree responses for Items 13 and 14 that focus on lecturer-student interactions.

Furthermore, 65% of the preservice teachers perceive good integration between offline and online learning modes, as shown in Items 1 and 7, indicating that the lecturers designed blended learning well. However, 30-40% of the preservice teachers selected Disagree for the items focused on prior knowledge and understanding that they constructed from online learning, including Items 2, 3, 4, 5, and 6. It indicates that prior knowledge and understanding became the preservice science teachers‘ biggest concerns during blended learning implementations.

Regarding SPSs, Figure 1 shows that most preservice science teachers agree (55%) and strongly agree (30%) that blended learning contributed to improving their SPSs. Only 15% of the preservice teacher did not perceive the effectiveness of this learning approach on the development of their SPSs. The reasons for these findings will be explained in the interview results.

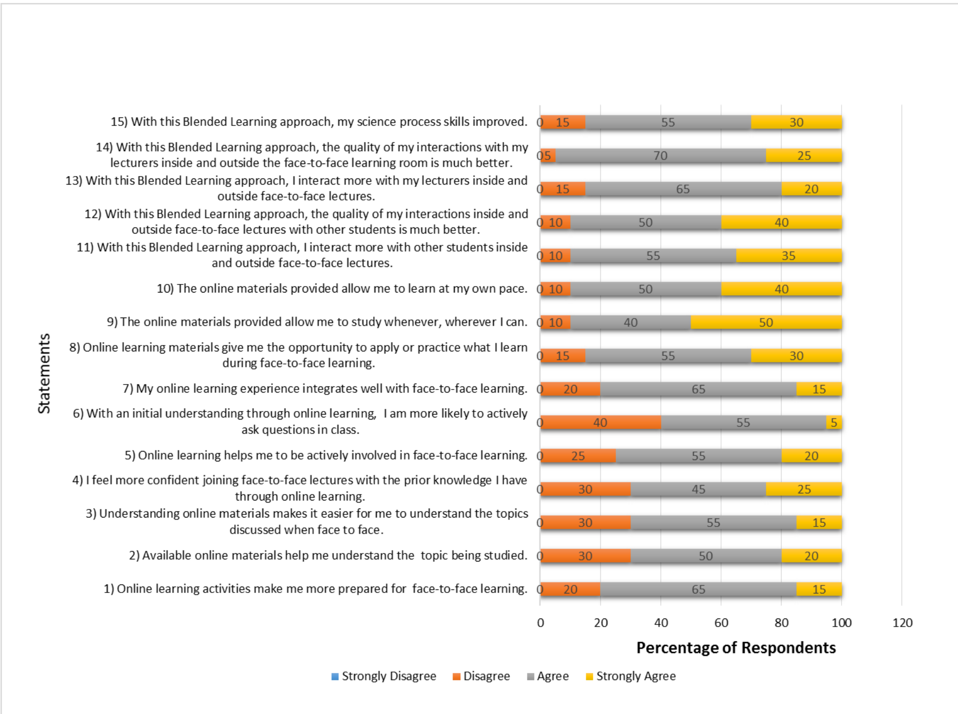

Figure 1: Percentage of respondents‘ response to the questionnaire.

3.3. The Results of the Interviews

Semi-structured interviews were conducted to gain more detailed information about participants’ perceptions toward blended learning implementation. The thematic analysis identified four aspects as the most affecting factors for blended learning implementation. The aspects included learning flexibility, self-regulated learning, personality, prior knowledge and interaction. The interview results for each aspect are presented in the following paragraph.

3.4. Learning Flexibility

Most of the preservice science teachers preferred blended learning compared to fully face-to-face or online learning modes due to the flexibility of this learning approach. This finding is apparent in the following responses:

1. R1: I prefer blended learning because I can study alone or in groups. If I do not understand a learning material, I can ask questions to the lecturers during offline meetings.
2. R2: Blended learning facilitates students to be more flexible in learning…we can study anywhere and at any time without being limited by distance, space, and time.
3. R3: Blended learning is better because I can learn the content online based on my learning style. In offline meetings, then, the learning material is discussed.

