Implementation of Integrated Science Course Program based on SAINS-Edu: Strengths and Weaknesses

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ABSTRACT

This research described the Integrated Science course program based on SAINS-Edu to improve students' conceptual mastery. The program utilized pedagogical scaffolding and an artificial intelligence-based recommendation system in SAINS-Edu. The research design employed was an experimental study using a one-group pretest-posttest approach. Data were statistically analyzed to test mean differences using the t-test and to measure the impact using effect size. The data were also descriptively analyzed to highlight its strengths and weaknesses. The t-test results indicated a significant difference with value of 29,881. The effect size showed a high category with value of 4,775, signifying the effectiveness of this program in enhancing students' conceptual mastery. The program combines personalization and integration aspects that allow students to design integrated science learning in line with their interests and needs. The program's strengths encompass the inclusion of scaffolding, enhanced conceptual mastery, and higher-order thinking skills, along with student collaboration. Challenges include the time and resources required for software design, curriculum changes, and technological dependence. The study's findings provide a foundation for the development of similar course programs and the potential to enhance students' conceptual mastery in various learning contexts.

Keywords: integrated science course, artificial intelligence, concept mastery

INTRODUCTION

Higher education, as part of the education system, plays a highly strategic role in the world of education. Higher education provides access to educational and training programs to enter the workforce with the necessary skills and knowledge (Paulsen & Kolstø, 2022). Higher education also serves as a vital hub for innovation and research for the advancement of science and technology. This is because higher education provides a unique environment where students can engage in innovative, diverse, and challenging learning experiences. The efforts that can be undertaken by higher education institutions include delivering education that is oriented towards 21st-century skills and harnessing the latest technology in its implementation.

Improving the quality of students is realized, in part, through integrated science education (Gunawan et al., 2020, 2021; Winarno, 2021). Students are required to master the essence of science as a whole (Wilujeng et al., 2010; Zhang & He, 2013). This supports students in becoming critical and creative thinkers, capable of connecting various aspects for application in real-world situations.

The effort to prepare future science teachers is realized through the Integrated Science Education course. This course is mandatory for students in the Science Education program. The Integrated Science Education course encourages students to acquire knowledge and skills in the field of science education. The science education field encompasses sub-disciplines that consist of physics, biology, chemistry, and Earth and Space Sciences, all of which are interrelated. This is intended to provide students with sufficient knowledge to integrate various science content and pedagogy.

The fulfillment of learning outcomes in the Integrated Science Education course at a university in West Java presents various challenges and issues. Inquiry-based learning is not implemented in the course as it is conducted through presentation of assignments with topic mapping based on a lottery system. The use of teaching media is limited to PowerPoint presentations and summaries of material that are repeated every year. Lecture activities also do not adequately facilitate students in thinking and constructing knowledge to grasp the concepts. Students also perceive that integrated science education is abstract and difficult to understand due to its coverage of various scientific fields. Other research findings indicate that when faced with the Integrated Science Education course, students have various misconceptions in integrating learning and constructing Integrated Science Education teaching materials (Gunawan *et al*., 2019).

Inquiry-based learning can be employed as an effort to assist students in the Integrated Science Education course. The inquiry-based learning method can be implemented with the assistance of scaffolding. Scaffolding is based on the concept of the Zone of Proximal Development (ZPD) by Vygotsky, as an approach that can be demonstrated through interventions to support the learning process (Mamun et al., 2022).

Pedagogical scaffolding can be implemented through the Predict, Observe, and Explain (POE) learning model. The POE learning model is a scientific inquiry activity designed to provide students with opportunities to develop knowledge through scientific activities. An adaptation of POE has been further developed into Predict, Observe, Explain, and Evaluate (POEE) (Mamun, 2022).

The role of scaffolding can also take the form of ICT in education. This refers to the utilization of ICT to provide assistance to students in their academic activities. Researchers continue to advance the role of ICT in education. The current development of ICT is focused on its combination with Artificial Intelligence (AI) to assist educators in facilitating the development of learning through various AI tools (Kim *et al*., 2021, 2022; Celik, 2023; Sun *et al*., 2023). The use of recommendation systems in AI has not yet been extensively explored to aid students in integrating science education.

