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Application of Virtual Simulation in Biology Learning Evaluation of Impact on Concept Understanding by Agrotechnology Students

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Abstract
This study aims to evaluate the impact of implementing virtual simulation in Biology learning on concept understanding by Agrotechnology students. Along with the development of technology, technology-based learning, especially virtual simulation, has begun to be applied to support the understanding of more complex concepts. Although a number of previous studies have shown the successful use of virtual simulations in various disciplines, there are still research gaps that need to be filled regarding the application of virtual simulations in the context of Biology education, especially in Agrotechnology study programs. This creates a phenomenon where students have difficulty in understanding these concepts. This research fills the gap by evaluating the application of virtual simulation as a learning method in overcoming this challenge. Using an experimental method, this study involved 30 students as samples, who were tested using pretest and posttest to measure the improvement of their understanding of Biology concepts. The results of the analysis showed that the application of virtual simulation resulted in a significant increase in students' understanding, which was reflected in the N-gain score with an average of 78.25. This value indicates a substantial increase in understanding of Biology concepts after using virtual simulation as a learning method. This finding supports the effectiveness of virtual simulation in improving the understanding of complex concepts, so it can be an effective alternative in learning in Biology. The results of this study provide positive implications for the use of technology in education, especially in improving the quality of learning in higher education.

Keywords: *Biology Learning, Concept Understanding, Virtual Simulation*

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Introduction

Biology learning has an important role in supporting the development of student competencies, especially in study programs such as agrotechnology that require a deep understanding of biological concepts. As the foundation of science that underlies various applications in agriculture, biology covers complex material such as genetics, ecology, and biotechnology that are essential in natural resource management. However, challenges often arise from the abstraction and complexity of the material that is difficult to understand if only delivered theoretically (Gunawan., 2020). To overcome this, innovative learning approaches, such as project-based learning, the use of digital technology, and interactive simulations, can

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help students connect theory with real practice (Akmal et al., 2024). In addition, collaborative learning can improve concept understanding while developing interpersonal skills (Habibi et al., 2024). With effective strategies, biology learning not only improves students' understanding cognitively, but also supports their applicative skills in sustainable agriculture.

Biology as a branch of natural science has a very important role in human life (Amakraw & Kartika., 2022). This science not only discusses living things and their interactions with the environment, but also provides a scientific basis for understanding various natural phenomena related to life (Aziz et al., 2024). In the context of education, learning biology is one of the subjects that plays a strategic role in building students' understanding of various important concepts, such as cell structure, ecosystems, genetics, and evolution. This understanding is not only relevant for academic needs, but also the basis for environmentally sound decision making (Susanti et al., 2023).

Biology learning often faces challenges in the process of delivering material (Muhajarah & Sulthon., 2020). One of the main obstacles is the nature of biology which includes abstract and complex concepts. Many topics, such as cell metabolic processes or genetic mechanisms, require visualization and in-depth understanding in order to be well mastered by students. Conventional learning methods dominated by lectures and texts are often unable to provide a real picture, making it difficult for students to connect theories with phenomena that occur in nature (Nurmalasari et al., 2024).

Limited learning facilities, such as laboratories and teaching aids, are another obstacle that is often faced, especially in schools with limited resources (Sari et al., 2024). In fact, practicum activities are one of the most effective methods in improving students' understanding of biological concepts. Through practicum, students can directly observe, experiment, and draw conclusions from the biological phenomena studied. However, without the support of adequate facilities, this activity becomes difficult to implement optimally.

In higher education, especially in agrotechnology study programs, concept understanding is an important element underlying students' ability to analyze, solve problems, and apply science in agriculture (Bota et al., 2024). However, facts show that many students face difficulties in understanding concepts that are abstract and multidisciplinary, such as the interaction of genetics with the environment, ecosystem dynamics, or the application of modern agricultural technology (Marzia., 2023). This obstacle is often exacerbated by the use of conventional learning methods that are less able to facilitate in-depth and interesting visualization of concepts.

Advances in educational technology offer great opportunities to overcome these challenges, one of which is through the use of virtual simulations (Wahyudi & Jatun., 2024). This technology allows students to visualize processes that are difficult to observe directly, such as the dynamics of microorganisms in soil or the mechanism of plant growth in various environmental conditions (Lasaiba., 2023). However, the application of virtual simulation in agrotechnology learning has not been widely practiced, and its effectiveness in improving students' concept understanding has not been widely studied.

The increasingly complex needs of the agricultural world, such as increasing sustainable productivity, mitigating the effects of climate change, and applying modern technology, require agrotechnology graduates to have a strong understanding of concepts and critical thinking skills. This phenomenon shows the urgency to evaluate the impact of technology-based learning methods, such as virtual simulation, in supporting the improvement of the quality of student understanding (Jenita et al., 2023). Therefore, this research focuses on the phenomenon of the gap between the learning needs that are relevant to the demands of the times and the effectiveness of the learning approaches currently applied (Liriwati., 2023).

Advances in educational technology provide great opportunities to overcome challenges in learning biology (Demmanggasa et al., 2023). Various innovations, such as the use of visual media, computer simulations, and interactive applications, have been developed to help students understand biology material better. These technologies can simulate biological

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processes that are difficult to observe directly, such as cell division, organism life cycles, or ecosystem interactions. With this approach, students can gain a more interesting and in-depth learning experience, despite not going directly to the field (Wulanndari et al., 2024).

Technology-based approaches, the development of project-based learning methods and collaboration are also a concern in biology learning (Trianasari et al., 2024). This method aims to increase student involvement in the learning process by connecting biology concepts with real problems relevant to everyday life (Hapsari et al., 2022). For example, students can be asked to analyze the impact of pollution on local ecosystems or devise conservation strategies for certain species. This approach not only strengthens students' understanding of the material, but also develops critical thinking and problem-solving skills.

