Journal of Education Technology
Volume 6, Number 4, 2022 pp. 634-642
P-ISSN: 2549-4856 E-ISSN : 2549-8290
Open Access: https://ejournal.undiksha.ac.id/index.php/JET

The Application of Inquiry Intelligent Tutoring System in Biology Practicum

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ARTICLE INFO

Article history:
Received June 20, 2022
Revised June 22, 2022
Accepted October 02, 2022
Available online November 25, 2022

Kata Kunci:
Inkuiri, Intelligent Tutoring System, Praktikum

Keywords:
Inquiry, Intelligent Tutoring System, Practicum

DOI:
https://doi.org/10.23887/jet.v6i4.48466

ABSTRAK

Pemberlakuan Pembelajaran Jarak Jauh (PJJ) yang diakibatkan oleh pandemi COVID-19 di Indonesia memicu pergeseran pendidikan dari tradisional ke digital di berbagai lini, termasuk dalam hal praktikum. Laboratorium virtual dapat menjadi alternatif di pembelajaran praktikum nyatanya masih memiliki beberapa kelemahan seperti belum tersedianya feedback secara langsung serta belum optimal dalam meningkatkan kemampuan berpikir tingkat tinggi. Penelitian ini bertujuan untuk menganalisa efektivitas Inquiry Intelligent Tutoring System (Inq-ITS) dalam meningkatkan hasil belajar Biologi. Penelitian ini bersifat kuantitatif dan menggunakan teknik eksperimen semu. Penelitian ini akan diterapkan pada mahasiswa Fakultas Teknik Sampoerna University. Metode penelitian kuasi-eksperimental digunakan untuk menjawab pertanyaan penelitian. Teknik pengumpulan data menggunakan beberapa instrumen yaitu pretest, posttest, dan laporan hasil praktikum. Analisa data menggunakan N-gain. Dari hasil perhitungan keefektifan produk diperoleh N-gain sebesar 0,76. Oleh karena itu, Inq-ITS sangat efektif dalam meningkatkan hasil belajar Biologi. Penelitian ini masih terbatas pada aplikasi Inq-ITS, perlu dilakukan penelitian lanjutan mengenai ITS dengan pengukuran menggunakan aplikasi lain. Implikasi dari penelitian ini adalah murid lebih mampu menyelesaikan soal HOTs dan membuat laporan praktikum lebih baik.

ABSTRACT

Implementing Distance Learning (PJJ) caused by the COVID-19 pandemic in Indonesia has triggered a shift in education from traditional to digital on various fronts, including practicum. The virtual laboratory can be an alternative to practical learning. It still has several areas for improvement, such as the unavailability of direct feedback. It is not optimal for improving higher-order thinking skills. This study aims to analyze the effectiveness of the Inquiry Intelligent Tutoring System (Inq-ITS) in improving Biology learning outcomes. This research is quantitative and uses quasi-experimental techniques. This research will be applied to students of the Faculty of Engineering, Sampoerna University. Quasi-experimental research methods were used to answer research questions. Data collection techniques use several instruments: pretest, posttest, and practicum results reports. Data analysis using N-gain. From the results of calculating the product's effectiveness, an N-gain of 0.76 is obtained. Therefore, Inq-ITS is very effective in improving Biology learning outcomes. This research is still limited to the Inq-ITS application. It is necessary to carry out further research on ITS by measuring using other applications. This research implies that students are better able to solve HOTs questions and make better practicum reports.

1. INTRODUCTION

The COVID-19 pandemic and the declaration of a state of emergency in Indonesia prompted the shift from conventional to digital education (A. Cahyadi & Widyastuti, 2022; Pujilestari, 2020). The COVID-19 pandemic is transforming how we instruct, and educational institutions are modifying their learning practices (Abidah et al., 2020; Widyastuti et al., 2021). The Ministry of Education and Culture has established recommendations for the execution of education regulations during the coronavirus 2019 (COVID-19) pandemic, including the distant learning procedure. Therefore, schools and colleges in Indonesia cannot open, and online learning is expected to prevent the spread of the COVID-19 virus (Ani Cahyadi et al., 2021; Herliandry et al., 2020). However, several problems arise such as student satisfaction with online learning services, internet access and limited learning support infrastructure, as well as teacher skills in designing lessons that are less attractive and challenging (Krasny et al., 2018; Surahman & Sulthoni., 2020). Biology practicum is one of the critical components of education (Kapilan et al., 2021; Staub et al., 2016). Students gain a better understanding of biology through hands-on experience and experimentation, and they also improve their critical thinking, creativity, and problem-solving abilities, as well as their ability to work in groups and integrate their newly acquired knowledge by practicum results. In addition, practicum makes students active in learning by seeing, observing, and doing. Biology consists of theory and practical science. However, the Biology learning process will be more straightforward if the learning process is not only obtained through a collection of theories, laws, principles, and facts and related to how knowledge is obtained, namely by experiment (Ani Cahyadi et al., 2021; Nirmala & Darmawati, 2021; Selwyn & Renaud-Assemat, 2020).

