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# Statistical Literacy of Pre-Service Primary Teachers: A Pre-experimental Research

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**Abstract.** This study aims to investigate the effect of a problem-based learning (PBL) approach on statistical literacy in mathematics education, taking into account students' initial mathematical ability. The study used a pre-experimental research design with students categorized according to their initial mathematical ability (high, medium and low). The statistical literacy test scores of 60 students were analyzed using one-way ANOVA to assess differences between the groups. The results showed that students' initial mathematical ability significantly influenced their level of statistical literacy. The constructivism-based PBL approach shows potential for improving mathematical literacy, especially for students with low and medium initial mathematical ability. However, too much focus on constructivism theory and a lack of proper lesson planning may hinder the effectiveness of PBL implementation.

## Introduction

Statistics are studied at secondary school, high school, and university level. Statistics plays a significant role in human life, where it is used to predict phenomena that require conclusions based on data analysis. The main concern in learning statistics is ensuring students understand and apply statistical concepts in real-world situations (Tishkovskaya & Lancaster, 2010). Society has realized the importance of statistical reasoning or knowledge in life (Gal, 2002). Therefore, society's mastery of statistics is crucial; therefore, if we want good statistical Literacy, we must teach students statistical data analysis early (Yotongyos et al., 2015). In statistics, there is a clear distinction between Literacy, reasoning, and thinking resulting from thinking ((Ben-Zvi, D. & Garfield, 2004; Ben-Zvi & Makar, 2016a)). Therefore, it is essential to study statistical Literacy due to the thinking process and the ability to apply it effectively.

The meaning of Literacy is essentially not only limited to reading and writing activities but also includes the ability to think critically when understanding different aspects of different fields (Damayantie, 2018). Reading activities involve efforts to understand and articulate each symbol of language to obtain a definition, while writing exercises are a way to express the results of thoughts based on these symbols of language to form a report. In statistics, statistical Literacy includes the ability to critically understand and evaluate statistical results used in everyday life and appreciate statisticians' contribution in presenting data and information (Hafiyusholeh 2015). The ability to think critically about statistics is becoming increasingly significant in our data-driven society, empowering individuals to make informed decisions and navigate the complexities of an information-rich world. Developing solid statistical Literacy and critical thinking skills is crucial for future leaders, equipping them to tackle the multifaceted challenges of a data-dependent world with confidence and evidence-based approaches.

Some questions relate to statistical Literacy, such as how reliable the measurements are, how representative the samples are taken, and whether the claims made are reasonable based on the available data and models ((Garfield & Chance, 2000). These questions lead students to think critically and reflectively when interpreting and investigating statistical phenomena. In this way, students become familiar with statistical activities, begin to be skilled in statistical thinking, and can make decisions based on statistical analysis, so that they have a tendency or attitude that is more statistically based in solving problems and making decisions related to the issues at hand (Fardillah et al., 2019). Solid Literacy and the ability to critically understand statistical data are essential skills in today's information age. In a society increasingly connected to data and information, individuals need to be able to evaluate and understand the implications of the data presented. Critical thinking skills in statistics are also valuable in supporting accurate and responsible decision-making in economics, politics, health, and the environment. Students who develop statistical Literacy and critical thinking skills will be future leaders who can face the complex challenges of a world that increasingly relies on data and statistics to take effective, evidence-based action. Therefore, deepening the learning of statistics and developing critical thinking skills in the context of statistics are essential steps to improve the ability and readiness of future generations to face an increasingly statistical and information-driven world.

The National Movement for Statistical Literacy Action Strategy aims to promote the correct use of statistics, proper application, and accurate interpretation of data(Tiro, 2018). The primary purpose of learning statistics is to teach individuals to understand data, explain data, document data limitations, manage data, find meaning in data, and take action based on data (Ala-Mutka, 2011; Data Institute, 2016). However, in reality, the understanding process of learning statistics is often not smooth because many statistical rules are complex and do not fit with intuition, making it difficult for students to engage in teaching statistics (Ben-Zvi, D. & Garfield, 2004; J. Ben-Zvi, 2004). Typically, higher education teaches statistics in isolation without being linked to more general research methodological frameworks or experimental designs relevant to real-life situations (Nikiforidou et al., 2010). It has implications for the statistics learning process in the classroom, as statistics learning should be presented in a meaningful context that can stimulate students' interest in education. They need to understand how statistics can be applied in real situations. Even if students do not conduct research, understanding statistics is still helpful in assessing the quality of their knowledge and the validity of their findings (Sharma, 2017). Therefore, it is essential to present statistics learning meaningfully so that students can see the relevance and usefulness of statistics in everyday life.

