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Suritno Fayanto
Universitas Halu Oleo, Indonesia

Erniwati
Universitas Halu Oleo, Indonesia

Husein
Universitas Halu Oleo, Indonesia

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Guided Experiment in Basic Electronics Simulations: Its Effect on Student Engagement and Motivation with Controlling Self-Regulation

Suritno Fayanto, Erniwati, Husein

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Abstract

This study investigates the impact of implementing guided experiments in basic electronics practicum simulation on student engagement and motivation, with particular attention to the role of self-regulation. While guided experiments have been extensively utilized in laboratory learning, prior research has predominantly concentrated on academic outcomes, overlooking the aspects of student engagement, motivation, and self-regulation. The study used Posttest-Only Design on 76 students, with MANCOVA analysis. The results showed that self-regulation had a significant effect on student engagement [F (1, 73) = 45.147; p = 0.000; $\eta\rho^2$ = 0.385] and motivation [F (1, 73) = 201.644; p = 0.000; $\eta\rho^2$ = 0.737]. However, guided experiments did not have a significant effect on engagement [F (2, 73) = 0.039; p = 0.962; $\eta\rho^2$ = 0.001] and student motivation [F (2, 73) = 0.101; p = 0.904; $\eta\rho^2$ = 0.003]. This conclusion confirms that self-regulation is a key factor in increasing student engagement and motivation, while the guided experiment method does not provide a significant impact. The implications of this study encourage the strengthening of student self-regulation in laboratory learning design to be more effective.

Introduction

Basic electronics laboratories generally incorporate a blend of theoretical instruction and practical lab exercises aimed at helping students grasp and apply essential concepts in electronics. Courses typically commence with lectures that cover key principles, including semiconductor physics, diodes, transistors, operational amplifiers, and circuit analysis (Robertson & Verhaevert, 2023; Watkins, 2013). These sessions typically involve using laboratory instrumentation such as oscilloscopes and function generators to analyze circuits, measure electrical parameters, and solve problems. Labs often include activities in which students design circuits to meet certain technical specifications, simulate them, and verify their functionality in a laboratory setting (Etxaniz, 2022). Students also learn the characteristics and functions of basic electronic components such as resistors, capacitors, and transistors (Yu & DiMassa, 2019).

In basic electronics practicums, guided experiment laboratory activities are often involved, which aim to help students understand the basic principles of electronics through structured and directed experiments. Guided Experiment or guided experiment laboratory is a practice that allows students to reach their conclusions about a set of data rather than verifying known results using a given experimental procedure (Vroom Redden et al., 2020). A guided experiment laboratory is an active learning strategy that engages students in specially designed activities to help them develop disciplinary knowledge and transferable skills (Loertscher & Minderhout, 2019). With the presence of a guided experiment laboratory, the laboratory environment can be a fun and satisfying place to teach. The laboratory allows students to participate in the learning process through hands-on activities actively. In addition, this dynamic environment is perfect for collaborative work, critical thinking, problem-solving, and discovery (L. Hall & Vardar-Ulu, 2014).

In recent years, guided experiment laboratory activities have focused only on achieving student learning outcomes. The entire practicum process is designed in such a way as to ensure that students achieve optimal academic skills and performance. This prompts a critical question: why do we focus primarily on learning outcomes or academic performance? What about the other essential elements, such as student readiness, self-regulation skills, motivation, and engagement in the practicum? These factors are often overlooked but important to the educational experience. Unwittingly, all activities in the laboratory only refer to achieving academic targets without considering how these internal factors support the student learning process. As a result, many students struggle to achieve the expected learning outcomes. For example, in the Basic Electronics practicum, students must complete the entire series of activities in a limited time to obtain good learning outcomes. However, the reality is the opposite—many students get low academic scores. It can be caused by various factors not considered in preparing rules and procedures for practicum, such as the level of the initial understanding of students, mental readiness, self-learning strategies, and student motivation in completing laboratory assignments.