In bridging the opportunities and challenges of AI, a system has been designed specifically for the Integrated Science Education course, created for this research. The designed recommendation system is called SAINS-Edu (Semi-Autonomous: Integrating Natural Science Education). This system is characterized as semi-automatic, facilitating students to think through recommended science learning themes and integration patterns across various content and pedagogy. The development of this educational program is innovative and unique, building upon previous research. As there has been no prior research on the development of this educational program, it is expected to become a state-of-the-art contribution to the field. The purpose of this study is to analyze the improvement of students' mastery of concepts through the Integrated Science Course Program based on SAINS-Edu, while simultaneously evaluating its strengths and weaknesses in enhancing conceptual mastery.

METHODS

This research was conducted in the Science Education program at a university in East Java. A total of 73 students who were taking the Integrated Science Curriculum and Design course in fifth semester were involved. This quantitative research used a one-group pretest-posttest design. In its implementation, one class was selected as the sample, and before the program implementation, a pretest was conducted to measure the students' prior knowledge. Following the program implementation, posttests were administered to the students. The data were analyzed using statistical tests. Data was analyzed to determine the mean differences within the treatment group using t-tests, and effect size values were also calculated (Cohen, 2013). The instrument used is a concept mastery test consisting of 24 essay questions. The choice of this essay test is motivated by the need to measure students' understanding of concepts in Integrated Science Education more deeply. Essay questions allow students to provide more explicit and detailed answers, which will help in evaluating a more complex understanding of concepts. The strengths and weaknesses data are analyzed from the implementation reflection during the research study. The research findings provided insights into the strengths and weaknesses of the program.

RESULTS AND DISCUSSION

Implementation Program

Based on the schedule of the implementation of the Integrated Science Course Program based on SAINS-Edu, there are a total of 6 meetings. There is 1 online meeting for discussing the SAINS-Edu software and creating accounts for each student, 3 in-person meetings for the actual course program, 1 in-person meeting for the pretest, and 1 in-person meeting for conducting the posttest. Each of these meetings has a time allocation of 150 minutes (equivalent to 3 credit units).

1. Training on the SAINS-Edu Recommendation System Software

Before the implementation of the program, students received training on how to use the SAINS-Edu recommendation system. This was done to ensure that when the course commenced, students would be prepared to use it. This training provided an overview of SAINS-Edu, the hardware and software requirements, as well as the menus and how to use them. The demonstration method was used to explain the steps in using the SAINS-Edu recommendation system. The demonstrations included how to access the site, create an account and log in, explain user profiles, use the recommendation page, upload student assignments, and use the discussion feature. The instructors also gave students the opportunity to simulate the steps in using the SAINS-Edu recommendation system and invited other students to practice it. As a result, all students now have accounts and are capable of using the SAINS-Edu recommendation system.

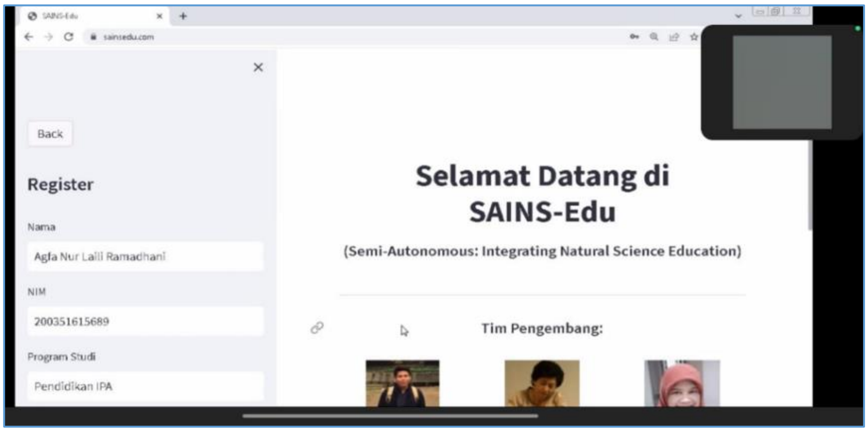

Figure 1. Online Demonstration of Student Use of the Recommendation System

2. Implementation of the Integrated Science Course Program based on SAINS-Edu

The implementation of this curriculum program is applied using the predict, observe, explain, evaluate (POEE) learning syntax. At the beginning of each meeting, learning objectives that need to be achieved are presented, along with an apperception to arouse student interest in learning. Students who have been trained in the use of SAINS-Edu are expected to use it more efficiently in their coursework.