The identification of students shows that they experience anxiety when taking statistics courses, which affects their lack of interest in learning statistics, leading to low achievement in their learning outcomes (Tishkovskaya & Lancaster, 2010). This problem is also evident in the field findings of public administration students, where the interview results show that most of them have a high school background with a focus on social sciences (IPS), and very few come from a high school background with a focus on natural sciences (IPA). They think that statistics is a complex subject because it belongs to the field of mathematics, even some of them choose to study public administration to avoid mathematical calculations. To improve statistical Literacy, it needs to be supported by a learning design that encourages the development of statistical reasoning. A learning design that allows students to develop their identity by analyzing data as a realistic and legitimate object of study is an important step (Carvalho & Solomon, 2012). Thus, these steps are expected to help overcome anxiety and improve student interest and learning outcomes in statistics courses.

The ability to process statistical information is essential for students because it can provide valuable benefits in their lives, such as being able to discuss different ways of using statistical data in everyday life, such as making important life choices, assessing and tracking personal progress in other aspects of life, and critiquing simple information intelligently (Songsore & White, 2018). Understanding and interpreting statistical information requires more than statistical knowledge (Gal, 2002). Students also need knowledge elements and dispositional elements to support their statistical Literacy. Recent research trends and challenges in statistics education emphasize the learning process, teaching, and curriculum design (Ben-Zvi & Makar, 2016b). Therefore, the statistical learning process is designed to motivate students, with teaching increasingly focused on context and using authentic activities that have significant meaning for students (Ben-Zvi & Aridor-Berger, 2016). This way, the ability to process statistical information will provide students with invaluable skills when facing challenges and making life decisions.

The learning process that is consistent with the above characteristics is the problem-based learning (PBL) model (Arends, 2014). The PBL model was developed based on modelling how we learn every day (Adiga & Adiga, 2015), and is based on the philosophy of constructivism theory. PBL has been proven to be an effective learning method for improving students' skills(Anjelina et al., 2021; Celik et al., 2011; Gokcek & Celik, 2020). In constructivism, learning takes place through the process of knowledge construction in the mind of the learner (Bodner, 1986). In PBL, students are confronted with everyday problems relevant to the material taught, which aims to motivate learning (Prince, 2004). Today's mathematics students need statistical Literacy as a skill that will equip them to become teachers. This study aims to investigate students' statistical literacy level as a reference for teachers to improve learning.

## Methods

The research method used in this study is a pre-experimental research method with a one-shot case study experimental design. This research design tests the effect of the treatment (X) on the dependent variable (Y) by providing a treatment group and then observing (measuring) the dependent variable to assess the effect of the treatment (Campbell & Stanley, 2015). In the one-shot case study design, only one group of subjects is given a particular treatment. The dependent variable is then observed or measured to see the changes or effects of the treatment on the same group of subjects (Fraenkel et al., 2011). An illustration of the One-Shot Case Study research design is shown in Figure 1, where the subject group is given a treatment (X) and then the dependent variable (Y) is measured in response to the treatment.

| X | Y |
|---|---|
| Treatment | Observation (Dependent Variable) |

**Figure 1** One-Shot Case Study Design (Fraenkel et al., 2011)

Although this one-shot case study design provides information about the effect of the treatment on the group of people who received the treatment, this design has limitations, such as the lack of a control group to compare the results with the untreated group. Therefore, the research results using this design should be interpreted cautiously, and extra care is needed when generalizing the results. The population of this study was all the prospective students of Primary Education in Semester IV of the academic year 2022/2023, divided into five classes with different graduation backgrounds and dominated by graduates of Social Studies but not too much by graduates of Science. The sample was determined by purposive sampling to facilitate the selection of a representative sample according to the researcher's wishes, namely a class with a balanced number of science and social studies graduates. The research samples were classes A-B-C, with a total of 60 students. Each class that became the research sample received a problem-based learning process. The research process began at the first meeting by giving an initial mathematics ability test to determine each category of student ability, namely high, medium, and low. The implementation of the research, namely intervention with problem-based learning, was carried out for seven meetings, and at the 8th meeting, a statistical literacy test question was given. The statistical literacy test results were analyzed using one-way ANOVA to get conclusions.