The responses above indicate that preservice science teachers appreciated the flexibility of blended learning. The online mode allows respondents to study anytime and anywhere according to their pace and learning style. Face-to-face discussions and activities help them to confirm or refine their prior understanding.

3.5. Self-regulation

Despite the preference for blended learning, some respondents found managing online learning difficult because of a lack of self-regulation. The following responses support the assertion.

1. R2: Blended learning is not optimal if you cannot manage your time. Online learning tends to be abandoned because it coincides with other activities, such as in organizations or at home.
2. R4: Sometimes, lecturers arrange online meetings. When there was a chat on my phone, suddenly, I couldn't focus on listening to the lecturer.

3. R5: During online meetings, it is usually noisy, so I am not motivated to take notes of important points and don't listen to the lecturer.

The statements above indicate the importance of self-regulation to implement blended learning effectively.

3.6. Personality

The preservice science teachers' characteristics affected their involvement in blended learning. Some respondents mentioned shyness and lack of confidence as the reasons for being passive in offline learning. This fact is shown in the following responses.

1. R4: conveniently responded to the lecturer's questions in online learning because no one can see my face. In offline mode, I am shy to express my ideas. I am a shy person.
2. R5: I am paranoid about offline meetings. I was afraid when the lecturer appointed me in the class, and it made me blank out because I felt many people were seeing me.
3. R6: I am less active in the class because I [felt] inferior. Sometimes, my friend asked the same question I wanted to ask.

This personality aspect needs to be considered when implementing blended learning. Blended learning must be designed to accommodate these particular preservice teachers.

3.7. Interaction

Natural interaction is one of the advantages of blended learning compared to full online mode. The following responses describe the interactions between the lecturers and preservice science teachers.

1. R1: The interaction with lecturers was good. We discussed the schedule...lecturers responded to our message via WhatsApp, sometimes fast but sometimes slow.
2. R3: During the offline practicum, I could ask my co-assist directly about using tools or materials that were not easy to understand.
3. R6: I was uncomfortable asking questions to lecturers because it would have interrupted the lecturer.

The responses indicate an excellent interaction during the blended learning implementation. However, the preservice teacher's perception, as shown by R6 (Number 15), needs to be considered for improving the inclusivity of blended learning.

3.8. Prior Knowledge

Preservice teachers' prior knowledge was constructed during the online learning before joining the classroom. This aspect was crucial for the in-class laboratory activities or discussions. Some respondents revealed difficulties in building accurate prior understanding, as explained in the following quotes.

1. R2: My prior knowledge was insufficient due to the lack of optimal online learning, so I lacked confidence.
2. R6: Because I don't understand online material, I understand offline material better.

From the respondents' explanations, it is apparent that the preservice teachers' prior understanding, which was constructed during online learning, was insufficient. The reason for the findings is because of their lack of self-regulated learning. As in Number 10, R2 did not try to provide conducive learning environments and tended to handle other disruptive activities. R6 (Number 14) also could improve understanding by asking the lecturer or others. However, the preservice teacher's personality and lack of self-regulation prevent R6 from doing the action.

3.9. Discussion

The effectiveness of blended learning on SPS development was identified in experimental-based studies [14, 18, 19]. For example, designed a website containing videos, animations, images, games and flash related to the basic concepts of plant tissue culture [14]. The authors used real problems that required students to carry out scientific activities. Similarly, Bonitasya et al. used Google Classroom and Zoom as platforms for blended learning with a collaborative problem-solving approach for vibration, wave and sound materials [18]. In line with these two studies, the current research used Vinesa as a learning management system and applied an authentic problem-based inquiry model related to Osmosis and Photosynthesis. Technology integration in blended learning increases learning flexibility and social interaction to achieve learning objectives [16, 17]. These advantages were also confirmed by the results of the blended learning questionnaire, indicating that the preservice science teachers appreciated the benefit of blended learning. Other relevant studies also observed similar responses [16].