Before the pandemic time, practicum was performed face-to-face. However, during the pandemic, the implementation of distance learning prevents students from performing face-to-face practicum. Therefore, there is a need for alternative practicum implementation strategies. A virtual laboratory is one alternative that can be implemented. Virtual laboratories may replicate several experimental models and bridge the gap between what students can perform in the real world and virtual worlds (Kapilan et al., 2021; Kua et al., 2021). The problem with the application's virtual laboratory for remote learning is that students do not receive prompt feedback when they make errors in the virtual laboratory. Moreover, many students struggle with formulating hypotheses, testing their theories, and completing practicums. In the conventional practicum, laboratory assistants will offer direct feedback when students make mistakes throughout the learning process (Almroth, 2015; Nirmala & Darmawati, 2021). However, in a virtual laboratory, lab assistants cannot accompany all students as they practice at home, and they do not receive feedback throughout the learning process when they misread data or lose vital knowledge (Bangert et al., 2022; Engzell et al., 2021). Virtual practicum, which is widely used in schools, has not been optimal in improving thinking skills, especially the ability to think creatively and scientifically, because the practicum model chosen is in the form of structured worksheets. Structured worksheets (cookbook recipe experiments) serve as practical guides and steps that are presented clearly and in a structured manner. This kind of practicum is still widely used because it is easy for teachers, and all children work uniformly according to the instructions in a structured worksheet. However, the structured worksheets do not foster active learning and empowering thinking skills (Huriye, 2015; Ningsyih et al., 2016). Moreover, students are not improving their ability to develop the new designs during the implementation of the practicum.

The author has also conducted preliminary research on the difficulty of conducting remote practicums. The survey results stated that students had difficulty forming hypotheses, testing their hypotheses, doing practicums, and making laboratory reports. The data of the laboratory report back this statement; it was found that 65% of students still have difficulty deciding between independent and dependent variables. In addition, 84% of students have difficulty making conclusions in the practicum. In addition, based on the results of the pretest and posttest, students still have difficulties in cognitive understanding, which includes understanding (C2), applying (C3), and analyzing (C4). Their average score is only 45 and this is due to the suboptimality of the remote practicum. Learning with guided inquiry effectively improves thinking skills in the classroom. In inquiry learning, students are allowed to think independently and help each other with other friends. In the guided inquiry laboratory method, students look for experiments with a given problem. In addition, in the guided inquiry, students are not given the laboratory books. Instead, students search for the experimental process and obtain scientific information through the experiments (Laksana, 2017; Ural, 2016). The inquiry model is a learning model that requires students to process messages to acquire knowledge and skills. In the inquiry model, students are designed to engage in making discoveries. The inquiry model is a student-centered educational model, so students learn more actively and develop intellectual abilities to think critically in solving problems (Castro-Schez et al., 2021; Kua et al., 2021; Lin et al., 2019).

The Intelligent Tutoring System (ITS) is the latest generation of computerized education systems, which tries to imitate the abilities of human tutors. The ITS is an artificial intelligence program that mimics human behavior and teaching skills. ITS is a learning tool and program that can be used independently and web-based to support students' needs and improve distance learning outcomes. In addition, ITS can be used as a pedagogical tool that serves to help students be more active in learning without human tutors because the ITS can improve knowledge and skills by motivating students by allowing them to practice independently (Mirchi et al., 2021; Robb, 2016). The inquiry ITS (Inq-ITS) is one type of web-based ITS application developed by Janice Gobert, a Professor of Learning Science and Educational Psychology at the Postgraduate School of Education at Rutgers University (Akuma & Callaghan, 2019; Luan et al., 2020). The Inq-ITS provides opportunities for students to develop their creative thinking skills when they create hypotheses, design experiments, discuss and analyze evidence, evaluate ideas and reflect on the validity of data in research. The Inq-ITS is designed and developed with a guided inquiry model so that students can learn actively and freely, allowing them to operate and manipulate the concepts of the subject matter. The Inq-ITS focuses on tutoring modules and how they can correct exercises and provide feedback for students to learn. The Inq-ITS applies an active teaching methodology that promotes learning through experimentation (Gobert et al., 2018; Knippelmeyer & Torraco, 2007). In addition, the Inq-ITS application provides scaffolding to students by providing feedback directly when students

make mistakes in the virtual laboratory (Nirmala & Darmawati, 2021; Su, 2020). Students who have no experience in designing experiments and hypothesis testing will be able to acquire skills after receiving feedback from the application. The Scaffolding system in Inq-ITS helps students decide when and how to use the system and assists facilities in solving problems. The Scaffolding system is indispensable, especially in distance learning (Duffy & Azevedo, 2015; Gambo & Shakir, 2021). So, based on the review above, the author applies the Inq-ITS in learning Biology. The objectives of this study are to investigate the effectiveness of Inq-ITS in helping students to solve cognitive question, understanding (C2), applying (C3), and analyzing (C4) related to the topic of the relationship of animal predation and prey. Moreover, this study also will reveal the the skill achived of making research reports with the help of the Inq-ITS.
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2. METHOD

The study is quantitative and employs quasi-experimental techniques. Purposive sampling was utilized for the research. The experimental group employed the Inq-ITS application, whereas the control group utilized a flash-based virtual lab. Data were collected from twenty undergraduate students in the experimental class and twenty undergraduate students in the control class. The application used is Inq-ITS Predation: Introduction with a scaffolding assistance feature. This application is accessible via the website https://www.inqits.com/. Moreover, students engage in practicum activities at home throughout the Biology class practicum (about 90 minutes). The method in practice using Inq-ITS showed in Figure 1.

