Journal of Honai Math, 5(1), 1-14, April 2022
https:/doi.org/10.30862/jhm.v5i1.246

Measuring students' statistical reasoning abilities using flipped classroom model with SPSS and STATCAL

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Received: 10 February 2022 | Revised: 2 March 2022 | Accepted: 7 March 2022 | Published: 9 March 2022

Abstract

The development of Technology, Information and Communication (ICT) in education has been growing considerably. Use of technologies contribute to supporting student learning and play a vital role in the learning process. The Covid-19 pandemic, since early 2020, has impacted the implementation of the learning process, especially in higher education. The learning instruction has shifted from face-to-face to online learning (e-learning). It is undeniable that the learning process experiences disruptions, resulting in significant changes in the learning environment. Thus, the flipped classroom model is likely to be on model for educators in higher education. This study aims to investigate an increase in the statistical reasoning abilities of engineering students taught using the flipped classroom model assisted by SPSS and STATCAL applications analyzed based on gender. Participants involved 55 first-year informatics engineering students. Data were collected using a test in the form of essay questions and then analyzed using the stacking method of the Rasch measurement model. The results showed that the statistical reasoning abilities of students improved after being taught using the flipped classroom model with the SPSS and STATCAL applications. This finding implies that the flipped classroom model assisted by SPSS and STATCAL applications is effectively implemented in technology-integrated statistics learning.

Keywords: Flipped Classroom Model, SPSS, STATCAL, Statistical Reasoning

Introduction

Education has undergone significant transformations since the onset of the Covid-19 pandemic. The learning process that was previously carried out face-to-face has experienced significant changes and disruptions. To anticipate this issue, education stakeholders have taken various approaches to find effective solutions for the optimal implementation of educational programs during the Covid-19 pandemic. One of the solutions offered is the implementation of a technology-integrated learning model. This notion is supported by Junaidi, et al (2020), stating that changes in the learning process, especially at the higher education level, can take advantage of learning models that support technology-integrated distance learning. In fact, the implementation of online learning has not only been motivated by the Covid-19 pandemic, but also the demands of the digital and information era. In this case, higher education ensures that the learning process transformed from face-to-face to online learning (e-learning) does not reduce the quality of the educational program. In addition, Sumantri, et al (2020) explained that changes in the learning process can be identified as part of improving the competence and quality of educational programs that integrate implementation procedures through technology. The existence of face-to-face learning is gradually replaced by virtual classrooms with various learning platforms that have been previously available and those developed by higher education institutions based on the learning management system. In addition to that, online learning is supported by implementing the flipped classroom model, which can have much of the learning occur online (e.g., instructional videos) and allow class time for practice and application learning. Moreover, in an online environment, active engagement of students during class has potential to keep student attention possibly compared to a lecture style of instruction.

The flipped classroom model is a mixed learning model in which learning activities are carried out in two stages: in-class learning (face to face) and out-of-class learning (online). In the first stage, in-class learning is carried out through discussions that prioritize students with high need for support as the main focus of improvement and make learning activities more active, interactive, and meaningful. Alternatively, out-of-class learning is conducted using an online learning platform that contains learning materials and videos. It aims to provide opportunities for students to learn the lesson before it is taught in the actual classroom (face to face) and to develop the ability of students to learn independently (Ramadhani, 2020; Ramadhani, Bina, et al., 2020; Ramadhani & Fitri, 2020).

Thus, the role of face-to-face learning in the classroom becomes “inverted”. It means that students already recognize what lesson will be taught in the actual classroom before it is conducted. Shraddha, et al. (2020) indicated that this model focuses on students’ active learning, in which students apply the concepts rather than merely memorize them. There are four pillars in the implementation of the flipped classroom model, including F (Flexible Environment), L (Learning Culture), I (Intentional Content), and P (Professional Educator). Several previous studies have acknowledged that the flipped classroom model as an active learning strategy can improve students’ learning experiences (Herreid & Schiller, 2013; Siegle et al., 2013) more effectively compared to traditional lecture and discussion-based learning models (Baytiyeh, 2017), and have a positive influence on students’ learning environment (Krouss & Lesseig, 2020).

