Students’ statistical reasoning reviewed from academic internal factors in two learning classes

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Abstract. This paper presents the research results about the profile of students’ statistical reasoning ability (SRA) based on their academic internal factors, namely statistical prior knowledge (SPK), the intensity of study, and length of time to study. Data was collected from the seventy students of mathematics educations in a year of 2018/2019 that divided into two learning classes. One class was determined randomly as an experimental group and another class as a control group. The SRA and SPK achievements were measured by a written test. The aged of students ranged from 19 to 22 years. Based on gender, there were about 71% of females and 29% of males. The result of the study showed that the most answered about the intensity to study was “seldom”. They used the length of time to study for reviewing the statistics topic for about one to two hours. Both of the intensity to study and the length of time to study was not a significant effect on the difference of students’ SRA achievement between experimental and control groups. The difference in learning model was not the only one factor that significantly influenced the difference of students’ SRA achievement. The difference of the SPK factor produced the difference of the SRA achievement between experimental and control groups. Nevertheless, there was no interaction effect between the learning model and the level of SPK to the difference of the students’ SRA achievement.

1. Introduction

Students’ statistical reasoning can be interpreted as a way or a process of students’ thinking in handling with information or statistical problem to obtain logical solution, interpretation, and conclusion based on one or more relevant statistical concepts [1–5]. Statistical reasoning abilities were needed by society in the 21st century as the information era [6, 7]. In educations, statistical reasoning ability was the main achievement of learning introductory statistics [8].

Statistical reasoning abilities can be achieved and improved through statistics learning [7, 9]. Statistics learning in the higher education curriculum in Indonesia aim to provide the basics of understanding and applying quantitative method for each of study programs graduates. However, some students have difficulties in learning statistics with the result there were some misconceptions and their statistical reasoning achievement have not improve enough. Some researchers who have observed difficulties and misconceptions, namely [10] found misconceptions in determining the mean, [11] revealed misconceptions about the median, [12] revealed misconceptions about standard deviation, and [13] revealed misconceptions about variability and probability in inferential statistics. To overcome the difficulties of learning statistics, misconceptions, and to improve students’ statistical reasoning, [14–
19] gave out their suggestions. One of their suggestions was to review and to pay attention to the learning model that applied in the classroom. The difference of learning model was thought as the influence factor of the difference in statistical reasoning achievement.

Other factors could influence students’ statistical reasoning achievement namely numerical and mathematical abilities especially among students from non-exact science backgrounds [5], from non-disciplines of science, technology, engineering, and mathematics [20]. Those factors often affected students’ anxiety about statistics and negatively correlated to students’ learning outcomes. In addition, stated by [21] that various forms of learning must be associated with individual experience or entry behavior. It has been known as the prior knowledge or the initial ability that someone has [22, 23].

This study aims to investigate the effect of learning models and academic internal factors on students’ statistical reasoning abilities. The academic internal factors include the intensity to study and the length time to study.

2. Method
2.1. Participants
Sample participants research was students of mathematics education at one of the private universities in the Bandung city. Seventy students registered in the statistics course for mathematics education research in the even semester of the 2018/2019 year. They were divided into two classes.

2.2. Experimental Design
The study used a quasi-experiment of two pretest-posttest groups [24 – 26]. The experimental group and the control group were determined by delivering group-judgment test to both learning classes.

2.3. Instruments
The test instruments used for writing test namely group-judgment test, statistical reasoning test, statistical prior knowledge test. Those test instruments had experts validation, empirical validity, and reliability instruments.

3. Result and Discussion
3.1. Participants Descriptive
Seventy students of mathematics education participated in the study. The age ranges from 19 to 22 years, with the most percentage were women (71%) and the rest were male. Description of students’ academic internal factors based on the intensity to study and the length of time to study are shown in Table 1.

| No. | Variable          | Category       | Experimental | Control | Percentage (%) |
|-----|-------------------|----------------|--------------|---------|----------------|
| 1   | Intensity         | Always         | 3            | 0       | 4.3            |
|     | to                | Sometimes      | 9            | 6       | 21.4           |
|     | Study             | Seldom         | 22           | 29      | 72.9           |
|     |                   | Never          | 1            | 0       | 1.4            |
| 2   | Length of Time    | More than 2 hours | 2          | 0       | 2.9            |
|     | to Study          | 1 – 2 hours    | 20           | 18      | 54.3           |
|     |                   | No more than 1 hour | 12         | 10      | 31.4           |
|     | *incomplete data  | Never          | 1            | 5       | 8.6            |