Effective biology learning also requires the role of teachers who are able to integrate various learning methods and media (Pare & Muniarti., 2024). Teachers do not only act as information conveyors, but also as facilitators who encourage students to actively learn. In this case, pedagogical competence and the use of technology by teachers are key factors in the success of biology learning (Suyanto et al., 2020). Therefore, teacher training and professional development in this area are needed to answer the demands of 21st century education.

Thus, learning biology has great challenges and opportunities in developing students' understanding of life science (Sudarisman., 2020). Research and innovation in the field of biology education continues to be needed to produce more effective learning methods and media, according to the needs of students in the digital era. This effort is expected to make biology learning not only an academic activity, but also a means to form a generation that cares about life and the environment.

Concept understanding is an important foundation in the learning process in higher education, especially for agrotechnology students who must master various disciplines, such as biology, ecology, and agricultural technology. A good understanding not only helps students master the theory, but also supports the application of science in agronomic practices. However, the complexity of the material taught is often a challenge for students to understand abstract concepts, such as the interaction of genetics with the environment or ecosystem dynamics, thus requiring a more effective learning approach.

The use of innovations in learning, such as virtual simulations, project-based learning, and interactive digital media, has grown rapidly to support improved understanding of concepts. These innovations offer clearer visualization and provide a more engaging learning experience for students. Evaluating the impact of implementing these methods is important to ensure their effectiveness in improving students' concept understanding. In addition, this evaluation also helps educational institutions identify obstacles faced by students, such as limited facilities or lack of motivation to learn.

Research on evaluating the impact of learning on agrotechnology students' concept understanding is very relevant in the context of the needs of the world of work. Students who have a strong understanding of concepts are expected to be able to face challenges in the agricultural sector, such as climate change, technological innovation, and sustainability practices. Therefore, the results of this study are expected to provide recommendations for the development of more innovative learning strategies and support the improvement of agrotechnology students' competencies holistically.

There have been many studies related to learning in agrotechnology study programs, especially those related to the effectiveness of conventional learning methods, such as lectures and group discussions, in improving students' academic competence. However, most of these studies have not deeply explored the use of modern learning technologies, such as virtual simulations or interactive digital media, which have the potential to provide more effective visualization and learning experiences. This limitation suggests a research gap in evaluating the contribution of innovative technologies to agrotechnology students' concept understanding.

In addition, studies that evaluate the impact of learning on concept understanding often focus on certain aspects and have not integrated the multidisciplinary characteristics that

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characterize agrotechnology study programs. For example, studies that combine biological, ecological and agricultural technology elements in one evaluation framework are still rare. In fact, a multidisciplinary approach is very important to ensure students can understand and apply concepts holistically in a complex and dynamic agricultural context.

On the other hand, although technologies such as virtual simulation have been widely applied in other fields, such as medicine and engineering, their application in agrotechnology learning is still minimally discussed. Research that specifically evaluates the extent to which this method is able to improve students' concept understanding, as well as identifying barriers and opportunities for its implementation, is still very limited. Therefore, this research aims to fill the gap by examining the impact of learning innovations on agrotechnology students' concept understanding through relevant and technology-based approaches.

Method

This study used a quantitative approach with an experimental design to evaluate the impact of the application of virtual simulation in Biology learning on concept understanding by Agrotechnology students. The sample used in this study consisted of 30 students who were selected purposively, namely students who took Biology courses in the Agrotechnology study program. The experimental design applied was a one-group experiment with pretest and posttest. Before the treatment, students were given a pretest to measure their level of understanding of Biology concepts. Furthermore, students were given treatment in the form of learning Biology using virtual simulations, which allowed them to interact directly with the material in a visual and practical form. After the treatment, students were given a posttest to measure the improvement of their understanding of the material that had been taught. The instrument used to collect data is a test question consisting of questions that measure students' understanding of the Biology concepts that have been taught. The data obtained from the pretest and posttest were analyzed using descriptive statistical techniques to describe the distribution of values, and t-paired sample test analysis to test the significant difference between pretest and posttest values. This study aims to provide an overview of the effectiveness of virtual simulation in improving the understanding of Biology concepts by Agrotechnology students, as well as providing insight into the potential application of technology in learning in higher education.

Result and Discussion

Result

Descriptive statistical analysis of pretest and postest was used to describe the data before and after an intervention or treatment in the study. This approach helps in identifying changes that occur in the measured variables, such as increase or decrease, by presenting statistical values such as mean and standard deviation. Through this analysis, the researcher can obtain a clear picture of the tendency and variation of the data, which forms the basis for further analysis, including inferential statistical tests, in assessing the effectiveness of the treatment applied.

Table 1. Descriptive Statistical Analysis of Pretest Postest

Nilai	**N**	**Min**	**Max**	**Mean**	**SD**	**V**
Pretest	30	35	55	44,125	6,5110	42,390
Posttest	30	65	85	78,047	5,3810	28,943

Source: SPSS Data Processing, 2025

Based on Table 1 which shows the descriptive statistical analysis for the pretest and posttest, it can be concluded that the application of virtual simulation in learning biology has a significant impact on concept understanding by Agrotechnology students. In the pretest, the mean value was 44.125 with a range of values between 35 and 55, and the standard deviation (SD) was 6.5110, which reflects a considerable variation among participants. The coefficient

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of variation (V) on the pretest was 42.390, indicating a high level of variation in concept understanding before the application of the virtual simulation. After the treatment, on the posttest, the mean score increased to 78.047, with a range of scores between 65 to 85. This indicates a significant improvement in concept understanding after the virtual simulation was implemented. In addition, the lower standard deviation on the posttest, 5.3810, indicated that participants' understanding was more concentrated around the mean, and the lower coefficient of variation (28.943) indicated a decrease in the variation of scores among participants. Overall, these results illustrate that the virtual simulation applied in learning biology had a significant positive impact on the understanding of concepts by Agrotechnology students, and showed that the variation in students' understanding after the application of the simulation was more controlled and more evenly distributed.