The use of the flipped classroom paradigm improves students' mathematical abilities, one of which is statistical reasoning. Statistical reasoning is defined as the way one thinks of statistical ideas and understands statistical information, including interpreting data, connecting one concept to another, and explaining statistical procedures. Statistical reasoning is also an ability associated with one's understanding of the basic concepts and logic of statistical reasoning and the practical ability to choose, generate, and interpret descriptive and inferential methods appropriately (delMas, 2002; Garfield, 2002). Sariningsih and Herdiman (2017) defined statistical reasoning as a form of reasoning closely related to probability numbers used in the process of drawing conclusions and making decisions in situations that cannot be expressed from probability perspectives that have been well-recognized. Chan et al. (2014, 2016) also provides an overview of statistical reasoning as the formation of conclusions and judgments according to data from observational studies, experiments, or surveys of certain samples.

Garfield (2002) has developed five levels of statistical reasoning model: idiosyncratic reasoning (Level 1), verbal reasoning (Level 2), transitional reasoning (Level 3), procedural reasoning (Level 4), and integrated reasoning (Level 5). The description of five levels of statistical reasoning ability are be presented in Table 1.

Table 1. The description of statistical reasoning ability

Level	Description
Level 1: Idiosyncratic Reasoning	Students can use statistical terms and symbols, but they cannot wholly comprehend and link them to relevant data, resulting in erroneous replies. Students, for example, understand the word standard deviation but are unable to apply it accurately and responsibly when faced with an issue involving the term.
Level 2: Verbal Reasoning	Students can do better since they understand the meanings of various statistical concepts, but they don't apply them correctly. Students may be able to choose the accurate definition of the interquartile range, but they may be unable to respond to an abstract topic or problem.
Level 3: Transitional Reasoning	Students can identify one or two components of the statistical process, but they cannot put the concepts together to discover answers. The student, for example, can recognize shapes, measurements of central tendency, variability, and graphical representations but is unable to apply them to problem-solving solutions.
Level 4: Procedural Reasoning	Students can identify statistical processes accurately, but they cannot wholly comprehend or integrate them. Students, for example, may grasp the concept of average but not fully interpret it.
Level 5: Integrated Reasoning	This level of students has a thorough understanding of statistical processes and is capable of coordinating rules and behavior and explaining processes in their own words.

Jones et al. (2000) and Mooney (2002) described the constructs developed in statistical reasoning: describing data, organizing and reducing data, representing data, and analyzing and interpreting data. Describing data refers to reading the data expressed directly in the charts, tables and other graphical displays. Organizing and reducing data involves classifying, organizing, or combining data into a synopsis form and reducing data using measures of central tendency and variability. Representing data can be interpreted as displaying data in a graphical form. Analyzing and interpreting data involves recognizing trends and making predictions or conclusions from graphical displays.

The flipped classroom model can be implemented in statistics learning for informatics engineering students. However, its implementation needs to be supported by technology-integrated learning media as many students find it difficult to understand statistical problems, especially those related to variability and standard deviation (Chan & Ismail, 2014). Students also encounter challenges to do statistical reasoning concerning the results of statistical tests carried out manually (Arum et al., 2018; Blackburn, 2015). Therefore, SPSS and STATCAL applications integrated with the flipped classroom model can be used as a supporting learning media in statistics learning. SPSS initially stood for "Statistical Package for the Social Sciences," which was previously used exclusively for social sciences. However, along with the market demand and the extensive use of this software, the abbreviation of SPSS changed to "Statistical Product and Service Solutions," which is a statistical application to manage and analyze data for a wide range of purposes by using statistical techniques in various fields (Ramadhani & Sribina, 2019).

STATCAL (Statistic Calculator) is a free statistical application and was developed was developed using the R programming language at RStudio. STATCAL uses the R package to perform statistical and graphical data analysis. In the STATCAL application, there are nine main menus: STATCAL, Input Numeric Data, Input Categorical Data, Graph, Descriptive, Statistics, Probability, Video Tutorials, and Guidance (Gio & Caraka, 2018).