Most students (73%) stated that they rarely studied at home about statistics material. For students who were studying at home, there were about 54% of students who used the time to study statistics for about 1 to 2 hours.
3.2. Statistical Prior Knowledge

The statistical prior knowledge test was given to explore the students’ knowledge about understanding concepts, applying concepts, making solutions, and interpreting statistics descriptive topics. Table 2 presents the results of the statistical prior knowledge test.

| Groups     | Measure          | Minimum | Maximum | Mean   | Standard Deviation |
|------------|------------------|---------|---------|--------|--------------------|
| Experimental |                  | 46.67   | 95.56   | 73.39  | 12.39              |
| Control    |                  | 26.67   | 91.11   | 68.63  | 14.57              |

In Table 2, the mean of statistical prior knowledge test results in the experimental group was higher than the mean of it in the control group but the standard deviation in the control group was higher than it in the experimental group. It showed that the students’ ability in statistical prior knowledge in control group were more varied than they in experimental group.

However, the result of the difference testing of students ability in statistical prior knowledge between the experimental and control groups showed a non-significant result (t = 1.472, sig = 0.146). This showed that students’ statistical prior knowledge in the experimental group was the same as students’ statistical prior knowledge in the control group. Students’ statistical prior knowledge ability in those two learning models have the same abilities.

The scores of statistical prior knowledge were grouped into three levels, namely high (score ≥ 75), low (score ≤ 65), and medium for others. Figure 1 displays the frequency distribution of those levels.

Figure 1. Frequency distribution of statistical prior knowledge.

3.3. Statistical Reasoning Test

The test instrument consisted of some problems about recognizing terms and statistical notation to express hypotheses, understanding and applying statistical concepts, giving arguments, understanding and applying rules/inference process, creating and interpreting logical conclusions. The description of the pretest, posttest, Gain, and N-Gain results of students from the two learning groups is shown in Table 3.

| Groups    | Pretest | Posttest | Gain  | N-Gain |
|-----------|---------|----------|-------|--------|
| Mean      |         |          |       |        |
| Experimental | 20.68   | 71.71    | 51.03 | 0.64   |
| Control   | 20.10   | 75.37    | 55.27 | 0.69   |
Based on Table 3, the differences in the values of statistical reasoning pretest and posttest of the experimental group and the control group showed a significant increasing. The positive N-Gain about 0.64 and 0.69 shows that the increasing value from the pretest to the posttest in each learning group were included in the criteria as a moderate change [27].

3.4. Learning Model, Statistical Prior Knowledge, and Statistical Reasoning Achievement
The learning model applied in the experimental group and the control group did not significantly differentiate statistical reasoning achievement between those groups (sig. = 0.139). However, the differentiation of statistical reasoning achievement between experimental and control groups was significant when the testing involving the level of statistical prior knowledge. This result showed that the learning model and the level of statistical prior knowledge could simultaneously significant influenced on statistical reasoning achievement (sig. = 0.030). Those two independent variables have an influence of around 17% on students’ statistical reasoning achievement. The learning models significantly influenced on the statistical reasoning achievement (sig. 0.032) as well as the level of statistical prior knowledge (sig. 0.016) in both of groups.

The intensity of study did not effect on the difference of statistical reasoning achievement between the experimental group and the control group (sig. 0.825) and so did the length of time to study a statistics topic (sig. 0.640).

4. Conclusion
The experimental group was a group of students who were given statistics topics by one of the learning models that applied student center oriented and constructivist theory, namely the projects-activities-cooperative-exercises (PACE) model. PACE learning models and project learning models have been applied by [28 – 35] on various topics. Those learning models compared to traditional learning models to investigate its effects on statistical reasoning achievement. The traditional learning models or direct instructions are one of the learning models that applies teacher-center oriented and behavioristic theory.

This research has not been successful in showing the effect of different learning model to statistical reasoning achievement between the experimental and control groups. The difference of learning model had not effectively improved statistical reasoning and had not successful showed the different of students’ statistical reasoning achievement. The failure of applying the constructivist theory was in line with [36] who stated that the constructivist theory could be less effective and efficient compared to behavioristic theory.