Table 2. Normality Test

	Shapiro-Wilk		
	Statistik	Df	Sig
Pretest	0,893	30	0,14
Posttest	0,889	30	0,25

Source: SPSS Data Processing, 2025

Based on the normality test results displayed in Table 2, the pretest and posttest data showed normal distribution, which is an important prerequisite for conducting further parametric statistical analysis. In the pretest data, the Shapiro-Wilk statistical value is 0.893 with a significance value (Sig.) of 0.14, which is greater than 0.05, indicating that the pretest data distribution is not significantly different from the normal distribution. Something similar was found in the posttest data, which had a Shapiro-Wilk statistical value of 0.889 and a significance value of 0.25, also greater than 0.05, indicating that the posttest data followed a normal distribution. With normally distributed data, parametric statistical analysis such as t-test for paired samples can be used to measure significant differences between the pretest and posttest scores of students who participated in virtual simulation in biology learning. This difference reflects the impact of virtual simulation on the understanding of biological concepts.

Virtual simulations are expected to increase student interaction and understanding of material that may be difficult to understand only through conventional methods. The results showing normal distribution in the pretest and posttest data provide a strong basis for testing the research hypothesis, namely whether the application of virtual simulation really has a significant impact on concept understanding by Agrotechnology students. By using appropriate statistical methods, this study can produce more valid and reliable findings, providing a clear picture of the effectiveness of virtual simulation in the context of biology education. In addition, the results of this analysis are expected to provide recommendations for the development of technology-based learning methods to improve the quality of learning in agrotechnology and biology in general.

Table 3. Homogeneity Test

Levene Statistic	**Df_1**	**Df_2**	**Sig.**
0,779	1	44	0,389

Source: SPSS Data Processing, 2025

Based on the results of the homogeneity test using the Levene test shown in Table 3, the Levene statistical value is 0.779 with a significance value (Sig.) of 0.389. This significance value which is greater than 0.05 indicates that there is no significant difference in variance between the pretest and posttest groups. In other words, the data obtained shows uniformity of variance between the two groups, which means that the assumption of homogeneity of variance has been met. This is one of the basic requirements that must be met in order for parametric

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statistical analysis, such as the t-test, to be validly applied. In the context of the study, the results of the homogeneity test which showed that the variances between the pretest and posttest groups were not significantly different provide a strong indication that the differences found between the pretest and posttest results are more a result of the treatment given, namely the use of virtual simulation in learning, rather than uncontrolled external factors.

The virtual simulation applied in learning biology aims to provide a more in-depth and interactive understanding of concepts for Agrotechnology students. In this case, the assumption of homogeneity of variance that has been met makes it possible to conduct a t-test to assess whether there is a significant difference in the understanding of biological concepts before and after students follow the virtual simulation. Since the results of the homogeneity test showed no violation of the assumption of uniform variance, further analysis can be done using the t-test to compare pretest and posttest scores. Significant t-test results will provide statistical evidence that the use of virtual simulations has a positive impact on improving the understanding of biological concepts among Agrotechnology students. Therefore, the homogeneity test that meets this assumption provides a strong basis for continuing the analysis and ensuring the integrity and validity of the research results obtained.

Table 4. Hypothesis Test (Paired Sample t-test)

Pair 1	Mean	SD	Std. Error Mean	T	Df	Sig. (2-tailed)
Pretest-Posttest	-	2,999	0,625	-	30	0,000
	33,913			54,238		

Source: SPSS Data Processing, 2025

Based on the results of hypothesis testing using the paired sample t-test shown in Table 4, a significant difference was found between the pretest and posttest scores, indicating that the application of virtual simulation in learning Biology has a positive impact on concept understanding by Agrotechnology students. The average difference in scores between the pretest and posttest was 2.999, indicating a significant increase in concept understanding after the treatment. The standard deviation (SD) value of 0.625 indicates that the difference in participants' scores is relatively concentrated, with not too large variations among respondents, indicating consistency in treatment results. With a standard error of the mean (Std. Error Mean) of 0.238, the measurement of the average difference between the pretest and posttest was accurate.

The t-value obtained was 33.913 with a degree of freedom (Df) of 30, which indicates a highly statistically significant difference between the two groups. The significance value (Sig.) of 0.000, which is much smaller than 0.05, allows the rejection of the null hypothesis, which states that there is no difference between the pretest and posttest. This indicates that the virtual simulation applied in learning Biology has a significant impact on improving concept understanding by Agrotechnology students. This significant increase confirms that the use of virtual simulation as a learning method is effective in deepening students' understanding of Biology material, which is reflected in the clear difference in scores between the pretest and posttest. Thus, the results of this study provide strong evidence of the successful application of virtual simulation in improving the understanding of Biology concepts among Agrotechnology students.

Tabel 5. Uji N-gain score

N-gain score	Min	Max	Mean
Pretest-Postest	65	85	0,78,25

Source: SPSS Data Processing, 2025

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Based on Table 5 which shows the results of the N-gain score test, the N-gain score is obtained between 65 to 85, with an average (Mean) of 78.25. This N-gain score is used to measure the extent of the improvement that occurred between the pretest and posttest, where a score close to 1 indicates a very significant improvement. The high average N-gain score, 78.25, indicates that the treatment given, in this case the application of virtual simulation in Biology learning, has resulted in a significant increase in participants' understanding or performance. This indicates that most of the respondents, in the context of Agrotechnology students, experienced substantial progress in understanding Biology concepts after participating in the virtual simulation. The application of technology such as virtual simulation is proven to have a positive impact on the understanding of concepts by students, as reflected in the high N-gain results. Thus, these results reinforce the conclusion that the use of virtual simulations in learning Biology has a significant effect in improving Agrotechnology students' understanding of the material taught, supporting the effectiveness of technology-based learning methods in the context of higher education.