Several studies have reported that student engagement, motivation, and self-regulation support learning outcomes. For example, effective engagement can have a significant impact on learning outcomes. For example, case study-based learning has been shown to improve all aspects of engagement (behavioral, emotional, cognitive, and agency), leading to better understanding and skill development (Raza et al., 2019). Likewise, with motivation, high motivation levels are associated with better learning outcomes. For example, students with high motivation in the experimental class obtained higher average grades than those with low motivation (Amini et al., 2018). It must be analyzed and considered at the beginning of the practicum because student engagement is related to readiness and how cognitive, behavioral, affective and social activities work on individuals. Similarly, motivation is related to attention, relevance, trust, and self-satisfaction when engaging in practicum activities. In addition, how students form self-regulation patterns is often less considered in practicum activities. Self-regulation refers to the active and constructive process in which students regulate and monitor their behavior, motivation, and cognition by setting their own goals during the learning process (Kayacan & Sonmez-Ektem, 2019). Self-regulation has an important impact on motivation and work performance. The fit between one's self-regulation and actual tasks can positively impact motivation and job satisfaction (Holler et al., 2005)

These various forms are often overlooked. In fact, based on search results in the Scopus database, no explicit studies have been found that discuss how guided experiment laboratories are studied in the realm of student engagement, motivation, and self-regulation, especially in the context of Basic Electronics practicums. It becomes even more relevant considering that Basic Electronics practicum activities are complex and require deep thinking and strong understanding. Therefore, student engagement and motivation are crucial factors that must support the effectiveness of learning in the laboratory. In addition, guided experiments are predominantly focused only on research skills (Maknun et al., 2022) and skill analysis (Fakayode, 2014). The ability's effectiveness is significantly enhanced when accompanied by strong engagement and robust motivation.

Therefore, considering the importance of these factors and seeing their potential as a valuable source of information in improving the effectiveness and progress of the practicum process, the author is interested in analyzing the effect of guided experiments on student engagement and student motivation by reviewing the role of self-regulation in the practicum process. This study is expected to provide more in-depth information on how the guided experiment approach can affect student engagement and motivation in practicum. The results of this study will be interesting findings because they can provide a more comprehensive picture of the effectiveness of the guided experiment method, which has been widely used in practicum activities. The research problem in this study is how guided experiments on basic electronics affect student engagement and motivation by considering self-regulation in physics education students.

Method

Research Design & Participants

This study uses a quantitative method with Posttest-Only Design with one group divided into two classes in basic electronics practicum. Both classes were given the same treatment, experimental integrated guided inquiry learning activities with several practicum contents. The variables consist of one independent variable (guided experiment) with two dependent variables, student engagement and motivation, and the covariate variable, self-regulation. Participants consisted of one group of 76 students, which were then divided into two classes, namely class A and class B, each containing 38 students. Participants were 80.3% male and 19.7% female, divided into three classes. This sample was selected using purposive sampling, or in the sense that Purposive Sampling is a non-probability sampling technique in which researchers deliberately choose participants based on certain characteristics, knowledge, or experiences relevant to the research objectives. Based on the research design, this study aims to analyze the effect of guided experiments on student engagement and motivation by considering self-regulation as a covariate variable. With the Posttest-Only Design approach, the results of this study are expected to provide empirical insight into the effectiveness of learning methods applied in basic electronics practicums. The findings of this study are expected to contribute to the development of more interactive and experiment-based learning strategies to increase student engagement and motivation in understanding electronics concepts more deeply

Research Procedures

To create an effective learning experience in a basic electronics practicum, it is essential to adopt an approach that emphasizes conceptual understanding, encourages active participation, and motivates students. The Guided

Experiment approach enables students to explore concepts independently with structured guidance, allowing them to develop a deeper comprehension of the material. In this context, self-regulation plays a crucial role in directing the student learning process, as it helps students set goals, monitor their progress, and evaluate their learning outcomes. Consequently, this learning scenario is designed to investigate the impact of the Guided Experiment approach in electronics practicum on student engagement and motivation. The details of the learning scenario are presented in Table 1.

