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Gender Differences in Basic Physics Laboratory Skills among Biology Education Students: A Quantitative Analysis

Muhammad Taufik[1*]., Syahrial, A[2]

[1,2] Physics Education Study Program, PMIPA, FKIP, Mataram University, Mataram, Indonesia.
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Correspondence:

Phone: +6287784784514

Abstract: This study investigated gender differences in physics laboratory skills among biology education students. A total of 90 students were recruited from three biology education classes at a university in Indonesia. The students completed five physics laboratory activities, and their performance was assessed using a rubric that measured skills in using laboratory equipment, data analysis, and communication. The results showed that there were no significant differences in physics laboratory skills between male and female students. However, there were some trends that suggest that female students may have a slight advantage in data analysis skills. These findings suggest that gender differences in physics laboratory skills may be minimal, and that both male and female students are capable of achieving high levels of performance in physics laboratory courses.

Keywords: gender, physics laboratory skills, biology education

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Introduction

Empowering learners to blossom into tomorrow's high-quality human resources starts with designing impactful learning experiences. These experiences, vibrant with interactivity, inspiration, engagement, and challenge, ignite learners' intrinsic motivation to actively participate. Equally crucial is fostering spaces where learners can cultivate and express their own initiative, creativity, and autonomy, guided by their unique talents, interests, and evolving abilities. By embracing this learner-centric approach, every field of knowledge, including the fascinating world of physics, can be transformed into a journey of meaningful exploration and discovery (Fadly,2011).

Physics is a branch of science that studies the physical properties of objects or events, such as their shape, size, roughness, weight, and how they interact with each other (Piaget, 1970, 1971; McDermott, 1996). Physics is built on deductive reasoning and inductive discovery.

Physics education necessitates not only a robust grasp of theoretical concepts but also the ability to translate them into tangible realities through the scientific method. Laboratory practice serves as a critical bridge, empowering students to directly test hypotheses, witness the workings of physical laws firsthand, and refine their understanding through active engagement.

Physical knowledge is acquired through direct interaction with the object or event. For example, to study the physical properties of an object, students can perform an experiment to measure its mass, volume, and density. To study the physical properties of a liquid, students can perform an experiment to measure its pressure, temperature, and viscosity. To study the physical properties of a wave, students can perform an

Email: taufik@unram.ac.id

experiment to measure its wavelength, frequency, and amplitude. Therefore, the ideal way to learn physics is through experimentation or laboratory work. In physics learning, it is important to pay attention to the elements of science, which are observation, experiment, theory formulation, and conclusion.

Observation is the process of observing physical phenomena that occur in nature or man-made. Experiment is the process of conducting experiments to test hypotheses or physical theories. Theory formulation is the process of formulating theories to explain physical phenomena that have been observed and experimentally tested. Conclusion is the process of drawing conclusions from the results of observation, experiment, and theory formulation.

Therefore, physics learning should not only focus on the mind, but also the hands through practical work. Practical work in physics can help students to observe physical phenomena directly, conduct experiments to test hypotheses or physical theories, prove physical theories directly, and develop critical thinking and problem-solving skills.

Practical work is a teaching method that allows students to learn by doing. It provides students with the opportunity to experience, perform, follow a process, observe an object, analyze, and draw conclusions independently. This is in line with the national curriculum, which states that physics learning should be conducted through scientific discovery and inquiry to develop academic skills. Academic skills are related to fields of work that require more thought or intellectual work.

Embedded within the curriculum of the Department of Mathematics and Natural Sciences Education at Mataram University, the foundational course "Basic Physics" stands as a compulsory requirement for all S1 undergraduate students. Carrying a credit load of 3, this cornerstone of scientific understanding seamlessly integrates theoretical exploration and practical engagement in a 2:1 ratio, dedicating 2 credits to structured lectures and 1 credit to immersive experimentation.

There were five fundamental physics laboratory Investigations:1). Characterization of Mechanical Measuring Instruments: This experiment explores the precision and accuracy of various mechanical tools like vernier calipers, micrometers, and meter sticks, emphasizing the importance of appropriate instrument selection for different measurements; 2). Investigation of the Simple Pendulum: This experiment focuses on determining the period of a simple pendulum and establishing its relationship to the pendulum's length and gravitational acceleration. The analysis involves applying the equation $T = 2\pi\sqrt{(L/g)}$ to understand the principle of isochronism; 3). Exploration of Elastic Properties: This laboratory activity investigates the behavior of elastic materials under applied forces. By measuring the elongation of a spring loaded with different weights, students demonstrate Hooke's Law and determine the spring constant, highlighting the relationship between force and displacement; 4). Verification of Archimedes' Principle: This experiment employs a buoyancy tank and graduated cylinder to verify the principle stating that the buoyant force acting on a submerged object is equal to the weight of the displaced fluid. By comparing the weight of an object in air and its submerged weight, students quantify the buoyant force and appreciate its dependence on the volume of displaced fluid; 5). Thermal Properties and Transfer Mechanisms: This investigation delves into the concepts of heat and temperature. Students use thermometers, hot plates, and calorimeters to measure temperature changes in water during heating and cooling, exploring heat capacity and heat transfer mechanisms like conduction and convection. These experiments provide hands-on experiences that solidify theoretical understanding within the realm of basic physics.