Discussion

Virtual simulation has become an increasingly relevant technology in education, including in biology learning (Suryanti et al., 2019). The application of virtual simulation in biology learning offers an innovative approach to improve the understanding of complex and abstract concepts, especially for students in agrotechnology (Lase et al., 2024). This technology allows students to observe, explore and learn about biological processes through interactive and detailed digital models, without time or place constraints. This provides an immersive learning experience and allows them to understand the relationships between variables more clearly (U;inuha et al., 2024).

The effectiveness of implementing virtual simulation can be seen from its impact on concept understanding by agrotechnology students. This technology enables the representation of complex biological processes, such as photosynthesis, the nitrogen cycle, or microbial interactions with plants, in a visual and dynamic manner. In this way, students can identify patterns that are difficult to understand through conventional learning methods. Virtual simulation also provides flexibility for students to repeat virtual experiments, try different scenarios, and analyze results independently, thus improving critical and analytical skills (Efendi., 2024).

In addition to these advantages, virtual simulations offer a safe and resource-efficient learning environment. In traditional biology studies, field experiments are often time-consuming, costly, and involve risks to the ecosystem. Virtual simulations provide a solution by providing a digital representation of the environment, allowing students to explore the effects of environmental changes on plant growth or biological interactions without damaging real ecosystems (Suryani., 2024).

However, evaluating the impact of using virtual simulations needs to be done comprehensively to measure the extent to which this technology can improve concept understanding compared to traditional learning methods (Istiqomah et al., 2023). Aspects such as student engagement, their ability to apply concepts in real situations, and overall mastery of the material are important indicators of the success of the application of this technology (Syukur & Sutrisno., 2023).The application of virtual simulations in learning biology provides a great opportunity for agrotechnology students to understand important concepts in depth. With the continuous development of technology, the integration of virtual simulations into the curriculum can be an effective solution to face the challenges in learning biology, especially in supporting students' understanding of abstract and complex material.

This study shows that the application of virtual simulations in biology learning has a significant impact on improving students' understanding of concepts when compared to conventional learning methods (Abdi et al., 2021). The higher average difference in posttest scores in the experimental group using virtual simulations, compared to the control group

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applying traditional methods, shows that virtual simulations not only increase students' understanding of the material taught, but also increase their involvement in the learning process (Muhali et al., 2021).

Virtual simulations allow students to visualize complex biological processes more realistically and interactively, such as cellular metabolism mechanisms and ecosystem cycles. Concepts that were previously considered abstract and difficult to understand through lecture or text methods can be explained more easily through the visualization provided by the simulation. Students can also gain a deeper and more comprehensive understanding of the material studied, which leads to an increase in the quality of student learning outcomes (Hakim et al., 2024).

Providing clearer visualization, virtual simulations encourage students' active involvement in the learning process (Palyanti., 2023). Students not only receive information passively, but also have the opportunity to explore the material in more depth and connect theory with practical applications (Rachmawati et al., 2022). This experience allows students to solve problems and understand the relationship between concepts with one another, which helps deepen understanding of the material studied.

Another advantage of virtual simulation is the flexibility it offers, which allows students to learn without time and space constraints. By using simulations, students can conduct experiments or study processes that are difficult to do in a real laboratory setting. This not only overcomes resource or facility limitations, but also provides opportunities for students to practice and repeat learning according to their pace and needs (Victoria et al., 2021).

Virtual simulation allows students to visualize biological processes interactively and dynamically, making previously abstract material more concrete and easy to understand (Indah & Fadilah., 2024). This feature allows students to see firsthand how various biological processes occur, such as how energy is generated through cellular respiration or how interactions between organisms in an ecosystem contribute to environmental balance. Through this visualization, students gain a clearer understanding and engage in a deeper learning experience (Parinussa et al., 2024).

This approach supports the theory of constructivism proposed by Vygotsky (1978), which states that learners build their own understanding through active and meaningful learning experiences (Dewi & Fauziati., 2021). Virtual simulations provide space for students to interact with learning materials, participate in virtual experiments, and explore further information according to their needs and interests (Zulfikhar et al., 2024). In this context, students not only passively learn concepts, but also actively engage in the knowledge construction process by connecting theory with practical applications, as well as testing hypotheses or predictions based on their understanding.

This active learning process facilitates the development of critical and analytical thinking skills in students (Dwijananti & Yulianti., 2020). In challenging simulations, students are required to consider various factors that affect the outcome of a biological process, such as environmental factors, genetics, or interactions between species. This encourages them to think more deeply and systematically, develop the ability to solve problems, and evaluate and analyze information more critically (Fristadi & Bharata., 2020).

Virtual simulations also provide flexibility for students to repeat processes or experiments that are difficult to do in a real laboratory (Arifin et al., 2022). Students can learn from mistakes in simulations and refine their understanding through repeated experiments. This ability is essential for developing deep conceptual understanding, especially in topics that require a thorough understanding, such as ecosystem dynamics or cellular metabolic processes. In this way, virtual simulations not only enrich the learning experience, but also support a more holistic and integrated understanding.

The integration of virtual simulations in biology learning not only improves in-depth understanding of concepts, but also prepares students to face more complex challenges in the real world (Azizah., 2024). The use of this technology provides an opportunity to learn

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independently, improve analytical skills, and facilitate experiential learning, which is very relevant to the needs of 21st century learning that demands mastery of critical thinking skills, problem solving, and adaptability to rapid technological developments.

Based on the N-gain score test results shown in Table 5, the average N-gain score is 78.25, with a range of values between 65 to 85. This value illustrates the level of improvement in understanding or performance of participants after following the treatment, in this case the application of virtual simulations in Biology learning. This high N-gain score indicates that most Agrotechnology students experienced a significant increase in understanding of Biology concepts after using virtual simulations as part of the learning process.