The research question for this study is as follows: Is there an increase in the statistical reasoning abilities of engineering students taught using the flipped classroom model assisted by SPSS and STATCAL applications analyzed based on gender?

Methods

The current study was conducted at Universitas Potensi Utama from March to May 2021. Participants involved in this study were 55 first-year informatics engineering students. The demographic characteristics of the participants are presented in Table 2.

Table 2. Demographic characteristics of participants

Indicator		The number of students	Percentage
Gender	Male	37	67.28%
	Female	18	32.72%
Age	17-19 years	48	87.28%
	20-22 years	7	12.72%

The participants in this study were split into two groups, with 30 students in the experimental group and 25 in the control group, who were chosen using a purposive sampling procedure. This study was experimental research with a pre-test post-test control group design, in which two classes were applied: the control class (using the flipped classroom model without SPSS and STATCAL applications) and the experimental class (using the flipped classroom model with SPSS and STATCAL applications). Based on the Table 1, the participants in this study are between the ages of 17 and 22. Students in that age range were chosen because, according to Piaget's cognitive development theory, they were at the formal operational level (11 years and above) at that age. Students are at their greatest level of cognitive development during the formal operational phase, in which they can think logically about all types of hypothetical situations, apply scientific reasoning, and accept other people's points of view (Heidari & Rajabi, 2017; Lefa, 2014).

The flipped classroom model consists of two stages: pre-class (out-of-class learning) and in-class learning. This study employed lecture videos uploaded on a sharing site (YouTube) for in-class learning and the learning management system (Google Classroom) for out-of-class learning. Prior to instructions, the students were given a pre-test on a statistics lesson to assess the extent to which they understood statistics. The same test was re-administered after they received the lesson using the flipped classroom model with SPSS and STATCAL (for the experimental class) and without SPSS and STATCAL (for the control class). Both pre-test and post-test results were then analyzed using the stacking analysis of the Rasch measurement model by means of the Winstep program. The Rasch model is used for analyzing categorical data.

Rasch Model Measurement is a type of measurement analysis that uses the Joint Maximum Likelihood Estimation (JMLE) equation to convert raw data into the interval (logit) data. It was invented by George Rasch (a Danish mathematician) (Soeharto, 2021). Rasch's estimation is based on how item-person and probability estimations interact. Logit values can be used to mathematically express the interaction between items and people (in this case, students) (log odd units). The difficulty of the item and person simultaneously determines the measurement's probability, resulting in the logit item value (using the odd probability of each item) and the logit person value (using the odd probability of each respondent). Based on that, the probability is inversely related to the distance between items (Boone, 2016; Boone et al., 2014). Rasch analysis was used to solve some of the problems with Classical Test Theory in this study (CTT). Rasch's analysis provides information that regardless of the item's difficulty level, the student's ability to measure remains constant, while the item's difficulty level remains constant regardless of the student's ability.

Rasch Model Measurement has developed several measurement models, ranging from dichotomous models to tests that involve multiple facets. One data analysis on the Rasch Model used in this research is Stacking analysis. Stacking analysis is a data analysis technique that vertically places pre-test and post-test data together (Combrinck et al., 2017). Each student has two rows of data, namely pre-test and post-test data. Each student appeared twice in the data set, while the test items used only appeared once in the experimental and control classes. The data placement allowed the researcher to examine changes in each student after the intervention. Each student examined must be based on the same test item, so that changes in students' abilities on the pre-test and post-test can be measured. Measures of student ability on each pre-test and the post-test item can be compared because the data is analyzed in one single measurement but produces an item size for each student and one measure for each item (Laliyo, 2021; Uzun & Öğretmen, 2021).