The implementation of the curriculum program is presented in three meetings. In the first meeting, students are directed to achieve learning objectives, which include: analyzing the characteristics of the integrated model, analyzing the junior high school science curriculum to determine learning outcomes that can be integrated using the integrated model, identifying learning themes, and analyzing critical and creative thinking skills that can be developed through the integrated model. In the second meeting, students are directed to achieve learning objectives, which include: analyzing key ideas in integrated science education, creating guidelines for learning activities, evaluating the suitability of these guidelines, and developing teaching materials. In the third meeting, students are directed to achieve learning objectives, which include: developing assessments for critical and creative thinking in integrated science education and evaluating them.

3. Improvement in Students' Concept Mastery

The data on concept mastery is obtained from the scores of concept mastery in the pretest and posttest. Based on the results of the concept mastery test, descriptive analysis and statistical tests were conducted. The results obtained from the analysis of both the pretest and posttest data are presented in Table 1.

Table 1. Statistical Test Results of Pretest and Posttest Concept Mastery Score

Statistic Test	Pretest Scores	Posttest Scores
n	73	73
Mean	27,68	65,47
Standard Deviation	5,87	9,53
Maximum Score	41	87
Minimum Score	13	45
Normality Test	0,200	
Mean Difference	37,78	
t-test (*Paired Samples t-test*)	29,881	
Sig. (2-tailed)	0,000	
Explanation	Differ significantly	

Statistical tests were conducted to analyze the impact of the Integrated Science Course Program based on SAINS-Edu in improving concept mastery. Testing was performed to determine the effect size of the treatment or intervention program developed in enhancing students' concept mastery. The effect size measure used in this analysis is the value of d. According to Table 1, the following values were obtained from the statistical tests n = 73, Mpre = 27,68, Mpost = 65,47, Sd_1 = 5,87, Sd_2 = 9,53, resulting in Sd=7,914. By inputting these values, the effect size (d) is calculated as follows:

$$d = \frac{M_1 - M_2}{Sd} = \frac{65{,}47 - 27{,}68}{7{,}914} = \frac{37{,}790}{7{,}914} = 4{,}775$$

The calculated effect size (d) is 4.775. According to the criteria this value falls into the high category (Cohen, 2013).

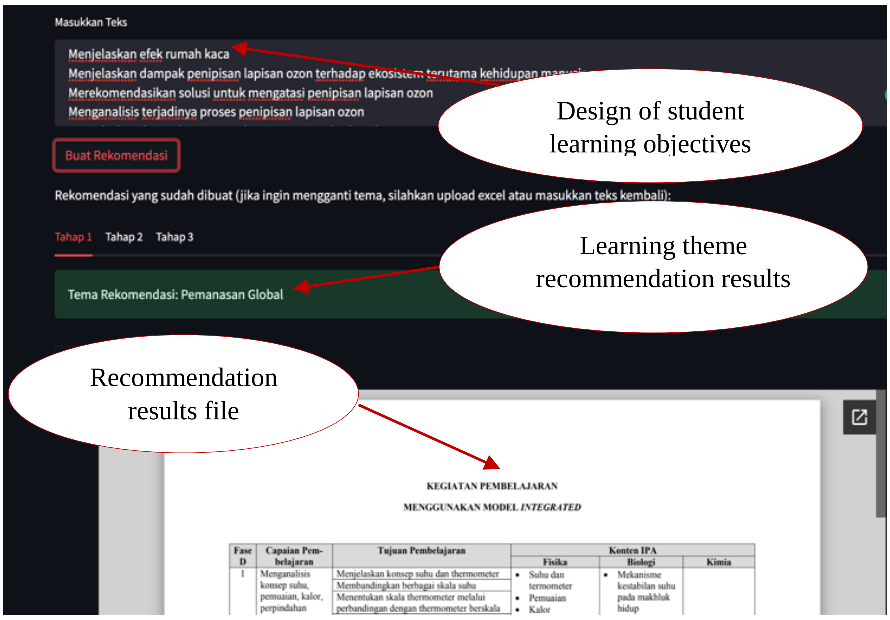

Figure 2. Sample of activities when integrating learning objective using SAINS-Edu