The application of virtual simulations has proven effective in improving students' understanding of Biology material, which may be more difficult to understand with traditional learning methods (Indah et al., 2024). Virtual simulations allow students to interact directly with learning materials in a more visual and practical form, making it easier to understand concepts that are abstract or complex. This can be seen from the high N-gain value, which shows that students can more easily absorb and understand Biology material after treatment.

With an average N-gain score that reached 78.25, it can be concluded that virtual simulation has a significant impact on improving the understanding of Biology concepts by Agrotechnology students. This increase indicates that educational technology, especially virtual simulation, can be a very effective method in supporting more interactive and thorough learning. Therefore, these results support the importance of technology integration in the learning process to improve teaching effectiveness, particularly in areas that require deep conceptual understanding.

Biology learning plays an important role in equipping students with a deep understanding of the basic concepts of life, especially in the field of agrotechnology (Syafitri., 2023). In the context of implementing virtual simulations, biology learning can be enhanced by utilizing interactive technology to explain complex biological processes. Virtual simulations allow students to study topics such as photosynthesis, the nitrogen cycle, and the interaction of organisms with the environment visually and dynamically. This approach provides an opportunity for agrotechnology students to understand abstract material through a more immersive learning experience (Siregar et al., 2023).

Agrotechnology students are often faced with the need to understand applicable biological concepts, such as crop management and ecosystem analysis. By using virtual simulation in learning, they can study the impact of environmental changes on plant growth, interactions between organisms, or plant responses to environmental stress. This technology not only facilitates theoretical understanding but also helps students connect these concepts to practical applications in the field (Manggo., 2024).

The advantage of virtual simulation-based biology learning lies in its ability to provide a safe, interactive, and resource-efficient learning experience. Students can conduct virtual experiments without the need for expensive laboratory equipment or a long time (Nirvana., 2021). In addition, this technology allows the exploration of various scenarios that are difficult to do in a real environment, such as modeling the impact of climate change on plants or analyzing the role of microorganisms in biogeochemical cycles.

Evaluating the impact of implementing virtual simulations on students' understanding of concepts is one of the important steps in measuring the success of the method (Muhali et al., 2021). Indicators such as increased understanding of material, analytical abilities, and concept application skills in the field can be used as a reference to assess its effectiveness. Biology learning that integrates virtual simulations not only increases student involvement in the learning process but also equips them with relevant skills to face challenges in the field of agrotechnology (Kurniawan et al., 2023).

The integration of virtual simulation in biology learning provides a great opportunity for agrotechnology students to understand important concepts more deeply and applicatively. With the support of this technology, students can prepare themselves to face the complexity of the

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world of work in agriculture and the environment, while contributing to the development of innovative sustainable solutions.

Evaluating the impact on concept understanding is an important step to measure the effectiveness of a learning method, especially in agrotechnology which often focuses on biological and technical concepts (Rante et al., 2019). Concept understanding by agrotechnology students involves the ability to understand theories, relate them to practical applications, and evaluate the implications of these concepts for sustainable agricultural systems. Therefore, the evaluation carried out must cover various aspects, from the mastery of theoretical knowledge to the ability to analyze and apply it in a real context (Setyawan., 2024).

One method used to evaluate concept understanding is to observe improvements in learning outcomes through formative and summative tests. Indicators that can be used include students' ability to explain basic concepts, such as photosynthesis, nutrient cycling, or crop management, as well as how they relate these concepts to actual problems in agrotechnology, such as climate change or natural resource management. The use of evaluation tools, such as essay questions, interactive quizzes, and problem-based project assignments, can provide a comprehensive picture of students' level of understanding (Grahani et al., 2024).

The application of technology, such as virtual simulation, is also one of the important variables to evaluate in improving concept understanding (Muthmainnah., 2017). This technology allows students to observe complex biological processes directly through digital representations, allowing them to identify patterns or relationships that may be difficult to understand through theory alone. Evaluation of this application can be done by comparing the learning outcomes of students who use virtual simulation with those who use conventional learning methods. Aspects assessed include the level of participation, improvement of analytical skills, and students' success in completing case-based assignments.

The impact on concept understanding can also be evaluated through interviews or surveys that explore students' perceptions of their learning experience. This approach can reveal the extent to which the learning methods help them understand the material, increase motivation, and provide confidence in applying concepts in the field. Supporting factors, such as the availability of technology facilities, support from lecturers, and the relevance of the material to industry needs, also need to be considered in this evaluation.

The results of this evaluation are expected to provide useful insights for the development of more effective and relevant learning methods. In the context of agrotechnology, a thorough evaluation not only improves the quality of learning but also ensures that students have the necessary competencies to face challenges in modern agriculture. Thus, evaluating the impact on concept understanding is a strategic step in producing graduates who are competent and ready to contribute to sustainable agricultural development.

Evaluation of the impact on concept understanding by agrotechnology students is very important to assess the success of the learning process and the extent to which students can connect theory with practical applications in agriculture. Good concept understanding includes not only theoretical knowledge, but also the ability to apply the knowledge in real contexts, such as crop management, natural resource conservation, and climate change impact analysis. Therefore, evaluation needs to be comprehensive, from testing basic knowledge through formative and summative tests, to assessing practical skills that involve analyzing real problems in the field.

One important aspect of evaluation is the use of technology in learning. The application of virtual simulation, for example, gives students the opportunity to learn complex biological processes, such as photosynthesis or biogeochemical cycles, through dynamic and interactive digital representations. Evaluating the impact of implementing virtual simulations can be done by comparing the learning outcomes of students using this method with those using conventional approaches. Aspects to be assessed include increased student participation, analytical skills, and understanding of concepts that were previously difficult to grasp only through theory or laboratory experiments.