Table 1. Guided Experiment Learning Scenario

Activity	**Description of activity**	**Role of Self-Regulation**	**Student Engagement**	**Motivation**
Orientation	Introduction to basic concepts	Planning and setting goals	Asking questions, actively participating in discussions	Curiosity, exploration motivation
Problem Formulation	Students are asked to formulate questions	Creating questions and identifying problems	Actively formulating questions	Motivated to find solutions
Experiment Design	Students design experiments	Planning experimental steps	Collaborating with group members	Motivated to solve challenges
Data Collection	Students conduct experiments	Organizing and recording data results independently	Focusing on the measurement process	Motivated to obtain accurate data
Data Analysis	Students analyze data from findings in experiments	Evaluating and reflecting on data	Group discussions, analyzing data together	Motivated to find answers
Conclusion	Students conclude the results of experiments and answer initial questions.	Assessing learning outcomes and making reflections	Presenting results in front of the class	Satisfaction in learning achievements
Preparation for Practical Report	Students write a lab report based on the data obtained and the analysis carried out.	Compiling reports independently	Compiling group reports	Motivated to document work results

After a practicum session, a formative evaluation was carried out through a post-test that involved distributing a questionnaire. This questionnaire included sections focused on student engagement, motivation, and self-regulation. The post-test results provided valuable insights into the levels of student engagement, learning motivation, and self-regulation exhibited during the practicum. Following data collection, a thorough analysis was conducted to assess the effectiveness of the guided experiment implementation.

Instruments, Data Collection Techniques and Data Analysis

The instrument used in this study is a questionnaire given to students who do basic electronics practicum. The questionnaire selection is based on the questionnaire's ability to collect data from various forms, such as attitudes, behaviors, and experiences from multiple populations and backgrounds(Curle & Derakhshan, 2021; Hurst & Bird, 2018). In addition, designing a questionnaire is relatively young, and the data collected is relatively easy to analyze using a statistical approach (Curle & Derakhshan, 2021; Marshall, 2005). Therefore, seeing this potential, this study uses a questionnaire as a research instrument.

Furthermore, the research instrument for the motivation variable uses a motivation questionnaire adopted from the research of Velayutham et al. (2011) consisting of 16 question items using a Likert scale with a score interval of 1-5 with a Cronbach's alpha of 0.91. Meanwhile, the student engagement instrument was adopted from the study (Gürbüz & Fırat, 2020) consisting of 26 question items using a Likert scale with a score of 1-5 with a CFI level. The original 4-dimensional structure of the scale was tested using confirmatory factor analysis. The goodness of fit index values obtained as a result of CFA ($\chi 2/df$ = 1.75; *RMSEA* = 0.038; *SRMR* = 0.049; *RMR* = 0.072; *CFI* = 0.98; N*FI* = 0.96) indicates that the 4-factor structure of the scale is acceptable. The learning strategy instrument was adopted from the study (Williamson, 2007) as a Likert scale consisting of 12 question items with a Crohn alpha data validation level of 0.71. Finally, the self-regulation instrument was adopted from the study (Velayutham et al., 2011) consisting of 9 question items with a Crohn's alpha of 0.91 as a Likert scale. It shows that all instruments are suitable for use.

In addition, all instruments are packaged in Google Forms as a data collection technique. The data analysis technique uses MANCOVA, which is based on a group consisting of classes A, class B & class C, with two dependent variables, one independent variable and one covariate variable. All data have met the analysis prerequisite test; namely, all data are normally distributed and homogeneous with a box variance value of p (0.485) > p (0.000) or in terms of student engagement variables p (0.723) and motivation p (0.875) or in the sense of homogeneous data. The research hypothesis is presented as follows:

H_1: Guided experiment affects student engagement and motivation with controlling self-regulation.

H_2: Classes that use guided experiments affect student engagement & motivation.

Results

In the learning process, active engagement and motivation of students to learn are crucial aspects supporting optimal learning outcomes. Appropriate learning strategies, such as Guided Experiments, can increase student engagement and motivation by providing interactive and explorative learning experiences. However, the effectiveness of this strategy does not only depend on the learning method alone but is also effectd by the internal factors of students, one of which is self-regulation. Self-regulation skills allow students to manage their learning process independently, thus encouraging active engagement and motivation to participate in learning activities. The initial analysis in this study is related to descriptive analysis, as presented in Figure 1.