Within the Basic Physics course, encompassing both theoretical and practical components, instructors, teaching assistants, and laboratory personnel uphold consistent standards and expectations for all students, irrespective of their gender. Academic outcomes are solely determined by individual competence and merit, independent of gender affiliation. While certain research may suggest disparities in performance between male and female students, other studies refute such claims, emphasizing the absence of a direct correlation between gender and academic achievement or intellectual aptitude. Ultimately, students' academic accomplishments are attributed solely to their inherent abilities and dedicated efforts, uninfluenced by gender constructs.

The purpose of this study was to investigate gender differences in physics laboratory skills among biology education students. The researchers hypothesized that there would be no significant differences in physics laboratory skills between male and female students.

Method

This study utilized a quasi-experimental design to examine the potential influence of gender on the post-intervention basic physics laboratory performance of undergraduate biology education students. Following exposure to the designated laboratory curriculum, participant performance was assessed solely through scores derived from their post-intervention laboratory activities. The primary research question investigated whether statistically significant differences exist in the basic physics laboratory performance of male and female students, as measured by their post-intervention scores.

A total of 51 students were recruited from three biology education classes at a Mataram University Lombok, Indonesia. The students were randomly assigned to one of two groups: a male group or a female group.

The laboratory grade is calculated as a weighted average of four components: the preliminary task score (N_1), the average laboratory report score (N_2), the activity score (N_3), and the final response score (N_4). The weights for each component are as follows: N_1: 10%; N_2: 60%;N_3: 20%and N_4: 10%.

Descriptive statistics, including mean, standard deviation, minimum, and maximum values, were employed to characterize the research data. These statistics were presented in both tabular and graphical format (i.e., histograms) to facilitate comprehensive data visualization. To confirm that the observed differences in mean practical session scores are not due to chance, the researcher conducted a one-way analysis of variance (ANOVA), a statistical method used to compare two or more means. This analysis is often used to test whether there is a statistically significant difference between two or more groups. (Riduwan,2008). Anova comes varians, namely a set of data describes the degree of difference or variation in the values of individual data points within that data set (Kukuh,2019). We also used Tukey Pairwise Comparisons, Fisher Pairwise Comparisons, Dunnett Multiple Comparisons with a Control and Hsu Multiple Comparisons with the Best (MCB).

Tukey Pairwise Comparisons test performs multiple pairwise comparisons between all group means (e.g., male vs. female, male vs. control). It controls for the overall family-wise error rate (FWER) to maintain a desired confidence level. Fisher Pairwise Comparisons conducts pairwise comparisons between groups. It's considered less conservative than Tukey's but might be suitable for smaller datasets. Dunnett Multiple Comparisons with a Control: This test focuses on comparing each group to a specific control group (e.g., comparing multiple experimental groups to a control group). It controls the FWER for comparisons with the control group. Hsu Multiple Comparisons with the Best (MCB): This newer test identifies the group with the best performance (highest mean) and then compares all other groups to that best performer. It controls the FWER for comparisons with the best group.

Result and Discussion

Result

The aggregated results of the Basic Physics practical sessions, comprised of five sessions and encompassing four evaluative components, are presented in the table below for S1 Biology Education students.

Table 1. Result Basic Physics among students

Variable	Gender	Mean	StDev	Minimum	Maximum
Laboratory_	1	85.56	4.56	80.68	92.00
Grade	2	87.008	3.971	77.530	93.930

The results of the practical session scores are presented in the following histogram for visual clarity. Figure 1 shows the scores for all genders (male and female students).