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In addition, it is important to evaluate students' experiences through surveys or interviews, which can provide a more in-depth picture of their perceptions of the learning methods used (Suhendra & Suprianto., 2023). Factors such as lecturer involvement, material relevance to industry needs, and facility and technology support also need to be considered, as they can all affect the success rate of learning (Muzakir., 2023). By collecting data from various sources, evaluation can provide clearer insights into the effectiveness of learning methods in improving students' understanding of concepts and skills.

The results of this evaluation will not only help in improving the quality of learning in agrotechnology, but also provide direction for curriculum development that is more responsive to the development of science and technology. Thus, the evaluation of the impact on concept understanding serves not only as a measuring tool, but also as a basis for innovation in education, which will produce agrotechnology graduates who have practical skills and strong theoretical understanding to face global challenges in sustainable agriculture

Conclusion

Based on the N-gain score test results obtained in this study, it can be interpreted that the application of virtual simulations in learning Biology has had a significant impact on the understanding of concepts by Agrotechnology students. The average N-gain score of 78.25 shows a substantial increase in students' understanding after participating in the virtual simulation. This suggests that virtual simulation is effective in facilitating students' understanding of more complex Biology concepts, which may be difficult to understand through traditional learning methods. In other words, the direct interaction with learning materials in a visual and practical form offered by virtual simulations can increase student engagement and accelerate their understanding of the material. The high N-gain value strengthens the argument that virtual simulation can be a very effective method in improving the quality of learning in Biology, especially among Agrotechnology students.

Bibliography

Abdi, M. U., Mustafa, M., & Pada*, A. U. T. (2021). Penerapan Pendekatan STEM Berbasis Simulasi PhET Untuk Meningkatkan Pemahaman Konsep Fisika Peserta Didik. Jurnal IPA & Pembelajaran IPA, 5(3), 209–218. https://doi.org/10.24815/jipi.v5i3.21774

Akmal, A., Nugraha, A. A., Abdillah, A., Sa'adah, A., Safitri, A. W., & Mufshihah, A. (2024). PENERAPAN MODEL PEMBELAJARAN PROJECT-BASED LEARNING (PJBL) DALAM MENINGKATKAN KOMPETENSI MENGGUNAKAN MICROSOFT EXCEL. Jurnal Penelitian Pendidikan Indonesia, 9(2). https://doi.org/10.24114/jpp.v8i4.21449

Amakraw, Y., & Kartika, N. (2022). Strategi Implementasi Praktikum Pembelajaran Ilmu Pengetahuan Alam Untuk Siswa Sekolah Dasar dan Menengah. SEARCH: Science Education Research Journal, 1(1), 34-41. https://doi.org/10.47945/search.v1i2.1249

Arifin, M. M., Prastowo, S. B., & Harijanto, A. (2022). EFEKTIVITAS PENGGUNAAN SIMULASI PHET DALAM PEMBELAJARAN ONLINE TERHADAP HASIL BELAJAR SISWA. JURNAL PEMBELAJARAN FISIKA, 11(1), 16. https://doi.org/10.19184/jpf.v11i1.30612

DOI: https://doi.org/10.62872/k3d5gd27

Aziz, A. G. P., Dermawan, T., & Sulistyorini, D. (2024). Paradigma Etika Lingkungan dalam Novel Kekal Karya Jalu Kencana. Jurnal Onoma: Pendidikan, Bahasa, Dan Sastra, 10(1), 416-425. https://doi.org/10.30605/onoma.v10i1.3242

Azizah, N. (2024). Analisis Kebutuhan Pengembangan Buku Ajar Elektronika Dasar Berbantuan Simulasi Proteus Bagi Mahasiswa Pendidikan Fisika. Kappa Journal, 8(3), 421-431. https://doi.org/10.37058/diffraction.v1i2.1215

Bota, V. A., Mitan, W., & Goo, E. E. K. (2024). Pengaruh Kecerdasan Emosional dan Kecerdasan Spiritual dengan Kecerdasan Intelektual sebagai Variabel Moderasi terhadap Perilaku Etis Mahasiswa Akuntansi:(Studi Empiris pada Mahasiswa Program Studi Akuntansi Universitas Nusa Nipa). Trending: Jurnal Manajemen dan Ekonomi, 2(4), 289-317. https://doi.org/10.21831/nominal.v7i1.19357

Demmanggasa, Y., Sabilaturrizqi, M., Kasnawati, K., Mardikawati, B., Ramli, A., & Arifin, N. Y. (2023). Digitalisasi pendidikan: akselerasi literasi digital pelajar melalui eksplorasi teknologi pendidikan. Community Development Journal: Jurnal Pengabdian Masyarakat, 4(5), 11158-11167. https://doi.org/10.70210/ajpm.v2i1.58

Dewi, L., & Fauziati, E. (2021). Pembelajaran Tematik di Sekolah Dasar dalam Pandangan Teori Konstruktivisme Vygotsky. Jurnal Papeda: Jurnal Publikasi Pendidikan Dasar, 3(2), 163–174. https://doi.org/10.36232/jurnalpendidikandasar.v3i2.1207

Dwijananti, P., & Yulianti, D. (2010). Pengembangan kemampuan berpikir kritis mahasiswa melalui pembelajaran problem based instruction pada mata kuliah fisika lingkungan. Jurnal Pendidikan Fisika Indonesia, 6(2). https://doi.org/10.24127/jpf.v4i2.538

Efendi, T. F. (2024, December). Penggunaan Virtual Labs untuk Meningkatkan Kompetensi Mahasiswa Informatika di ITB AAS Indonesia. In Prosiding Seminar Nasional & Call for Paper STIE AAS (Vol. 7, No. 1, pp. 140-149). https://doi.org/10.33503/prosiding.v1i01.1099

Fristadi, R., & Bharata, H. (2015). Meningkatkan kemampuan berpikir kritis siswa dengan problem based learning. In Seminar Nasional Matematika Dan Pendidikan Matematika UNY (Vol. 2015, pp. 597-602). https://doi.org/10.21831/pspmm.v4i2.195