Results and Discussion

The assessment instrument comprised five essay questions with a score ranging from 1 to 5. The validity and reliability of the instrument were tested using the Rasch measurement model. The validity test refers to the following indicators:

a. Item (Column): Fit Order, where the value of Outfit Mean Square (MNSQ) is between 0.5 and 1.5
b. The value of Outfit Z-Standard (ZSTD) is between -2 and +2
c. The value of Point Measure Correlation (Pt. Mean Corr) is between 0.4 and 0.85 (Arnold et al., 2018)

Meanwhile, the reliability of essay questions and the questionnaire was assessed using Cronbach's alpha, as presented in the statistics summary table in the Winstep program. The validity test utilizing the Winstep program revealed that the five essay questions and questionnaire have satisfied the three indicators and are declared valid. The reliability values (Cronbach's alpha) of the essay questions and questionnaire in the Rasch measurement model using the Winstep program are 0.92 and 0.82, indicating a very good category. The valid and reliable instruments (essay questions and the questionnaire) were then applied to the experimental and control classes.

Data derived from the implementation of flipped classroom model (the control class) and the flipped classroom model with SPSS and STATCAL (experimental class) were analyzed using the stacking method of the Rasch measurement model. The test results yield a logit value which will then be used to observe changes in students' statistical reasoning abilities before and after treatment.

The logit value is obtained from students' raw test scores. Thus, the Rasch stacking method does not use students' overall final score but rather each student's score for each question. This method refers to the item response theory (IRT). The difference of logits in the pre-test and post-test scores of students' statistical reasoning abilities in both classes (experimental and control) is depicted in Table 3.

Table 3. The difference of logits in the experimental and control classes

Student Code	Experimental Class			Control Class		
	Logit in Pretest	Logit in Posttest	The Difference of Logits	Logit in Pretest	Logit in Posttest	The Difference of Logits
01	-1.44	3.38	4.82	-3.24	1.22	4.46
02	-1.44	3.38	4.82	-2.68	2.17	4.85
03	-0.23	3.95	4.18	-3.84	1.71	5.55
04	-2.10	3.95	6.05	-3.84	2.17	6.01
05	-1.44	3.95	5.39	-3.24	2.17	5.41
06	-1.44	2.36	3.8	-2.68	2.64	5.32
07	-2.83	3.38	6.21	-3.24	2.17	5.41
08	-0.82	3.95	4.77	-3.84	2.64	6.48
09	-2.83	2.86	5.69	-2.14	2.17	4.31
10	-1.44	4.64	6.08	-1.60	1.22	2.82
11	-2.10	3.38	5.48	-2.14	2.64	4.78
12	-2.83	4.64	7.47	-2.68	1.22	3.9
13	-3.61	2.86	6.47	-2.68	1.71	4.39
14	-2.10	3.38	5.48	-2.14	1.71	3.85
15	-0.82	2.36	3.18	-2.14	0.70	2.84
16	-1.44	3.38	4.82	-1.60	1.71	3.31
17	-0.82	2.36	3.18	-3.24	1.22	4.46
18	-2.10	2.86	4.96	-2.14	1.71	3.85
19	-0.82	3.38	4.2	-2.14	2.17	4.31
20	-2.10	3.95	6.05	-2.68	0.70	3.38
21	-0.82	3.95	4.77	-2.68	1.71	4.39
22	-2.83	3.95	6.78	-3.24	0.14	3.38
23	-4.40	3.38	7.78	-1.60	1.71	3.31
24	-4.40	2.86	7.26	-2.68	0.70	3.38
25	-2.10	3.38	5.48	-2.14	1.71	3.85
26	-0.23	3.95	4.18			
27	-1.44	4.64	6.08			
28	-0.82	4.64	5.46			
29	-2.10	2.86	4.96			
30	-2.83	3.38	6.21			
Mean			**5.402**			**4.320**

Table 3 revealed that the average difference in logits for pre-test and post-test in the two classes is different. The experimental class has a higher mean logit than the control class (5.402

> 4.320). The difference in the logits of the pre-test and post-test for each student in both classes is presented in Figures 1 and 2.