## Results And Discussion

Some factors that influence success in learning mathematics include internal factors, one of which is initial mathematical ability. This study starts with a test of initial mathematical ability, which aims to map students' abilities. Students' initial mathematical ability is the ability they already have before they engage in the learning that will be given to them (Lestari, 2014). Students with good initial ability are more likely to easily follow the learning process and quickly understand the mathematics material (Hevriansyah & Megawanti, 2017). Before being given the posttest, students were grouped based on the category of Initial Mathematical Ability (Miliyawati, 2012). The criteria for grouping initial mathematical ability is based on **Table 1.** The description of the average score ($\bar{x}$) and standard deviation (SB) are as follows:

**Table 1.** The Scale of Initial Mathematical Ability

| | Scale |
|---|---|
| $\text{KAM} \geq \bar{x} + SB$ | High |
| $\bar{x}$ - $SB \leq \text{KAM} \geq \bar{x} + SB$ | Moderate |
| $KAM \leq \bar{x}$ - $SB$ | Low |

The results of the statistical literacy test, categorized based on the initial mathematical ability test, are shown in **Table 2.** below:

**Table 2.** Results of Statistical Literacy Category Based on Initial Mathematical Ability

| Scale | Total |
|---|---|
| High | 15 |
| Moderate | 27 |
| Low | 19 |
| Total | 60 |

Since the data are distributed from normal and homogeneous data, the analysis used is a one-way ANOVA. It is shown in the table below:

**Table 3.** One-way Anava

| Statistical Literation | Sum of Squares | df | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 5824,60 | 2 | 3057,30 | 193,30 | ,000 |
| Within Groups | 832,72 | 57 | 14,80 | | |
| Total | 7157,33 | 59 | | | |

Based on Table 3. above, it can be concluded that for statistical literacy ability of students in the three categories of initial mathematical ability obtained a p-value $< 0.05$. Then Ho is rejected so that there is a significant difference in statistical Literacy between students based on the category of initial mathematical ability (high, low and low). Between students based on the category of initial mathematical ability (high, medium and low). To see the differences in each category of initial mathematical ability, category of initial mathematical ability, the post hoc test was performed using LSD. The results of the calculation of the post-hoc test with LSD are presented in **Table 4.** below:

**Table 4. Post Hoc LSD**

| Initial mathematical ability | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|
| Moderate | 16,15* | 1,20 | ,00 | 12,87 | 17,87 |
| Low | 31,11* | 1,29 | ,00 | 23,63 | 28,88 |
| High | -16,15* | 1,20 | ,00 | -17,73 | -12,94 |
| Low | 10,10* | 1,21 | ,00 | 8,63 | 13,48 |

| | | | | | |
|---|---|---|---|---|---|
| High | -27,11* | 1,34 | ,00 | -28,89 | -23,743 |
| Moderate | -09,96* | 1,22 | ,00 | -13,59 | -8,67 |

*. The mean difference is significant at the 0.05 level.

The data analysis process starts with the one-way ANOVA test and also the LSD post hoc test, which is more detailed, to see any significant differences between the initial ability categories. The researcher investigated the effect of implementing a problem-based learning process on mathematical literacy test scores in three initial ability categories: high, medium and low. The data analysis process included a one-way ANOVA statistical test and an LSD post hoc test to test for significant differences between the categories. One-way ANOVA (analysis of variance) is used to compare the means of three or more different groups. In this context, the groups are the initial ability categories: high, medium and low. The purpose of the ANOVA test is to determine whether there is a significant difference between the means of these groups in terms of mathematical literacy test scores. If the ANOVA test shows a significant difference between at least two groups, the LSD post hoc test can be used to compare all pairs of groups in more detail. The aim is to find out which pairs of groups are significantly different and which are not. The results of the data analysis can provide researchers with information about how implementing the problem-based learning process can affect the results of the mathematical literacy test at different levels of initial ability. If the post hoc test results show significant differences between the groups, it can be concluded that implementing the problem-based learning process has different effects on the initial ability categories.

The logical thinking accepted by the researcher is that for each category of initial ability, there should be at least one or more categories that are not significantly different. In particular, for the categories of low and medium initial mathematical ability, this suggests that the problem-based learning process facilitated the improvement of students' mathematical literacy in both categories. It is also supported by the high levels of statistical literacy in both categories. The researcher believes implementing the problem-based learning process is less effective in improving students' statistical literacy skills, supported by the low-class average score. The learning process aims to achieve behavioural and thinking changes in the long-term memory of each student.

The researcher's consideration of constructivism theory as the basis of the problem-based learning process shows that this view has dominated students' learning approaches at different levels of education. However, the researcher predicts that the researcher's emphasis on constructivism theory in the learning approach is a contributing factor to the less successful implementation. That is, the researcher focuses more on planning learning that focuses on activities that engage students in discovering and understanding statistical concepts. The problem-based approach emphasizes students' direct and active experience in solving real problems, so constructivism is fundamental to this approach. However, the researcher's prediction implies that there may be barriers to effective implementation due to an excessive focus on constructivism theory and a lack of appropriate lesson planning to achieve the learning objectives effectively. To improve the implementation of the problem-based learning process, researchers need to ensure that lesson planning is more focused and structured so that the activities designed can better assist students in discovering statistical concepts and support their understanding construction process. The use of constructivist theory should be in line with effective learning design to achieve the desired learning objectives.