Strengths and Weakness

Integrated Science Course Program based on SAINS-Edu can be effectively implemented for students. However, there are strengths and weaknesses that can be summarized based on the findings during the implementation. The strengths are as follows:

1. These programs are facilitated by scaffoldings: POEE and AI-based recommendation systems.

POEE and SAINS-Edu serve as scaffoldings to assist students in building their knowledge in integrating Integrated Science Education. The provision of this scaffolding originates from inquiry-based learning, aimed at minimizing potential difficulties and obstacles students may encounter when integrating Integrated Science Education. This helps achieve a better understanding and optimal learning outcomes. The POEE learning model provides a systematic framework for students to gain deeper knowledge and understanding. The SAINS-Edu recommendation system offers technology and data analysis to assess students' preferences and needs in designing integrated science education, through thematic learning.

2. Optimal Learning Environment

The Integrated Science Education course program based on SAINS-Edu is designed with a focus on students' enthusiasm as a critical factor in creating a positive learning experience. Understanding that students' enthusiasm significantly impacts their motivation and engagement in the learning process is taken into account in the development of this program. The program is designed with an engaging and relevant approach to meet the needs and interests of students. The selection of captivating topics, the use of innovative AI technology, and interactive learning approaches can spark students' interest and enthusiasm. Furthermore, the use of AI as an aid in the curriculum is also appealing to students. Students tend to be interested and enthusiastic about the latest technology, and the use of AI can provide an exciting and unique learning experience.

3. Enhancement of students' concept mastery and higher order thinking skills

Integrated Science Course Program based on SAINS-Edu is designed to enhance students' concept mastery. At the beginning of the course, students are encouraged to analyze the curriculum to map the learning outcomes. While working on LKM assignments, students also employ their thinking capacities through various in-depth analyses and evaluations. Referring to the t-test results and effect size obtained from this research, it is evident that this curriculum is capable of improving students' concept mastery. This learning program also has the potential to enhance students' thinking skills, such as critical thinking and creative thinking.

4. Team collaboration

Integrated Science Course Program based on SAINS-Edu is designed to enable students to collaborate with each other. Collaboration is one of the essential aspects of 21st-century skills required in the workplace and daily life. Group tasks are given in this curriculum. Students are encouraged to work together, share responsibilities, and face challenges collectively. Collaborating in groups can help students develop negotiation skills, compromise, and mutual respect for opinions and differences.

While the Integrated Science Course Program based on SAINS-Edu has many advantages, it cannot be denied that this program also has some limitations.

1. Requires a substantial amount of time and resources in designing the SAINS-Edu recommendation system.

Integrated Science Course Program based on SAINS-Edu requires a significant amount of time and resources in designing its software. Developing and designing software that meets the needs of the course program can be a time-consuming process. This design process involves selecting the right technology, developing complex AI algorithms, testing, and iterations to ensure that the software functions effectively. The lengthy software design phase can impact the implementation schedule of the course program.

2. Curriculum Changes

Curriculum changes also present a drawback in this course program. The initial course, Integrated Science Education, experienced curriculum changes, which required adjustments. Furthermore, curriculum changes occurred from the 2013 Curriculum to the Merdeka Curriculum. This affected the dataset used in the development of the recommendation system.

3. Dependency on Technology

The course program relies on AI technology and adequate infrastructure. If there is a system disruption or technical issues, the program's implementation could be hindered or disrupted. Dependence on technology also means that students must have stable and adequate access to technological devices, internet connectivity, and sufficient technical skills.

Discussion

Integrated Science Course Program based on SAINS-Edu is an educational program designed for students to master concepts. This program is primarily built on inquiry-based learning. Inquiry-based learning enables students to independently construct their knowledge through learning activities and allows it to evolve over time through their experiences (Odebiyi, 2023). The provision of scaffolding, in the form of pedagogy and ICT, is implemented in the development of this integrated science course program. Pedagogical scaffolding takes the form of the POEE model, while in the realm of ICT, it involves an AI-based recommendation system software. Both of these scaffolding components are distinctive features of the development of this Integrated Science Education program. They are used to assist students in integrating various content in the process of knowledge construction and the design of Integrated Science Education.