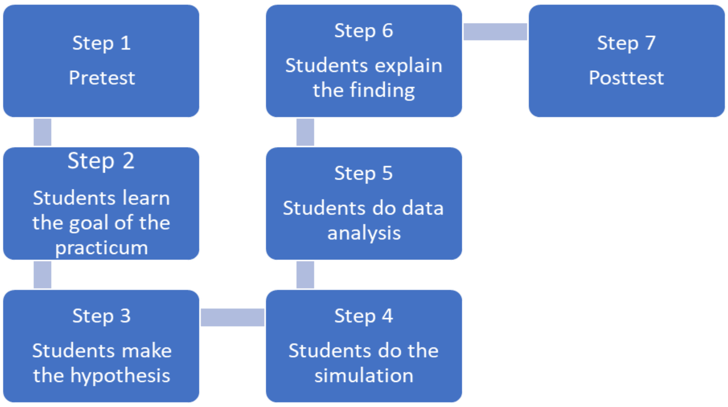

Figure 1. The Stages of Students in Doing Practicum

Each undergraduate works individually on a device on their own time, which means that not all undergraduates complete the full set of events by the end of the practical. Each student is given the purpose of this practicum, but each student will compile their hypothesis, identifying independent and dependent variables. Practicum reports are written individually and uploaded in the Canvas LMS. The data collection technique uses several instruments, namely pretest, posttest, and the results of practicum reports. The validity and reliability of all instruments have been tested in the previous research. The types of pretest and posttest used are multiple-choice tests and essays of 12 question items using the google form application (Gunawan et al., 2018). The indicators measured in this research instrument use categories in the cognitive process dimension, namely understanding (C2), applying (C3), and analyzing (C4). There are 4 questions on understanding (C2), 4 questions on applying (C3), and 3 questions on analyzing. A grid of research instruments showed in Table 1.

Table 1. A grid of Research Instruments

Category	Indicator	Items	Sum
Understanding (C2)	To explain how a starting seal population influences the length of the predation cycle.	1,4,7	3
Applying (C3)	To do a virtual simulation of how shark birthrate influences other populations.	2,5,8	3
Analyzing (C4)	To Investigate how the seal birthrate influences the maximum shark population.	3,6.9	3

The data were analyzed to see if there was a difference between the initial ability (pretest) and the final ability (posttest) between the treatment and control groups. The score test determines the level of efficacy of product development (N-gain). The index gain description showed in Table 2.

Table 2. Index Gain Description

Score	Category	Information
(g) ≥ 0.70	High	Highly effective
0.70>(g) ≥0.30	Medium	Effective
(g) < 0.30	Low	Ineffective

3. RESULT AND DISCUSSION

Result

The research was conducted in the General Education study program of Sampoerna University on February – Mei 2022 using the web-based inquiry intelligent tutoring system. Before doing the practicum virtually, the students conducted a pretest. In the experimental class, the understanding of C2 is 41%, C3 is 29%, and C4 is 18%. Whereas in the control class, the understanding in C2 is 45%, C3 is 33%, and C4 is 18%. Table 2 shows that the two classes have initial values that do not differ much or equally. This is shown by the results of the homogeneity test analysis obtained F count lower than the F table, which is 1.34< 1.85, meaning that both classes are homogeneous. The results of the pretest found that the C4 questions are the most difficult in both the experimental and control classes. Percentage Average Score Based on Level Indicators on the Pretests of the Experimental and Control Classes showed in Table 3.

Table 3. Percentage Average Score Based on Level Indicators on the Pretests of the Experimental and Control Classes

Indicator	*Experiment Class (%)*	*Control Class (%)*
C2 (understanding)	64	66
C3 (applying)	39	43
C4 (analyzing)	28	28
Average	43,6	45,6
Mode	45	45
Median	43	47
Highest Value	65	75
Lowest Value	50	20
Standard Deviation	8.7	9.2

After conducting a pretest, students learn the practicum's goal and then create a hypothesis. In the process of making this hypothesis, students will determine independent variables and dependent variables. There are 2 goals in this experiment: (1) to Investigate how seal birth rates affect shark populations and (2) to Investigate how early seal populations affect predator cycle lengths. After completing a virtual practicum, students completed a posttest. C2 is graded at 96 percent, C3 at 92 percent, and C4 at 86 percent in the experiment class. In contrast to the control group, C2 has 75 percent indicator achievement, C3 has 72 percent, and C4 has 70 percent. Here is the table of explanations. Percentage (%) of Concept Understanding in the Experimental Class and Control Class Post-test showed in Table 4.