Figure 1 displays those four students with codes OE10M, OE12F, OE27F, and OE28M from the experimental class attain the highest logit in the post-test. In the pre-test, a student with a code PE28M occupies the logit less than 0, students with codes PE10M and PE27F are located in the logit less than -1, and a student with a code PE12F holds a position less than -2 logits. Meanwhile, students with codes PE23M and PE24M show an increased logit score in the post-test, located at the logit less than +4 (i.e., OK23M and OE24M); whereas they attain the lowest logit in the pre-test).

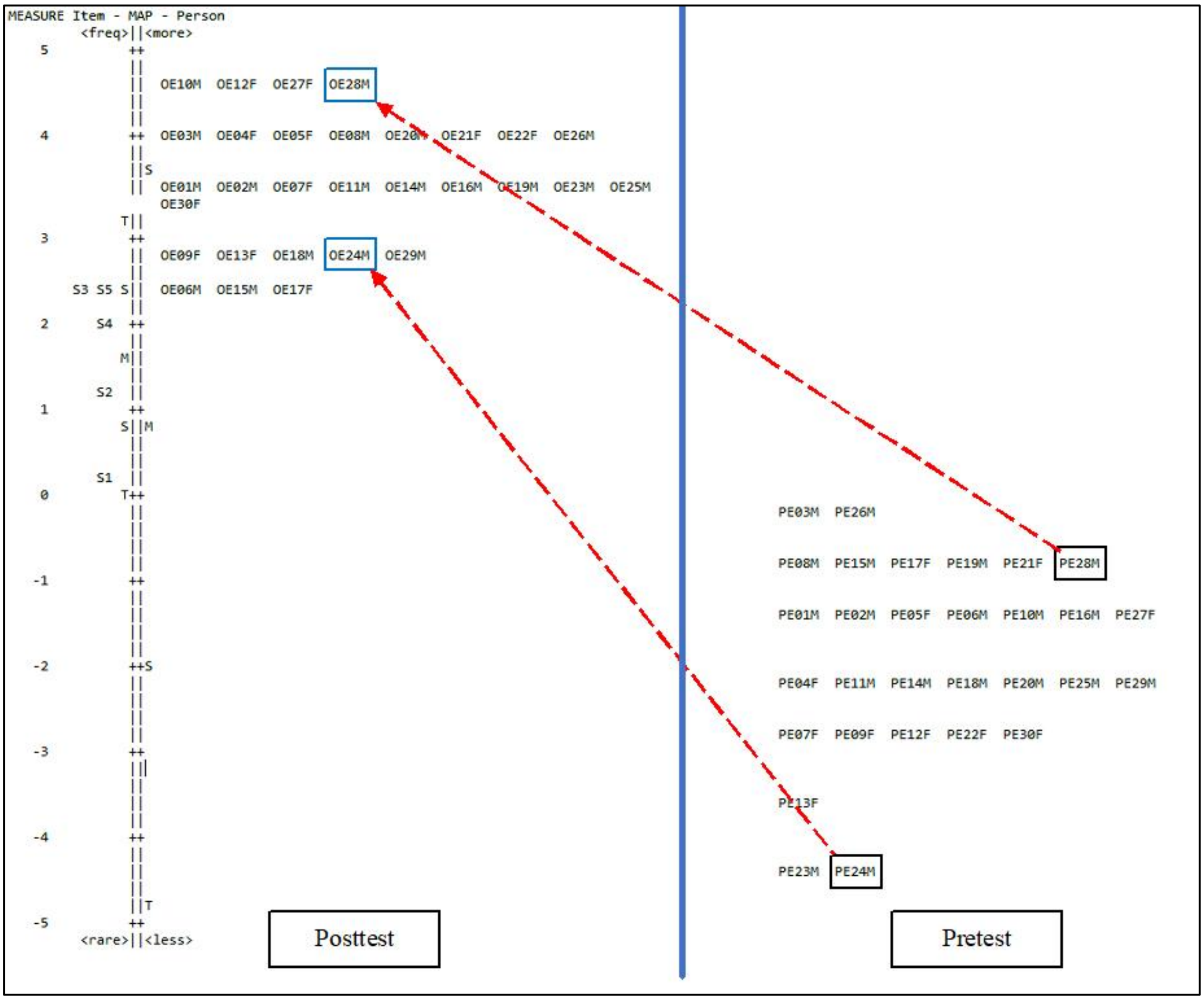

Figure 1. The wright map of the difference in logits between pre-test and post-test in the experimental class

The finding indicates that the difference of the logits for the four students seems quite significant. Both male and female students in the experimental class do not have a significant difference in the logit scores in the post-test. It is evident from a subtle difference in the logits among several male and female students. This result implies a proportional increase in statistical reasoning abilities of students in the experimental class in terms of genders.