However, the SPS test results show that the effect size values for the five integrated SPSs are relatively low, except for graphing and interpreting data. This finding indicates that blended learning implemented in this study did not significantly impact the preservice science teachers' SPSs. This result contradicts the existing research that focused on the impact of blended learning on SPSs [11, 14, 19]. Similar to the research conducted by Çakiroğlu et al. (2020), in this current study, preservice science teachers were exposed to experiment-related videos accompanied by an inquiry-based worksheet and learning materials before joining the laboratory activities. These learning materials were provided in the Vinesa to facilitate preservice teachers' development of prior knowledge anytime and anywhere. Nevertheless, the results of these two studies were contradictory. The insufficient gain of SPSs was also observed in the study using PhET simulations as online learning followed by offline discussions [34].

The inconsistent findings of studies about blended learning were also recognised by many scholars [24]. While some studies reported positive impacts of blended learning on students' outcomes (Vo, 2020) and engagement [35]. Researcher observed a higher failure rate of students in flipped classrooms than in traditional teaching in the Electromagnetic Fields and Waves course. In response to these contradictory findings, [26] highlighted flexibility, interaction, and students' cognition as importance aspects to be considered in blended learning instructions. According to the authors, a well-designed blended learning integrating technologies to support the balance between flexibility and interaction during knowledge construction process. When the learning is possible anytime and anywhere, the interaction should be an insentive during the distant phases. In this current study, the respondents perceived the flexibility and good interaction during the blended learning implementation, indicating that the two essential aspects were accommodated in this learning. In addition to flexibility and interaction, students' cognitive characteristics need to take into account to promote positive impacts of blended learning. Mueller and Wulf suggested five strategies to accommodate students' cognitive characteristics including formulating achievable, motivational, and clear learning goals, giving direct and immediate feedback, conducting initial assessments, proving learning materials, guiding students to identify skills gaps [26].

Judging from the blended learning questionnaire results, the high percentages of negative responses are related to prior knowledge and understanding. This finding is confirmed by the interview results indicating that the preservice science teachers' insufficient prior understanding contributed to the ineffectiveness of blended learning.

The influence of prior knowledge on blended learning effectiveness in SPS development was also observed in similar studies [14, 20]. Prior knowledge is fundamental for students to understand inquiry activities and to build new understanding based on the results of inquiry activities [11]. Prior knowledge also affects students' motivation and self-confidence in experimental activities [11]. This fact is also identified in this study (Interview Number 13).

In addition to prior knowledge, the success of blended learning is determined by the preservice science teachers' self-regulation [27], as online learning mode needs autonomy [36]. Self-regulation is a metacognitively, motivationally, and behaviourally active process to master their learning, including the aspects of planning, learning, self-assessment, and monitoring. The flexibility of blended learning may be beneficial for students but detrimental for those lacking self-regulation [36] Students need to be able to manage their learning independently and motivate themselves for success in the blended learning environment.

The preservice science teachers' personalities also contributed to the successful blended learning implementation. Introvert personality and lack of confidence were identified as the reason for the preservice teachers' low participation in offline meetings [28, 37]. The previous studies also revealed similar findings [38]. This condition prevented the preservice teachers from benefiting from social interaction, resulting in learning difficulties.

4. CONCLUSION

This study explored the impact of blended learning on the preservice science teachers' SPSs in a particular study program. Data from the SPS test, blended learning questionnaire, and semi-structured interviews were analysed to understand the case being investigated. The research findings suggested that preservice science teachers appreciated the benefits of blended learning, mainly because of the learning flexibility and social interaction offered by this learning approach. However, the effectiveness of blended learning on the preservice science teachers' SPSs was relatively low, except for graphing and interpreting data skills. The main factors contributing to the ineffectiveness of blended learning were insufficient prior knowledge and understanding, lack of self-regulation, and personality aspect. These three factors need to be taken into account when designing blended learning to improve SPSs.

ACKNOWLEDGMENT

We would like to thank all the participants of this study for their participation and contribution. We are very grateful to the reviewers of our teaching materials and the manuscript for their constructive comments and advice. We also would like to acknowledge the Directorate General of Higher Education, Research and Technology of Indonesia for providing financial support for this research, as shown in Decree Number 0536/E5/PG.02.00/2023. The authors declare no potential conflicts of interest concerning this article's research, authorship, and publication. All research participants received and signed informed consent forms before participating in this study.

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