Table 4. Percentage (%) of Concept Understanding in the Experimental Class and Control Class Post-test

Indicator	Experiment Class (%)	Control Class (%)
C2	96	74
C3	92	72
C4	86	70
Average	91	72
Mode	90	70
Median	92	70
Highest Value	100	85
Lowest Value	80	65
Standard Deviation	6.5	5.4

Table 4 shows that both classes have increased in aspects of C2, C3, and C4, but questions with a low cognitive level (C2 and C3) got a higher score than questions with a high cognitive level (C4). This is because low cognitive questions are more straightforward than questions with high cognitive levels. In this practicum, students are directly involved in problem-solving. For example, for the first simulation, the practicum's goal is to investigate how the seal birth rate affects the shark population. With this goal, the students made it possible to make variations in making hypotheses such as: (1) the birth type of seals increases, the number of shark populations increases (2) the number of seal births decreases, the number of shark populations decreases. First, students can choose the hypothesis model and simulation model used. Then the student will test the hypothesis. This kind of learning process is called the inquiry learning process. The results of the study to determine the effectiveness of Inq-ITS in improving student understanding can be seen from the results of the pretest analysis of the experimental class. Based on data analysis, the results of the N-gain calculation, namely by comparing the average critical thinking ability of the pretest and posttest, the gain results (g) = 0.76 with high criteria were obtained so that the Inq-ITS was highly effective in improving Biology learning outcomes.

In addition to analyzing the pretest and posttest scores, the author also analyzes the laboratory report. This laboratory report is also used to determine how far the undergraduates understand the concept. In this study, there are 7 aspects of skills to be studied; these aspects are the skill of making hypotheses, the skill of identifying independent variables, the skill of identifying dependent variables, skills in planning and carrying out practicum work procedures, skills in analyzing and interpreting data, skills in making discussions and skills in making conclusions and suggestions. The average score of the experimental class's skills in making hypotheses in the experiment class is exceptionally high. However, it is found that the experimental class students still have difficulty explaining the findings. It can be known that the average score of the treatment class is 93.64, and the average value of the control class is 73. The highest score on the laboratory report for the experiment class is 100, while the lowest score is 70. In the Inq-ITS application, each student uses a different number of scaffoldings, some students use only one scaffolding, and some use scaffolding more than 6 times in one chapter. For example, the average student needs 2x scaffolding in hypothesis, 2x Scaffolding in the work planning and procedures, 1x scaffolding in analyzing and interpreting data, and 3x scaffolding in making practicum discussions showed in Table 5.

Table 5. The Average Number of Scaffolding Students Need in an Experimental Class

Types of Scaffolding	**Average required amount**
Scaffolding in hypothesis drafting	2x
Scaffolding in the preparation of planning and practicum work procedures	2x
Scaffolding in analyzing and interpreting data	1x
Scaffolding in making practicum discussions	3x

The scaffolding is adjusted to each student's skill level, allowing students to ask for explanations and clarification per each student's needs. Although scaffolding personalizes each student's learning, every student needs different amounts of help to hone different sub-skills successfully. The scaffolding Rex model is similar to that of cognitive tutors. The scaffolding can also help students improve their problem solving and inquiry skills, make appropriate generalizations about critical points in science, acquire scientific knowledge, and hold a positive attitude towards science. The average score of undergraduates in the treatment and control class in the skill of making practicum reports showed in Table 6.

Table 6. The Average Score of Undergraduates in the Treatment and Control Class in the Skill of Making Practicum Reports

Students' Skills	**Experiment Class**	**Control Class**
Hypothesis-making skills	97,30	71,21
Skills to identify independent variables	97,43	73,11
Skills to identify dependent variables	99,35	72,26
Skills in planning and performing practicum work procedures	91,71	74,51
Skills in analyzing and interpreting data	91,66	72,21
skills in making discussion	79,28	65,41
Skills in making conclusions and suggestions	89,78	82,31
The average score of the practicum report	93,64	73

The results of this study show that the use of Inq-ITS increases the level of student achievement and has a positive impact on students' attitudes toward Biology. However, the students still lack the skills to explain the findings, which is because they did not state the reasons in detail in the discussion. There are two indicators of discussion in the laboratory report, (1) explaining the relationship between seal birth rates that will affect shark populations and (2) early populations of seals that will affect the length of the predator cycle. In the first indicator, 95% of students were able to correctly hypothesize and explain the relationship between seal birth rates that would affect the shark population. Students can also provide evidence with data that the hypotheses they create match the data they obtained in the practicum. In the second indicator, 80% of students could hypothesize correctly. However, some students are still wrong in hypothesizing on the topic of relationships between early populations of seals that would affect the cycle length of predators. For example, many students made hypotheses that if I change the initial population of sharks so that it increases, then the length of the predation cycle will also increase. This is inconsistent with the reality in nature, which states that if there are many sharks born, the number of seals will get less and less as time goes by. This means that the length of the predation is reduced. In the control class, the average score in the discussion-making skills is 65 because there is no feedback or scaffolding in the control class. Specific feedback will help students significantly improve their knowledge of scientific writing, summary writing, and technical writing skills.