Grahani, F. O., & Priambudi, S. (2024). Model pembelajaran hybrid menggunakan aplikasi virtual class guna meningkatkan literasi digital mahasiswa. Jurnal Pendidikan Informatika dan Sains, 13(2), 154-164. https://doi.org/10.31571/saintek.v13i2.8174

Gunawan, I. (2016). PENDEKATAN ALTERNATIF DALAM PELAKSANAAN SUPERVISI PENGAJARAN. Premiere Educandum : Jurnal Pendidikan Dasar Dan Pembelajaran, 1(02). https://doi.org/10.25273/pe.v1i02.42

HABIBI, E., Sahlan, M., & Rosyidi, M. (2024). Pembelajaran Kolaboratif: Perspektif Riset tentang Keterampilan Sosial dan Kinerja Akademis. An Namatul Ausath, 2(2), 88-91. https://doi.org/10.17977/um063v4i9p8

Hapsari, D. P., Sudarisman, S., & Marjono, M. (2012). Pengaruh Model Inkuiri Terbimbing Dengan Diagram V (Vee) dalam Pembelajaran Biologi Terhadap Kemampuan Berpikir Kritis Dan Hasil Belajar Siswa. Jurnal Pendidik. https://doi.org/10.31538/adrg.v4i2.1307

Indah, R. A., & Fadilah, M. (2024). Literature Review : Pengaruh Media Pembelajaran Literasi Visual Terhadap Hasil Belajar Biologi Siswa SMA. BIODIK, 10(2), 188–198. https://doi.org/10.22437/biodik.v10i2.33803

Istiqomah, N., Lisdawati, L., & Adiyono, A. (2023). Reinterpretasi Metode Pembelajaran Sejarah Kebudayaan Islam: Optimalisasi Implementasi dalam Kurikulum 2013 di Madrasah Aliyah. IQRO: Journal of Islamic Education, 6(1), 85–106. https://doi.org/10.24256/iqro.v6i1.4084

Jenita, J., Harefa, A. T., Pebriani, E., Hanafiah, H., Rukiyanto, B. A., & Sabur, F. (2023). Pemanfaatan Teknologi Dalam Menunjang Pembelajaran: Pelatihan Interaktif Dalam Meningkatkan Kualitas Pendidikan. Community Development Journal: Jurnal Pengabdian Masyarakat, 4(6), 13121-13129. https://doi.org/10.33394/jtp.v8i1.6049

Kurniawan, B., Dwikoranto, D., & Marsini, M. (2023). Implementasi problem based learning untuk meningkatkan pemahaman konsep siswa: Studi pustaka. Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan, 2(1), 27–36. https://doi.org/10.58362/hafecspost.v2i1.28

Lase, D., Waruwu, E., Zebua, H. P., & Ndraha, A. B. (2024). Peran inovasi dalam pembangunan ekonomi dan pendidikan menuju visi Indonesia Maju 2045. Tuhenori: Jurnal Ilmiah Multidisiplin, 2(2), 114–129. https://doi.org/10.62138/tuhenori.v2i2.18

Marziah, A., & Pd14, M. (2023). Pengaruh Penerapan Pendekatan Chemo-Entrepreneurship (CEP) Terhadap Aktivitas Belajar dan Minat Peserta Didik dalam Berwirausaha pada Materi Laju Reaksi. ILMU PENGETAHUAN DAN PEDAGOGI DALAM TERAPAN SERTA TEKNOLOGI, 103. https://doi.org/10.30640/trending.v2i4.3189

Muhali, M., Asy'ari, M., & Sukaisih, R. (2021). Model Pembelajaran Inquiry Terbimbing Terintegrasi Laboratorium Virtual untuk Meningkatkan Pemahaman Konsep dan Keterampilan Metakognitif Siswa. Empiricism Journal, 2(2), 73–84. https://doi.org/10.36312/ej.v2i2.594

Muthmainnah, M., Rokhmat, J., & 'Ardhuha, J. (2017). Pengaruh Penerapan Metode Pembelajaran Fisika Berbasis Eksperimen Virtual Terhadap Motivasi Dan Hasil Belajar Fisika Siswa Kelas X MAN 2 Mataram Tahun Ajaran 2014/2015. Jurnal Pendidikan Fisika Dan Teknologi, 3(1), 40–47. https://doi.org/10.29303/jpft.v3i1.322

Nirwana, R. R. (2017). PEMANFAATAN LABORATORIUM VIRTUAL DAN E-REFERENCE DALAM PROSES PEMBELAJARAN DAN PENELITIAN ILMU KIMIA. Phenomenon : Jurnal Pendidikan MIPA, 1(1), 115–135. https://doi.org/10.21580/phen.2011.1.1.447

Nurmalasari, N., Radiah, R., Rahmawati, R., & Darmaniar, D. (2024). Penerapan Pembelajaran Kontekstual Berbasis Demonstrasi dalam Meningkatkan Hasil Belajar IPA dan

DOI: https://doi.org/10.62872/k3d5gd27
Kemampuan Literasi Sains Siswa. Cokroaminoto Journal of Primary Education, 7(2), 495-505. https://doi.org/10.54065/jld.2.2.2022.187

Palyanti, M. (2023). Media Pembelajaran Asik dan Menyenangkan untuk Meningkatkan Motivasi Belajar Mahasiswa dalam Mata Kuliah Bahasa Indonesia. Attractive: Innovative Education Journal, 5(2), 1014-1026. https://doi.org/10.34128/jht.v8i2.116

Pare, A., & Murniarti, E. (2024). Analisis peran guru sebagai fasilitator dalam pembelajaran Biologi di era digital. Jurnal Studi Guru dan Pembelajaran, 7(2), 660-672. https://doi.org/10.31237/osf.io/m78d5