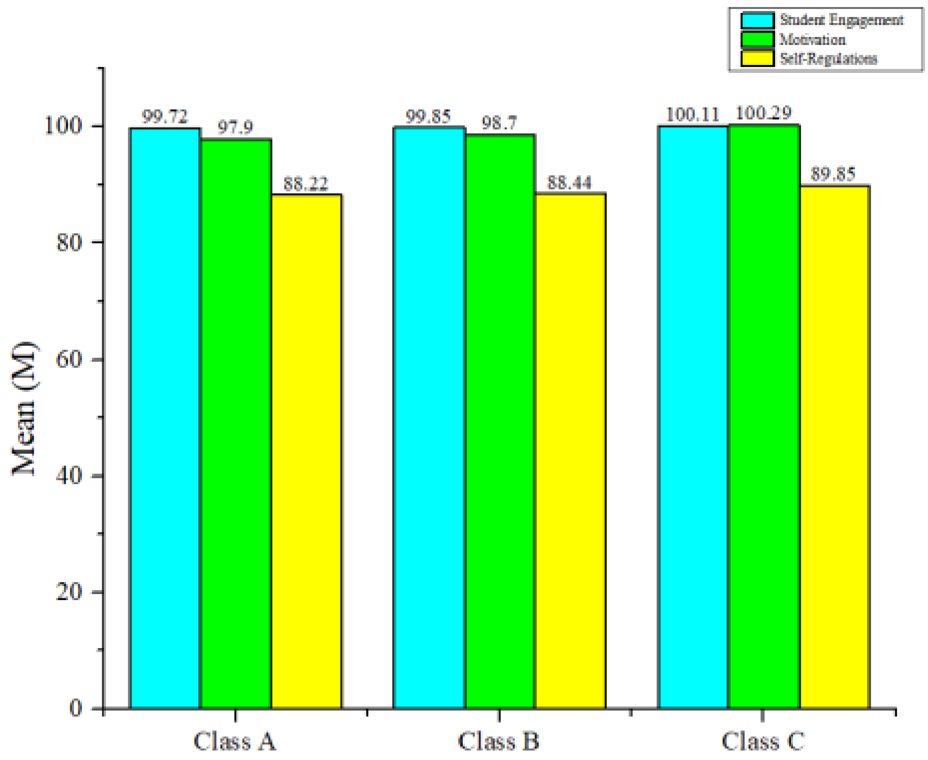

Figure 1. Plotting the Results of Descriptive Analysis

Based on the analysis results as shown in Figure 1, from 76 students divided into 3 classes, namely Class A (*N* = 22), Class B (*N* = 27), and Class C (*N* = 27), it is known that the implementation of guided experiments showed positive results on three aspects, namely student engagement, motivation, and self-regulation. In the aspect of student engagement, the highest average score was in Class C (*M* = 100.11; SD = 15.54), followed by Class B (*M* = 99.85; SD = 15.75) and Class A (*M* = 99.72; SD = 17.05). This shows that students in Class C are more involved during learning with the guided experiment method than in other classes. For the motivation aspect, Class C also showed the highest score (*M* = 100.29; SD = 14.34), followed by Class B (*M* = 98.7; SD = 13.29) and Class A (*M* = 97.9; SD = 13.44). These results indicate that the guided experiment method can increase students' learning motivation, especially in Class C. Meanwhile, in the self-regulation aspect, the highest average value was also achieved by Class C (*M* = 89.85; SD = 2.51), followed by Class B (*M* = 88.44; SD = 2.44) and Class A (*M* = 88.22; SD = 2.78). While the difference may seem minor at first glance, these findings suggest that guided experiments can significantly enhance students' self-regulation skills during the learning process. It's a fascinating insight highlighting the power of structured guidance in education.

In addition, further analysis was carried out using MANCOVA with self-regulation as a covariate to assess the impact of the guided experiment on student engagement and motivation while controlling for self-regulation. This approach is designed to ensure that any differences in student engagement and motivation between classes are not affected by variations in students' self-regulation abilities, allowing for a clearer understanding of the direct effects of the guided experiment method on these two dependent variables. The findings of this analysis are presented in Table 2.

Table 2. MANCOVA Analysis Results

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	**Sig.**	**ηρ²**
Self-Regulation	Wilks' Lambda	0.195	146.428[b]	2.000	71.000	0.000	0.805
Class	Wilks' Lambda	0.997	.061[b]	4.000	142.000	0.993	0.002