Discussion

The result found that students' scores increased at all cognitive levels compared to the pretest. However, the cognitive aspect of the C4 questions has the lowest average value compared to other cognitive aspects. The C4 questions is a high-level cognitive problem. The active verbs used in this cognitive aspect are equalizing, combine, decipher, compile, select, group, oppose and connect (Mulatsih, 2021; Simorangkir et al., 2020). Moreover, 67.8% of students had difficulty answering C4 questions (Hadi & Faradillah, 2020). In addition, students' low scores in C4 questions are because students are not familiar with using high order thinking skills (HOTS). The learning most often occurs in the low cognitive order thinking skill (LOTS) area (Febrina et al., 2019; Mahendra, 2020; Rochman & Hartoyo, 2018). Students need to be familiarized with HOTS questions because it will positively impact students in the future so that learning is not just remembering and understanding. In addition, the HOTS question will impact the growth of students' curiosity to create new things (Mahendra, 2020; Utami & Aryeni, 2017) . The Inq-ITS is an approach where students follow similar methods and practices to professional scholars to construct information. It is described as the procedure of finding causal relationships by creating and testing the hypotheses (Gobert et al., 2018; Lim & Yeo, 2021; Pedaste et al., 2015). The Inq-ITS has the opportunity to improve the learning achievement, motivation, and attitudes of students by Scaffolding. The use of scaffolding in Inq-ITS shows that Scaffolding significantly influences student learning achievement based on post-test scores (Gobert et al., 2018; Li et al., 2019).

Scaffolding helps students in working on HOTs questions and working on practicum reports. The Inq-ITS application supported by the Scaffolding feature helps students with a cognitive level (Castro-Schez et al., 2021; Pionera et al., 2020). This can be seen from the increase in the achievement of indicators also in the experimental class by 72%. One of the advantages of Inq-ITS is the existence of Scaffolding, Rex TIP (W. Chen, 2018; Gobert et al., 2018). This scaffolding can be used to help students to create free variables and bound variables. In addition, scaffolding can also provide students with explanations during experiments to produce more in-depth learning. One of the problems in practicum is that students have difficulty forming hypotheses that can be tested and difficulty testing their hypotheses. Students also have difficulty conducting experiments (Nasir, 2017; Wyeth & Wonham, 2018). The Inq-ITS will help students who do not have skills related to planning, making hypotheses, and conducting experiments. This proactive strategy is critical because undergraduates may not realize they need help with scaffolding. Once this Scaffolding appears, students can also ask Rex for clarification and additional support. The use of scaffolding is also related to Self-Regulated Learning (SRL). SRL refers to a dynamic process by which students actively learn and adapt various parts of learning (Pionera et al., 2020; Wackerly, 2018). In the SRL, the learner must be cognitively involved in learning; there is an essential conceptual consistency and little practical difference between the cognitive aspects of self-regulation and cognitive involvement in the current literature (Krasny et al., 2018; Selwyn & Renaud-Assemat, 2020). Therefore, using the Scaffolding rex also promotes SLR since it assists students in choosing the next steps for doing the practicum and encourages them to persevere despite difficulties.

In Table 7, the skill of explaining findings is a writing skill that has the highest level of difficulty compared to other skills (Masoud & al Muhtaseb, 2021; Wackerly, 2018). Most first-year students have not been able to meet the writing skills standards (Selwyn & Renaud-Assemat, 2020; Wilkes et al., 2015). In addition, the feedback also increases self-confidence in writing and basic writing skills. The average value in the skill of making conclusions and suggestions is the second-lowest average value. This is because students do not explain the purpose of the practicum with the findings obtained. Students are less able to connect the theory related to practicum and the purpose of practicum with the findings (Q. Chen et al., 2018; Wyeth & Wonham, 2018). They also added that the conclusions contained answers according to the experiment's objectives written in simple sentences. Another reason some students receive low laboratory report grades is that they lack experience in writing laboratory report discussions (Masoud & al Muhtaseb, 2021; Selwyn & Renaud-Assemat, 2020). Students' challenge while composing practicum reports is that they are not accustomed to do it (Ural, 2016; Wackerly, 2018). This study also collected data on several students who received high posttest scores but poor laboratory report scores. The ability to elaborate on a discussion of the practicum report is indicative of the student's writing skills. Writing skills are distinct from cognitive talents. It is possible that the student comprehends the practicum's topics but finds it challenging to put those understandings into words (Anwar et al., 2020; Bakri et al., 2020). Finally, the Inq-ITS program may be utilized by teachers or for the instruction of courses requiring particular experiments in chemistry, physics, and Biology. The Inq-ITS application is not only able to assist teachers in conducting practicums remotely without the need for costly laboratory utilities, but it can also assist students in becoming more resilient, active, and developing higher-order thinking abilities.