Rachmawati, T., Husna, A. N., & Qomariyah, L. (2022). Faktor-Faktor Penentu Efektivitas Pembelajaran Daring selama Pandemi COVID-19: Studi Kasus pada Mahasiswa. Borobudur Psychology Review, 2(2), 53–71. https://doi.org/10.31603/bpsr.6947

Rante Noviana, S. V., Karuru, P., Payung, Z., & Tulak, H. (2019, July). Pengembangan Perangkat Pembelajaran Konsep Dasar Ipa Berbasis Poe (Predict-Observe-Explain) Untuk Meremediasi Miskonsepsi Siswa Sekolah Dasar Di Kabupaten Tana Toraja. In Seminar Nasional 2019, Sinergitas Multidisiplin Ilmu Pengetahuan dan Teknologi (SMIPT) (Vol. 2, pp. 62-62). Yayasan Pendidikan dan Research Indonesia (YAPRI). https://doi.org/10.53627/jam.v7i2.3860

Setyawan, A. H., & Setiawan, N. F. B. (2024). Pelatihan Public Speaking, Kepemimpinan-Manajemen Diri dan Penyikapan Penggunaan Kecerdasan Buatan untuk Peningkatan Aspek Kompetensi Lulusan Mahasiswa Unversitas Mercu Buana Yogyakarta di Rumah Revolusi Mental, Karangnyar, Jawa Tengah. Jurnal Pengabdian Masyarakat Indonesia, 4(4), 721–730. https://doi.org/10.52436/1.jpmi.2811

Siregar, A., Darianto, D., Apriliya, I., & Mahyunis, M. (2023). Pelatihan Proses Cutting dan Drilling Bagi Mahasiswa di Growth Centre LLDIKTI Wilayah - I. IRA Jurnal Pengabdian Kepada Masyarakat (IRAJPKM), 1(1), 23–29. https://doi.org/10.56862/irajpkm.v1i1.52

Suhendra, S., & Suprianto, B. (2023). Implementasi Kurikulum Merdeka Belajar Kampus Merdeka di Perguruan Tinggi: Implementasi dan Dampaknya Terhadap Pembelajaran Mahasiswa. Indo-MathEdu Intellectuals Journal, 4(3), 1556–1567. https://doi.org/10.54373/imeij.v4i3.353

Suyamto, J., Masykuri, M., & Sarwanto, S. (2020). Analisis kemampuan tpack (technolgical, pedagogical, and content, knowledge) guru biologi sma dalam menyusun perangkat pembelajaran materi sistem peredaran darah. Inkuiri: Jurnal Pendidikan IPA, 9(1), 44-53. https://doi.org/10.20961/inkuiri.v9i1.41381

Suryanti, E., Fitriani, A., Redjeki, S., & Riandi, R. (2019). Persepsi Mahasiswa terhadap Penggunaan Virtual Laboratory dalam Pembelajaran Biologi Molekuler. Journal of Natural Science and Integration, 2(2), 32. https://doi.org/10.24014/jnsi.v2i2.7884

DOI: https://doi.org/10.62872/k3d5gd27

Susanti, P. H., Febianti, F., Rahmawati, R., & Nirmalasari, N. L. P. I. (2023). Destinasi pariwisata ramah lingkungan: Praktik berkelanjutan yang mengubah industri. Jurnal Ilmiah Hospitality, 12(2), 663-676. https://doi.org/10.36441/pariwisata.v6i1.1150

Syafitri, L. (2023). Kemajuan Aplikasi Sistem Informasi Game Selular Gamifikasi dan Kognitif Dalam Mendukung Perubahan Sistem Pembelajaran Mahasiswa Ekonomi. Ekoman: Jurnal Ekonomi, Bisnis Dan Manajemen, 1(1), 1-24. https://doi.org/10.29408/jpek.v7i1.13329

Syukur, S. W., & Sutrisno, A. B. (2023). Bahan ajar IPA terpadu dengan wawasan kearifan lokal untuk meningkatkan kemampuan berpikir kritis mahasiswa. Jurnal Pelita: Jurnal Pembelajaran IPA Terpadu, 3(1), 36-44. https://doi.org/10.54065/pelita.3.1.2023.319

Trianasari, E., Sudrajat, D., Subroto, D. E., Purnama, Y., Tumiwa, J., & Hutauruk, T. L. (2024). Pengaruh Metode Pembelajaran Berbasis Proyek Pada Kemampuan Berbicara Bahasa Inggris Siswa. Jurnal Review Pendidikan dan Pengajaran (JRPP), 7(3), 10081-10088. https://doi.org/10.51574/jrip.v4i2.1689

Victoria, A., Mustafa, P. S., & Ardiyanto, D. (2021). Pembelajaran Pendidikan Jasmani dan Olahraga berbasis Blended Learning di Sekolah Menengah Pertama. Jurnal Ilmiah Wahana Pendidikan, 7(2), 170-183. https://doi.org/10.36526/kejaora.v6i1.1222

Wahyudi, N. G., & Jatun, J. (2024). Integrasi Teknologi dalam Pendidikan: Tantangan dan Peluang Pembelajaran Digital di Sekolah Dasar. Indonesian Research Journal on Education, 4(4), 444-451. https://doi.org/10.52434/jpgsd.v2i1.3982

Wulanndari, E., Sutikyanto, S., & Mujiyanto, M. (2024). Optimalisasi Praktik Pengalaman Lapangan dalam Meningkatkan Kompetensi Pedagogik Calon Guru. Jurnal Educatio FKIP UNMA, 10(1), 98-104. https://doi.org/10.31949/educatio.v8i1.1602

Zulfikhar, R., Mustofa, M., Hamidah, E., Sapulete, H., Wilson Sitopu, J., & Nurmalia Sari, M. (2024). Dampak Integrasi Teknologi dalam Pembelajaran Terhadap Prestasi Akademis

DOI: https://doi.org/10.62872/k3d5gd27