In a naive interpretation of constructivism (Cortes & Pfaff, 2000; Lerman, 1989; Taber, 2012), researchers prepare student-centred learning activities by providing minimal guidance. However, it should be remembered that constructivist learning processes should be formulated as a clear theory with testable predictions (Mayer, 2004a). It means that when a lecturer prepares the material to be taught, they should also consider the predictions of student responses that may arise during the learning process. This approach adopts the idea that a lecturer should be able to think as a mathematician (thinking about the content and how to teach it), as a teacher (understanding students' needs and characteristics) and as a student (understanding students' perspectives) (Brousseau, 2006). Thus, teachers should prepare learning materials and activities by predicting students' responses. In the theoretical framework of the modified didactic triangle, the concept of pedagogical prediction is considered something that must be prepared by the teacher (Suryadi, 2015). The resulting predictions must be based on previous studies and not just estimates.

Furthermore, analyzing learning obstacles, such as epistemological, didactic and ontogenetic, can be an alternative to assessing student response predictions (Brousseau, 2006). By identifying these barriers, a teacher can prepare appropriate strategies to overcome differences in students understanding. Thus, a more mature understanding and recognition of constructivism and thinking about predicting student responses and recognizing learning barriers will help lecturers design learning more effectively and respond to students' needs. Children tend to learn better when they are active and engaged in learning. This idea is supported by research, as Mayer put it in 2004. When a teacher directs students' activities in a productive direction, it helps students understand and assimilate the material better.

Constructivism is indeed a complex and diverse doctrine in education. However, when educators look for practical implications of the constructivist philosophy, they often conclude that the discovery method is important. This method emphasizes students' active participation in seeking and constructing knowledge rather than passively receiving information. Problem-based learning (PBL) is an approach consistent with the constructivist view. In PBL, students are presented with real problems and encouraged to actively participate in finding solutions or concepts. The teacher's role in PBL is as a facilitator or guide, providing minimal support to guide students towards a deeper understanding. This thinking reflects the researcher's thinking about implementing Problem-Based Learning (PBL) based on constructivism. In PBL, students are invited to discover concepts and knowledge, and the teacher acts as a companion to help and guide the student's learning process. Thus, PBL is a learning method that combines student activity, knowledge discovery and teacher guidance to achieve learning objectives.

Constructivist thinking based on the minimal guidance view does not always produce better results than the maximal guidance approach, especially for students with good prior knowledge (Clark et al., 2012; Sweller et al., 2007). This study found that learning outcomes were not significantly different between the two approaches. Furthermore, according to Mayer (2004b), constructivist learning focusing on practical activities could be disastrous for education. It is because there is a conflict between the idea that knowledge is not transferable and that knowledge is constructed. It is important to consider the cultural background of students when designing learning. Transferring knowledge according to students' language and cultural background and providing maximum guidance can make learning more meaningful. Students' conceptual understanding and assumptions influence their thinking and interpretation of learning materials (Bowers, 2005).

Regarding Problem-Based Learning (PBL), this method aligns with constructivism, emphasizing hands-on experience and individual student inquiry. PBL also relates to deeper ideas, such as the philosophy of Science and psychological knowledge under discovery. However, research results on PBL do not always outperform conventional learning methods, and some studies even found no significant difference in student learning outcomes between PBL and conventional methods (Albanese et al. 1993) (Albanese et al., 1993). It shows that although constructivism and PBL have advantages and are attractive approaches, research findings on their effectiveness are not always consistent. Therefore, there is a need for a holistic approach to learning design that considers students' characteristics, culture and learning context to achieve optimal learning outcomes.

## Conclusion

The results showed that students' initial ability affects the learning of mathematics. Students with good initial ability tend to follow the learning process more easily and understand the mathematical material more quickly. The theory of constructivism is the basis of problem-based learning. Students actively discover and understand mathematical concepts through direct experience and investigation in this approach. More attention must be paid to guidance and appropriate lesson planning in designing constructivist learning. Students' conceptual understanding and cultural background should be considered to make learning more meaningful. Although PBL can potentially improve learning, some studies have found no significant difference between PBL and conventional learning methods. It highlights the importance of a holistic and effective approach to learning. This research highlights the importance of carefully evaluating the implementation of a problem-based learning approach to understand its impact on different levels of student's initial abilities. Good lesson planning and understanding of students' characteristics can improve the effectiveness of the learning process. A PBL-based constructivist approach can effectively improve mathematics learning if supported by appropriate guidance and lesson planning. Educators must consider students' characteristics and cultural backgrounds to design meaningful learning and successfully achieve learning objectives.

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