Referring to Table 2, it is known that Self-Regulation has a significant effect on the dependent variables (student engagement & motivation) simultaneously. It is shown by the Wilks' Lambda value (Λ = 0.195) with F (2, 71) = 146.428, p = 0.000 ($p < 0.05$), which means there is a significant difference between groups (The value of $\eta\rho^2$ = 0.805 indicates that 80.5% of the variability in the dependent variable can be explained by Self-Regulation, which indicates a large effect based on the interpretation of the effect size. In contrast, the results of the analysis indicate that the Class variable does not have a significant impact on the dependent variable. The Wilks' Lambda value approaching 1 (Λ = 0.997) with F (4, 142) = 0.061, p = 0.993 ($p > 0.05$) indicates that there is no significant difference between class groups. The value of $\eta\rho^2$ = 0.002 indicates that only 0.2% of the variability in the dependent variable can be explained by Class, which is included in the very small effect size category. These results indicate that Self-Regulation significantly effects the dependent variable with a large effect size, while Class does not have a considerable effect and has a very small effect size (H_1 = rejected). Furthermore, to strengthen this finding, further analysis was carried out in the form of Tests of Between-Subjects Effects.

Table 3. Tests of Between-Subjects Effects

Source		**Type III Sum of Squares**	**df**	**Mean Square**	***F***	***Sig.***	**ηρ²**
Self-Regulations	Student Engagement	7263.963	1	7263.963	45.147	0.000	0.385
	Motivation	10127.063	1	10127.063	201.644	0.000	0.737
Class	Student Engagement	12.439	2	6.220	0.039	0.962	0.001
	Motivation	10.117	2	5.059	0.101	0.904	0.003
Error	Student Engagement	11584.474	72	160.895			
	Motivation	3616.014	72	50.222			

a. R-Squared = .385 (Adjusted R Squared = .360)

b. R-Squared = .738 (Adjusted R Squared = .727)

The results of the Tests of Between-Subjects Effects Multivariate Analysis of Covariance (MANCOVA) indicate that Self-Regulation, as a covariate variable, significantly impacts Student Engagement (F = 45.147, p = 0.000, η^2 = 0.385) and Motivation (F = 201.644, p = 0.000, η^2 = 0.737). A very small p-value (below 0.05) shows that Self-Regulation significantly affects both dependent variables, with a stronger effect on Motivation than Student Engagement. The substantial effect size value (η^2) reveals that Self-Regulation accounts for 73.7% of the variance in Motivation and 38.5% in Student Engagement.

In contrast, the independent variable of the guided inquiry class, consisting of three implementation groups, did not demonstrate a significant effect on Student Engagement (F = 0.039, p = 0.962, η^2 = 0.001) or Motivation (F = 0.101, p = 0.904, η^2 = 0.003). The p-value, being well above 0.05, suggests that the differences in the guided inquiry class have no significant impact on either dependent variable once the effect of Self-Regulation is controlled. The R^2 value for the Student Engagement model is 0.385 (Adjusted R^2 = 0.360), indicating that this model accounts for 38.5% of the variance in Student Engagement. Conversely, the R^2 value for Motivation is 0.738 (Adjusted R^2 = 0.727), signifying that the model explains 73.8% of the variance in Motivation. These findings highlight that Self-Regulation plays a significant role in enhancing Motivation and Student Engagement, while guided inquiry does not significantly affect these outcomes when the Self-Regulation effect is controlled in this model.

Discussion

Guided experiment is a learning activity that is predominantly used in laboratory practicums. This activity is simple: students conduct laboratory activities with an investigative approach in experiments. However, the learning process, especially in laboratory practicums, tends to be oriented towards learning outcomes without considering student engagement, motivation, and self-regulation during the experimental process. This phenomenon is found in almost all laboratory practicums, including basic electronics practicums. The practicum focuses more on achieving cognitive aspects through learning outcomes or simply completing the material and implementing laboratory activities. Meanwhile, aspects of active engagement, motivation, and students' self-regulation abilities are often neglected. By considering internal and external factors, a student-centered practicum approach will be more optimal in improving the quality of learning and student learning outcomes. Therefore, this study aims to explore how the guided experiment learning strategy effects and its effect on student engagement and motivation by controlling self-regulation.

The results of the analysis show that Self-Regulation has a significant effect on Student Engagement and Motivation. The Wilks' Lambda value (Λ = 0.195) with F (2,71) = 146.428 and p = 0.000 shows a significant difference between groups, with a contribution of variability of 80.5% ($\eta\rho^2$ = 0.805), which is classified as a large effect size. Self-regulation contributes 38.5% ($\eta\rho^2$ = 0.385) to Student Engagement, indicating that students who manage themselves are more active in learning. In the Guided Experiment strategy in basic electronics practicum, students with high Self-Regulation can reasonably follow procedures, evaluate results, and find solutions to problems. This strengthens conceptual understanding and active engagement in the learning process.