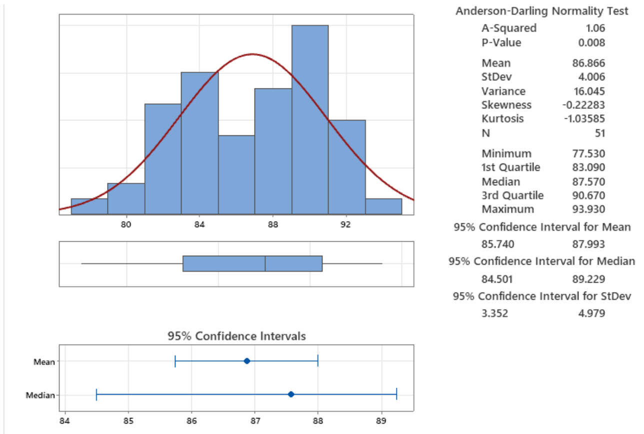

Figure 1. Summary report for laboratory grade

Figure 2 shows the scores for men only, mean 85.56 and standard deviation 4.56, minimum 80 out of 100 and maximum 92 out of 100.

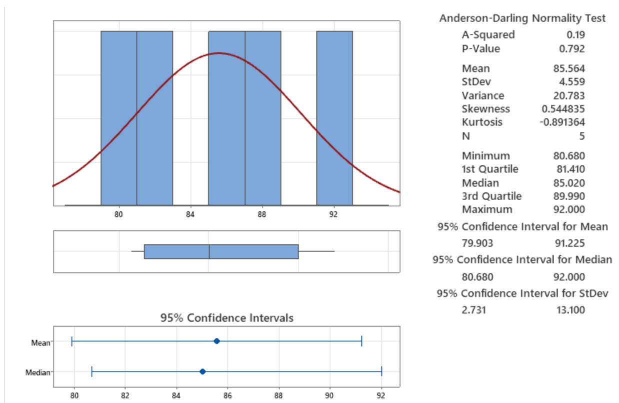

Figure 2. Summary report for men laboratory grade

Figure 3 shows the scores for men only, mean 87.008 and standard deviation 3.971, minimum 77.53 out of 100 and maximum 93.93 out of 100.

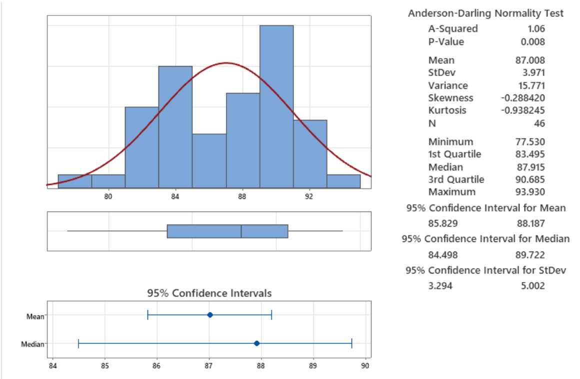

Figure 3. Summary report for women laboratory grade

In order to statistically assess whether the two groups demonstrate equivalent practical session scores, independent of gender influence, a one-way analysis of variance (ANOVA) was employed. The resulting data are presented in Table 2 and table 3.

Table 2. Analysis of Varians two groups (Men and women)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Gender	1	9.404	9.404	0.58	0.449
Error	49	792.844	16.180		
Total	50	802.249			

Table 3. Grouping Information Using the Tukey Method, Fisher, Dunnett with 95% Confidence

Gender	N	Mean	Grouping
2	46	87.008	A
1	5	85.56	A

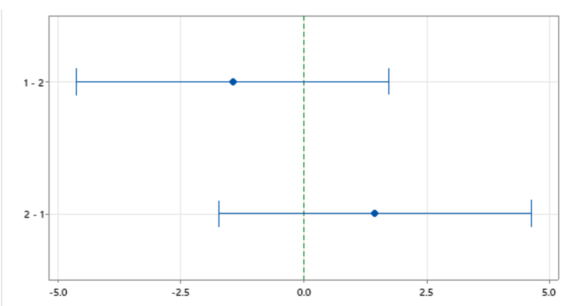

Figure 4. Hsu Simultaneous 95% CIs

Discussion

A cursory glance at Table 1 or Figures 2 and 3 suggests that the mean practical session scores for the female group (87.008) are higher than those for the male group (85.56). The standard deviation for the female group (3.971) is also lower than that for the male group (4.56).

The presented ANOVA table 2 shows no statistically significant difference between genders (p-value = 0.449, which is greater than the conventional alpha level of 0.05). This implies that the observed difference in mean scores (87.008 for females vs. 85.56 for males) might be due to chance. The P-value of 0.449 is greater than the commonly used threshold of 0.05. This further supports the lack of evidence for a significant difference between the groups.

The results of the ANOVA are also consistent with Tukey, Fisher, Dunnett, and HSu, which state that there is not enough evidence to claim that the two groups are different.

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Conclusion

In conclusion, based on the provided information, there is no evidence for a statistically significant difference in mean scores between genders. However, further investigation might be warranted to understand the factors influencing performance more comprehensively.

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