In the POEE learning model, it guides students through a systematic series of steps, starting with activities to make predictions, observe, explain their findings, and further enhance their understanding through reflection and evaluation (Mamun *et al*., 2022). In the predict step, during the initial meeting, students are encouraged to formulate predictions or hypotheses about the learning outcomes they want to integrate using the integrated model. In other activities to design learning and High Order Thinking Skills (HOTS)-based assessments, students use the prediction step to formulate topics proposed by the AI-based recommendation system. This activity encourages students to think critically and make assumptions based on their knowledge. Next, in the observe step, students are given the opportunity to collect data and information through the AI-based recommendation system by providing the learning objectives they formulated earlier. Students can use the system to assist their observations. Then, students are invited to explain their findings in the explain step. Students are asked to interpret and formulate explanations about their work using the integrated model. The next step is to expand understanding through evaluation. Students are asked to reflect on their findings, identify emerging patterns or relationships, and evaluate the knowledge they have developed. This process is also aided by feedback from the instructor and peers to help deepen their understanding and relate it to broader concepts.

The stages in this course can be particularly beneficial in building conceptual mastery and stimulating thinking skills. The process of practicing and integrating science learning provides students with repeated opportunities to understand the relationships between learning outcomes in various fields of study. This process continually encourages the cognitive domains of students to be utilized. This condition is beneficial as a process to stimulate the development of conceptual mastery, critical thinking skills, and creative thinking skills in students significantly. (Siburian *et al*., 2019; Kurdiati, 2022; Suciati *et al*., 2022; Kaczkó & Ostendorf, 2023).

The utilization of AI technology as part of ICT scaffolding is to assist the integration of various content and pedagogy in integrated science learning. This is one of the innovations in this research. The use of AI technology in integrated science learning allows for automated personalized learning that provides recommendations for suitable learning themes to be integrated. Additionally, this recommendation system can suggest topics for designing high-order thinking skills (HOTS) based learning and assessments. The use of this system has the potential to enhance the effectiveness and quality of integrated science learning. This personalization allows for precise customization according to the needs and interests of individual students (Ingkavara *et al*., 2022).

The diverse content of integrated science can be aided by the AI-based recommendation system that is actively explored by students using both of them. This provides assistance to students in integrating it into a learning theme in accordance with the integrated model. The results of this research indicate that both the POEE and AI scaffolding contribute positively to the inquiry process by actively involving students and exploring various content and pedagogy for designing integrated science learning.

Inquiry-based learning with the scaffolding of POEE and SAINS Edu, which forms the basis for the development of this academic program, has a positive impact on students' conceptual mastery (Kuisma & Ratinen, 2021; Laliyo *et al*., 2022; Mamun *et al*., 2022). The Integrated Science course program based on SAINS-Edu provides strong support for students in mastering science concepts. The integration of various relevant concepts in designing learning experiences has a significant impact on students' conceptual mastery. This indicates that the Integrated Science course program based on SAINS-Edu offers optimal opportunities for students to develop a holistic and in-depth understanding in the field of Integrated Science (Acar, 2014; Andrews-Larson *et al*., 2019; Hong *et al*., 2021; Wen *et al*., 2020).

CONCLUSION

The Integrated Science course program based on SAINS-Edu has the following characteristics: it involves scaffolding POEE and AI-based recommendation system SAINS-Edu, focuses on improving students' conceptual mastery, and uses inquiry-based learning as the foundation for program development. This program has a positive impact on enhancing students' conceptual mastery, with a high effect size. It also offers advantages such as the involvement of scaffolding POEE and SAINS-Edu in inquiry-based learning, optimal learning environment, enhancement of students' concept mastery and higher order thinking skills, also team collaboration. However, it has some limitations, including the substantial time and resource requirements for the design of SAINS-Edu, curriculum changes, and dependence on technology.

The findings and advantages of this research can serve as a model for developing other Integrated Science course programs tailored to the curricula of different universities. This is especially beneficial for enhancing students' conceptual mastery. Future researchers can further develop the recommendation system with a larger database and more complex algorithm structures, taking into account the cognitive development aspects of students.

SAINS-Edu can be expanded beyond web-based AI usage and integrated with Android and iOS systems to enhance accessibility. Additionally, it can be integrated with Learning Management Systems (LMS) for implementation in online classes.

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