Figure 2 illustrates those three students with codes OK06M, OK08F, and OK11M in the control class have the highest logit in the post-test. In the pre-test, a student with a code PK11M is located at -2 logits, a student with a code PK06M is below -3 logits, and a student with a code PK08F holds a position below -4 logits. Whilst students with codes PK03M, PK04M, and PK08F who hold the lowest logit in the pre-test also perform an increase in the logit score in the post-test. That is, a student with a code OK03M has a position less than +2 logits, a student with a code OK04M is below +3 logits, and a student with a code OK08F is located at the logit less than +3. OK08F is one of the students who achieve the highest logit in the control class although he obtains the lowest logit in the pre-test.

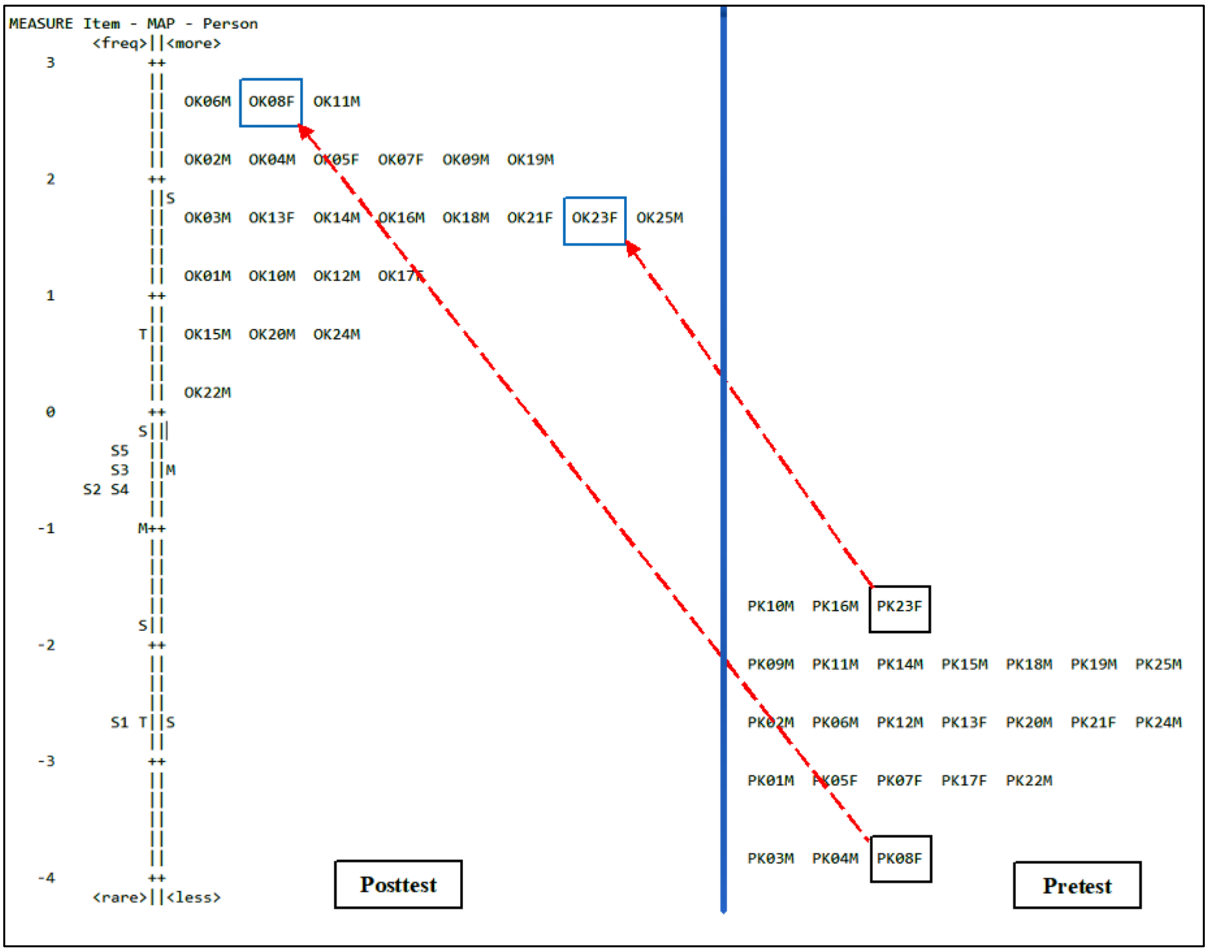

Figure 2. The wright map of the difference in logits between pre-test and post-test in the control class

The finding also shows a fairly significant difference in the logits among the three students. In the post-test, male and female students from the control class do not demonstrate a significant difference in the logits. It is indicated by insignificant changes in the logits among some male and female students. This finding points out that students in the control class perform a balanced increase in statistical reasoning abilities when analyzed based on genders.

The findings have answered the research question proposed in this study; the statistical reasoning ability of engineering students has increased, indicated by differences in the logits.

These differences are observed based on the scores attained by students from the experimental and control classes, either in pre-test or post-test. The findings also suggest that gender does not influence the increase in statistical reasoning abilities of engineering students, which means there is no difference in the treatment received by male and female students.

Ramadhani, et al (2020) stated that gender does not influence the increase in students' mathematical abilities. The increase in students' mathematical abilities is strongly influenced by the treatment students receive during the learning process (Ching et al., 2020; Markauskaite, 2006), that is, the implementation of the flipped classroom model, either with SPSS and STATCAL (experimental class) or without SPSS and STATCAL (control class). In this regard, one may conclude that the SPSS and STATCAL applications appear to be significant to assist students in understanding the statistics lesson, thereby increasing their statistical reasoning abilities.