4. CONCLUSION

The Inq-ITS is extremely effective in improving Biology learning outcomes. Moreover, the intelligent tutor system is extremely helpful for students to work on practicums from home so that they do not lose critical information in laboratory learning. The Inq-ITS has a significant influence on student learning achievement based on post-test scores and practicum report. On the practicum report, the student achived significant skills in making hypotheses, analyzing and interpreting data, making discussion, conclusions and suggestions. Further research may employ to the other topic in Biology where students struggle the most to increase their comprehension of that topic..

5. REFERENCES

Abidah, A., Hidaayatullaah, H. N., Simamora, R. M., Fehabutar, D., & Mutakinati, L. (2020). The impact of covid-19 to indonesian education and its relation to the philosophy of “merdeka belajar.” *Studies in Philosophy of Science and Education*, *1*(1), 38–49. https://doi.org/10.46627/sipose.v1i1.9.

Akuma, F. V., & Callaghan, R. (2019). Teaching practices linked to the implementation of inquiry-based practical work in certain science classrooms. *Journal of Research in Science Teaching*, *56*(1). https://doi.org/10.1002/tea.21469.

Almroth, B. C. (2015). The Importance of Laboratory Exercises in Biology Teaching; Case Study in An Ecotoxicology Course. *Pedagogical Development and Interactive Learning*, *september*, 1–11. https://pil.gu.se/digitalAssets/1550/1550056_carney-almroth-laboratory-studies-in-teaching.pdf.

Anwar, Y. A. S., al Idrus, S. W., & Siahaan, J. (2020). Analisis kesulitan mahasiswa calon guru dalam menyusun laporan praktikum. *Jurnal Pijar MIPA*, *15*(4), 329–331. https://doi.org/10.29303/jpm.v15i4.1743.

Bakri, F., Permana, H., Wulandari, S., & Muliyati, D. (2020). Student worksheet with AR videos: Physics learning media in laboratory for senior high school students. *Journal of Technology and Science Education*, *10*(2), 231–240. https://doi.org/10.3926/jotse.891.

Bangert, K., Bates, J., Beck, S. B. M., Bishop, Z. K., Benedetti, D. M., Fullwood, J., Funnell, A. C., Garrard, A., Hayes, S. A., & Howard, T. (2022). Remote practicals in the time of coronavirus, a multidisciplinary approach. *International Journal of Mechanical Engineering Education*, *50*(2), 219–239. https://doi.org/10.1177/0306419020958100.

Cahyadi, A., & Widyastuti, S. (2022). COVID-19, emergency remote teaching evaluation: the case of Indonesia. *Education and Information Technologies*, *27*(2), 2165–2179. https://doi.org/10.1007/s10639-021-10680-3.

Cahyadi, Ani, Hendryadi, Widyastuti, S., Mufidah, V. N., & Achmadi. (2021). Emergency remote teaching evaluation of the higher education in Indonesia. *Heliyon*, *7*(8), e07788. https://doi.org/https://doi.org/10.1016/j.heliyon.2021.e07788.

Castro-Schez, J. J., Glez-Morcillo, C., Albusac, J., & Vallejo, D. (2021). An intelligent tutoring system for supporting active learning: A case study on predictive parsing learning. *Information Sciences*, *544*(1), 446–468. https://doi.org/10.1016/j.ins.2020.08.079.

Chen, Q., Kong, Y., Gao, W., & Mo, L. (2018). Effects of socioeconomic status, parent-child relationship, and learning motivation on reading ability. *Frontiers in Psychology*, *9*(JUL), 1297. https://doi.org/10.3389/FPSYG.2018.01297/BIBTEX.

Chen, W. (2018). Introduction to research: A new course for first-year undergraduate students. *Journal of Chemical Education*, *95*(9), 1526–1532. https://doi.org/10.1021/acs.jchemed.8b00102.

Duffy, M. C., & Azevedo, R. (2015). Motivation matters: Interactions between achievement goals and agent scaffolding for self-regulated learning within an intelligent tutoring system. *Computers in Human Behavior*, *52*(11), 338–348. https://doi.org/10.1016/j.chb.2015.05.041.

Engzell, P., Frey, A., & Verhagen, M. D. (2021). Learning loss due to school closures during the COVID-19 pandemic. *Proceedings of the National Academy of Sciences*, 1–7. https://doi.org/10.1073/pnas.2022376118.

Febrina, F., Usman, B., & Muslem, A. (2019). Analysis of reading comprehension questions by using revised Bloom's taxonomy on higher order thinking skill (HOTS). *English Education Journal*, *10*(1), 1–15. http://www.e-repository.unsyiah.ac.id/EEJ/article/view/13253.

Gambo, Y., & Shakir, M. Z. (2021). Review on self-regulated learning in smart learning environment. *Smart Learning Environments*, *8*(1), 1–14. https://doi.org/10.1186/s40561-021-00157-8.

Gobert, J. D., Moussavi, R., Li, H., Sao Pedro, M., & Dickler, R. (2018). Real-time scaffolding of students' online data interpretation during inquiry with Inq-ITS using educational data mining. *In Cyber-Physical Laboratories in Engineering and Science Education*, 191–217. https://doi.org/10.1007/978-3-319.