In addition, Self-Regulation also has a significant effect on Motivation, with a contribution of 73.7% ($\eta\rho^2$ = 0.737). Students with high Self-Regulation tend to have strong intrinsic motivation, can set goals, and complete tasks well. In basic electronics practicums, this motivation encourages students to actively seek additional information, discuss, and reflect on experimental results. Thus, self-regulation significantly effects student engagement and motivation and has a large effect size. The Guided Experiment strategy in basic electronics practicums supports the improvement of Self-Regulation so that students are more actively involved and motivated in the learning process. Developing independent learning skills and self-reflection is an effective step in improving the quality of learning.

These results are confirmed by several studies that may be a source of support in different content and contexts, namely that the more students self-regulate, the more likely they are to engage in co-regulation with other students in the class (Park & Kim, 2022). The learning environment plays an important role in supporting self-regulation and engagement. An environment that encourages critical thinking, peer learning, and problem-solving can enhance students' self-regulation practices and, consequently, their engagement in learning activities (Maison et al., 2019). Motivation is an important component of self-regulation that helps regulate the effort an organism is willing to expend to achieve a desired goal (Locke & Braver, 2010). It differs from the three classes that used guided experiments in basic electronics practicum, where no significant effect was found on student engagement and motivation. This finding shows that the practicum process that has only been oriented towards learning outcomes needs to consider student engagement, motivation, and self-regulation of students. Interestingly, the practicum activities provided so far have not been able to build student engagement and motivation.

It is important to note that previous studies have reported that guided experimentation methods in the form of guided experimentation laboratories can improve academic achievement and learning outcomes. However, the results of this study show that improving learning outcomes does not necessarily significantly impact student engagement and motivation. As reported in a study, guided experiments have a more effective impact on improving research skills than regular learning (Maknun et al., 2022). Another study highlighted that students expressed greater satisfaction and demonstrated remarkable enhancements in the quality of their work (L. Hall & Vardar-Ulu, 2014).

This recommendation is very interesting because it emphasizes the importance of active student engagement and motivation in every practicum activity. Student engagement is not only limited to physical participation but also includes cognitive and emotional aspects that encourage a deeper understanding of the studied material. Through practicums designed interactively and collaboratively, students can develop curiosity, critical thinking skills, and problem-solving abilities. In addition, high student motivation can strengthen interest in learning, thus encouraging them to be more active in exploring information and exploring during practicum activities.

Conclusions

Based on the analysis, this study shows that self-regulation significantly effects student engagement and motivation in guided experiment-based learning in basic electronics practicums. Self-regulation abilities contribute significantly to increasing active engagement and student motivation during the learning process, with a large effect size on both dependent variables. This confirms that internal factors of students, especially the ability to manage themselves in the learning process, play an important role in supporting active participation and enthusiasm for learning. In contrast, applying the Guided Experiment method used in three classes did not significantly affect Student Engagement or Motivation. These results indicate that individual student factors effect the effectiveness of the learning strategy more than the learning method itself. Thus, strengthening self-regulation abilities is an important aspect that needs to be considered in designing learning to increase student engagement and motivation.

Future Research

Based on this study's results, several directions for future research can be explored further. First, further research can deepen the study of other factors that moderate or mediate the relationship between self-regulation, student engagement, and motivation in experimental-based learning practices. In addition, further research studies can explore the impact of guided experiments in a broader context, for example, in other experimental-based courses or at different levels of education. Thus, the results of this study can be the basis for developing more effective laboratory learning strategies oriented towards student engagement and motivation

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Author Information

Suritno Fayanto
https://orcid.org/0000-0003-3969-2940
Universitas Halu Oleo
H.E.A. Mokodompit Street
Indonesia
Contact e-mail: *suritnofayanto@uho.ac.id*

Erniwati
https://orcid.org/0000-0002-3216-6043
Universitas Halu Oleo
H.E.A. Mokodompit Street
Indonesia

Husein
https://orcid.org/0000-0001-5094-9327
Universitas Halu Oleo
H.E.A. Mokodompit Street
Indonesia