Moreover, the flipped classroom model offers students comfort and a different learning experience. It allows them to promote creativity and excellent communication skills during the learning process impacted by the Covid-19 pandemic (Molnar, 2017; Qurat-ul-Ain et al., 2019). Moreover, these findings present evidence that technology-based distance learning can be carried out optimally, albeit amid the pandemic, by applying innovative, creative, and attractive learning instructions. One of the recommended learning models is the flipped classroom model.

Conclusion

Implementing an appropriate learning model provides comfort and a new learning experience. The flipped classroom model is a recommended learning instruction for technology-based distance learning amid the pandemic and perhaps beyond. The use of media, such as SPSS and STATCAL, provides convenience and flexibility for students in developing creativity and statistical reasoning needed to learn statistics. According to research findings examined using Stacking Analysis, the statistical reasoning skills of engineering students had improved, as seen by changes in the logit value produced by students. The outcome of the changes in students' statistical reasoning abilities before and after the flipped classroom model treatment. According to the stacking analysis technique, the development in statistical reasoning abilities of engineering students was not affected by the gender or gender of the students, according to the stacking analysis technique. According to the findings, there is no difference in how male and female pupils are treated. More detailed research findings connected to changes in students' statistical reasoning ability can be found using stacking analysis approaches. It demonstrates that factors such as gender have little bearing on changes in students' statistical reasoning abilities.

The research findings recommend that other researchers implement the flipped classroom model in mathematics learning, not only for students at the higher education level but also at the primary and secondary levels. It is also necessary to conduct further research applying other media, such as GeoGebra, Cabri-3D and others, to ease students and teachers in mathematics learning, particularly during the Covid-19 pandemic. Other external factors can also be used to compare the increase in mathematical abilities among students.

Acknowledgment

We would like to thank Universitas Potensi Utama and Pace University for providing facilities and opportunities to develop this research to completion and collaboration.

Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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