Gunawan, I., Triwiyanto, T., & Kusumaningrum, D. E. (2018). Pendampingan penulisan artikel ilmiah bagi para guru sekolah menengah pertama. *Abdimas Pedagogi: Jurnal Ilmiah Pengabdian Kepada Masyarakat*, *1*(2), 128–135. https://doi.org/10.17977/um050v1i2p128-135.

Hadi, W., & Faradillah, A. (2020). Hambatan mahasiswa calon guru Matematika dalam menyelesaikan masalah bermuatan high-order thinking skills. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(3), 662–670. https://doi.org/10.24127/ajpm.v9i3.3006.

Herliandry, L. D., Nurhasanah, N., Suban, M. E., & Kuswanto, H. (2020). Pembelajaran pada masa pandemi COVID-19. *JTP-Jurnal Teknologi Pendidikan*, *22*(1), 65–70. https://doi.org/10.21009/jtp.v22i1.15286.

Huriye, D. C. (2015). Development of metacognitive skills: designing problem-based experiment with prospective science teachers in biology laboratory. *Educational Research and Reviews*, *10*(11). https://doi.org/10.5897/err2015.2283.

Kapilan, N., Vidhya, P., & Gao, X.-Z. (2021). Virtual laboratory: A boon to the mechanical engineering education during covid-19 pandemic. *Higher Education for the Future*, *8*(1), 31–46. https://doi.org/10.1177/2347631120970757.

Knippelmeyer, S. A., & Torraco, R. J. (2007). Mentoring as a Developmental Tool for Higher Education. *Online Submission*, *1988*, 8. https://eric.ed.gov/?id=ED504765.

Krasny, M. E., DuBois, B., Adameit, M., Atiogbe, R., Alfakihuddin, M. L. B., Bold-erdene, T., Golshani, Z., & González-González, R. (2018). Small groups in a social learning MOOC (sIMOOC): Strategies for fostering learning and knowledge creation. *Online Learning*, *22*(2), 119–139. https://eric.ed.gov/?id=EJ1181445.

Kua, M. Y., Suparmi, N. W., & Laksana, D. N. L. (2021). Virtual Physics laboratory with real world problem based on Ngada local wisdom in basic Physics practicum. *Journal of Education Technology*, *5*(4), 520–530. https://doi.org/10.23887/jet.v5i4.40533.

Laksana, D. N. L. (2017). The effectiveness of inquiry based learning for natural science learning in elementary school. *Journal of Education Technology*, *1*(1), 1–5. https://doi.org/10.23887/jet.v1i1.10077.

Li, H., Gobert, J., & Dickler, R. (2019). Evaluating the transfer of scaffolded inquiry: what sticks and does it last? *International Conference on Artificial Intelligence in Education*, 163–168. https://doi.org/10.1007/978-3-030-23207-8_31.

Lim, S. L., & Yeo, K. J. (2021). A systematic review of the relationship between motivational constructs and self-regulated learning. *International Journal of Evaluation and Research in Education (IJERE)*, *2252*(8822), 330–335. https://doi.org/10.11591/IJERE.V10I1.21006.

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2019). Effects of 6E-oriented STEM Practical Activities in Cultivating Middle School Students' Attitudes toward Technology and Technological Inquiry Ability. *Research in Science and Technological Education*, 1–18. https://doi.org/https://doi.org/10.1080/02635143.2018.1561432.

Luan, H., Geczy, P., Lai, H., Gobert, J., Yang, S. J. H., Ogata, H., & Baltes, J. (2020). Challenges and future directions of big data and artificial intelligence in education. *Frontiers in Psychology*, *11*(10), 1–11. https://doi.org/10.3389/fpsyg.2020.580820.

Mahendra, I. W. (2020). *Teachers' formative assessment: accessing students' high order thinking skills (HOTS)? Teachers' Formative Assessment: Accessing Students' High Order Thinking Skills (HOTS)? 12*(12), 180–202. http://repo.mahadewa.ac.id/id/eprint/1088.

Masoud, M. I., & al Muhtaseb, A. H. (2021). Improving engineering students' writing/presentation skills using laboratory/mini-project report. *The International Journal of Electrical Engineering & Education*, *58*(3), 701–714. https://doi.org/10.1177/0020720919833051.

Mirchi, N., Ledwos, N., & del Maestro, R. F. (2021). Intelligent tutoring systems: re-envisioning surgical education in response to COVID-19. *Canadian Journal of Neurological Sciences*, *48*(2), 198–200. https://doi.org/10.1017/cjn.2020.202.

Mulatsih. (2021). Implementation of revised Bloom taxonomy in developing Chemistry questions in the domain of knowledge. *Ideguru: Jurnal Karya Ilmiah Guru*, *6*(1), 1–10. https://doi.org/10.51169/ideguru.v6i1.158.