The mean score of students’ statistical reasoning achievement in the control group performed a slightly higher achievement compared to the mean score of students in the experimental group. Students’ statistical reasoning in the traditional learning models showed better achievement than students’ statistical reasoning in the experimental learning model. This result was in line with [37] who stated that the conventional learning models could provide a better and especially impact when dealing with subjects who tend to have low achievement and have difficult in learning.

It needs further investigate about the influence of the interaction between learning models and other academic internal factors. The investigation aims to find a combination of learning models and academic internal factors that could effectively improve students’ statistical reasoning achievement.

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6. References
[1] Joan G 1997 The Assessment Challenge in Statistics Education 2 99
[2] Joan G 2002 J Stat Educ 10 1
[3] Dani B Z and Joan G 2004 Statistical Literacy, Reasoning, and Thinking: Goals, Definitions, and Challenge (New York: Kluwer Academic Publishers)
[4] Shiau W C and Zaleha I 2012 Procedia Soc. Behav. Sci. 46 3660
[5] Maria P P, Mirian A, Maribel P C and Joan G 2014 T Qual Quant 48 173
[6] Colin C, Ian H, Jane W and Rosemary C 2010 AJEDP 10 83
[7] Rabia K, Bengu B and Gulseren K A 2014 Internasional Electronic Journal Element Education 7 107
[8] Michael R H and Linda M W 2009 A Guide to Teaching Statistics: Innovation and Best Practice (United Kingdom: Wiley-Blackwell)
[9] Dani B Z and Joan G 2004 The Challenge of Developing Statistical Literacy, Reasoning, and Thinking (New York: Kluwer Academic Publisher)
[10] Pollatsek A, Lima S and Well A D 2009 Educational Studies in Mathematics 12 191
[11] Linda L C and Felice S 2008 S Journal of Statistic Education 16 324
[12] Robert D 2005 SERJ 4 55
[13] Shiau W C and Zaleha I 2013 Procedia Soc. Behav. Sci. 93 1478
[14] Dani B Z 2004 SERJ 3 42
[15] Robert D 2002 JSE 10 3
[16] Robert D 2006 Defining and Distinguishing Statistical Literacy, Statistical Reasoning, and Statistical Thinking online: https://apps3.cehd.umn.edu/artist/glossary.html
[17] Joan G 1995 International Statistical Review 63 25
[18] Joan G 2002 JSE 10 58
[19] Joan G 1993 JSE 1 1
[20] Ellen G, K Andrew R R, David N and Chantal L B 2015 JSE 23 1
[21] Inzahul I S M, Elisabeth R and Lazarus N M 2013 S MIER Journal Educational Studies. Trends Practices 3 218
[22] Flip D, Mien S and Michael M B 1999 Rev. Educ. Res. 69 145
[23] Johannes G and Alexander R 2010 Instr. Sci. 38 417
[24] John W C 2008 Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (Third Boston: Pearson International Edition)
[25] John W C 2008 Mixed Methods Research Design and Procedures (California: SAGE Publications, Inc)
[26] John W C 2014 Research Design Qualitative, Quantitative, and Mixed Method Approaches (London: SAGE Publications Ltd)
[27] Hake R R 1999 Analyzing Change/Gain Scores online: http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf
[28] Timur K and Bulen G 2014 EU-JER 3 145
[29] Timur K and Bulen G 2015 International Journal Mathematics Education Science Technology 46 658
[30] Carl Land Maria M M 2003 Joint Statical Meeting 1 2326
[31] Anthony J O and Nancy L L 2005 JISRM 8 375
[32] Carl L1997 The 6th International Symposium on Mathematics Education 1
[33] Carl Land Wachtel H 2002 The 6th International Conference on Teaching Statistics 1
[34] Zoi N, Aspasia L and Jenny P 2010 Procedia Soc. Behav. Sci. 9 795
[35] Pearce A R and Cline R L 2006 Am. J. Psychol. Res. 2 1
[36] Paul K, Richard R C and John S 2006 Educ. Psychol. 41 75
[37] Paul E and Don K 2012 Strategic and Models for Teachers: Teaching Content and Thinking Skills (Jakarta: Indeks)