Nasir, M. (2017). Analisis kesulitan belajar dan miskonsepsi mahasiswa dalam praktikum berbasis proyek. *Edu Sains: Jurnal Pendidikan Sains Dan Matematika*, *5*(1), 56–65. https://doi.org/10.23971/eds.v5i1.602.

Ningsyih, S., Junaidi, E., & al Idrus, S. W. (2016). Pengaruh pembelajaran praktikum berbasis inkuiri terbimbing terhadap kemampuan berpikir kritis dan hasil belajar Kimia siswa. *Jurnal Pijar Mipa*, *11*(1), 55–59. https://doi.org/10.29303/jpm.v11i1.63.

Nirmala, W., & Darmawati, S. (2021). The effectiveness of discovery-based virtual laboratory learning to improve student science process skills. *Journal of Education Technology*, *5*(1), 103–112. https://doi.org/10.23887/jet.v5i1.33368.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., Pedaste, M., & Mäeots, M. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*(2), 47–61. https://doi.org/10.1016/j.edurev.2015.02.003.

Pionera, M., Degeng, I. N. S., Widiati, U., & Setyosari, P. (2020). Instructional methods and self-regulated learning in writing. *International Journal of Instruction*, *13*(3), 43–60. https://doi.org/10.29333/iji.2020.1334a.

Pujilestari, Y. (2020). Dampak positif pembelajaran online dalam sistem pendidikan Indonesia pasca pandemi covid-19. *Adalah*, *4*(1), 49–56. https://doi.org/10.15408/adalah.v4i1.15394.

Robb, M. K. (2016). Self-regulated learning: Examining the baccalaureate millennial nursing student's approach. *Nursing Education Perspectives*, *37*(3), 162–164. https://doi.org/10.5480/14-1349.

Rochman, S., & Hartoyo, Z. (2018). Analisis high order thinking skills (HOTS) taksonomi menganalisis permasalahan fisika. *SPEJ (Science and Physic Education Journal)*, *1*(2), 78–88. https://doi.org/10.31539/spej.v1i2.268.

Selwyn, R., & Renaud-Assemat, I. (2020). Developing technical report writing skills in first and second year engineering students: a case study using self-reflection. *Higher Education Pedagogies*, *5*(1), 19–29. https://doi.org/10.1080/23752696.2019.1710550.

Simorangkir, A., Napitupulu, M. A., & Sinaga, T. (2020). Analisis kesulitan belajar siswa pada materi sistem ekskresi manusia. *Jurnal Pelita Pendidikan*, *8*(1), 1–11. https://doi.org/10.24114/jpp.v8i1.11247.

Staub, N. L., Poxleitner, M., Braley, A., Smith-Flores, H., Pribbenow, C. M., Jaworski, L., Lopatto, D., & Anders, K. R. (2016). Scaling up: adapting a phage-hunting course to increase participation of first-year students in research. *CBE—Life Sciences Education*, *15*(2), 1–11. https://doi.org/10.1187/cbe.15-10-0211.

Su, J. (2020). A rule-based self-regulated learning assistance scheme to facilitate personalized learning with adaptive scaffoldings: A case study for learning computer software. *Computer Applications in Engineering Education*, *28*(3), 536–555. https://doi.org/10.1002/cae.22222.

Surahman, & Sulthoni. (2020). Student satisfaction toward quality of online learning in Indonesian higher education during the COVID-19 pandemic. *2020 6th International Conference on Education and Technology (ICET)*, 120–125. https://doi.org/10.1109/ICET51153.2020.9276630.

Ural, E. (2016). The effect of guided-inquiry laboratory experiments on science education students' Chemistry laboratory attitudes, anxiety and achievement. *Journal of Education and Training Studies*, *4*(4), 217–227. https://doi.org/10.11114/jets.v4i4.1395.

Utami, I. P., & Aryeni, A. (2017). Analisis soal ujian akhir semester mata pelajaran Biologi berdasarkan dimensi proses kognitif taksonomi Anderson. *Jurnal Pelita Pendidikan*, *6*(3), 185–192. https://doi.org/10.24114/jpp.v6i3.10990.

Wackerly, J. W. (2018). Stepwise approach to writing journal-style lab reports in the organic chemistry course sequence. *Journal of Chemical Education*, *95*(1), 76–83. https://doi.org/10.1021/acs.jchemed.6b00630.

Widyastuti, N., Riswandi, R., & Fitriawan, H. (2021). The development of advance organizer based distance learning in Chemistry bonding material. *Journal of Education Technology*, *5*(2), 228–235. https://doi.org/10.23887/jet.v5i2.33613.

Wilkes, J., Godwin, J., & Gurney, L. J. (2015). Developing information literacy and academic writing skills through the collaborative design of an assessment task for first year engineering students. *Australian Academic & Research Libraries*, *46*(3), 164–175. https://doi.org/10.1080/00048623.2015.1062260.

Wyeth, R. C., & Wonham, M. J. (2018). Patterns vs. causes and surveys vs. experiments: Teaching scientific thinking. *The American Biology Teacher*, *80*(3), 203–213. https://doi.org/10.1525/abt.2018.80.3.203.