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The Effects of Statistical Reasoning Learning Environment in Developing Secondary Student's Statistical Reasoning

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Abstract: Statistics is generally taught using conventional methods in most schools but such approach can only enhance students' procedural understanding and not conceptual understanding. As an alternative, a new model called Statistical Reasoning Learning Environment (SRLE) was examined to investigate the effects of SRLE in developing the statistical reasoning ability of tenth grade students. A quasi-experiment was designed in the form of pretest-posttest non-equivalent group. Total 67 students were chosen from two secondary schools in Johor, Malaysia. About 35 of them were assigned as experimental group that would receive treatment in SRLE while 32 of them were assigned as control group with no treatment given. Technology-based statistical reasoning tasks were utilized during the treatment. Meanwhile, the pretest and posttest were administered to all students in both groups before and after the treatment. The data obtained was analyzed using two-way mixed design ANOVA and one-way ANOVA. The findings showed that statistical reasoning ability of students who had been exposed to SRLE was better than students in the control group. There was no considerable discrepancy on the statistical reasoning ability of students who was exposed to SRLE with regard to the chosen four constructs. To conclude, SRLE has great positive impact on students' statistical reasoning ability in this study

Key words: Supply chain technology, supply chain agility, textile and apparel industry, ability, Malaysia

INTRODUCTION

Statistics is an essential domain in many fields, for instance economics, engineering, physics, education and chemistry. It is also one of the mandatory disciplines in the Malaysian education system from primary to tertiary levels. However, traditional teaching techniques have largely failed in fostering most student's conceptual understanding of statistics due to its biased emphasis on skills, procedures and calculation (Miyahara and Pazzani, 2000). Besides, the traditional assessments are by large, incapable of guiding students to reason statistically, this has left students equipped only with procedural understanding in statistics. At the same time, their understanding is also constrained by common statistical misconceptions, notably when interpreting graphs and tables (Zieffler *et al*., 2008). Hence, many researchers and instructors in the statistics field have begun to put in more efforts to transform the teaching and learning environment for statistics at all educational levels from its contents and pedagogy to its technology aspects (Sharma, 2006).

To enhance students' conceptual understanding in statistics, appropriate instruction and assessment should be adopted in the statistics classroom. Therefore, the Statistical Reasoning Learning Environment (SRLE) which is an instructional model, is proposed in this study. This model is different from traditional approaches from the perspectives of its role in technology, focus of lesson, assessment, centre, data, discourse and function of textbook (Garfield and Zvi, 2008). Nevertheless to date, there is still a lack of empirical support for the SRLE's

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effectiveness in spite of its application in many studies and this is especially so within the secondary school context. Moreover, no study has yet to be done in Malaysia. Thus, this study intends to bridge this gap by determining the impact of SRLE on the statistical reasoning ability of tenth grade students. The following research questions were scrutinized in this study:

- Is there a statistically significant main effect of the pretest and posttest between students who are exposed to SRLE and a control group
- Is there a statistically significant interaction between tests (pretest and posttest) and groups (experimental group and control group)
- Is there a statistically significant difference in the statistical reasoning ability of students who are exposed to SRLE with respect to the four constructs?

Literature review: There are six instructional principles in Statistical Reasoning Learning Environment (SRLE) as recommended by Cobb and McClain (2004) and Garfield and Zvi (2008) namely: emphasis on developing central statistical concepts; utilization of real and stimulating data sets; usage of classroom activities; incorporation of appropriate technological tools; enhancement in classroom discourse and employment of alternative assessment. In the SRLE class, central statistical ideas like measures of central tendency, distribution and variability are highlighted by the instructors. The instructors also assist the students in observing the interrelationship of these ideas (Garfield and Zvi, 2008). The central statistical ideas need to be emphasized because most students have misconceptions even in basic concepts (Cobb and McClain, 2004). Excessive information in the syllabus may result in the students' inability to truly understand the essence of the concept. Hence, it is wiser to draw the attention to the central statistical concepts.

This study has exploited real and stimulating data sets in the SRLE classroom. According to Shaughnessy *et al*. (1996) real data can be categorized into several types such as archival data, simulated data and classroom generated data and these can be obtained through several approaches recommended by Garfield and Everson (2009). One of the approaches is by searching surveys and internet. Another way is by generating the data from the students in the classroom. The involvement of students in the real world context activities can motivate and facilitate their learning of statistics as well as promote their statistical ideas and thinking about data.

The classroom activities can be performed in the SRLE class through various kinds of methods such as cooperative learning, collaborative learning and problem-based learning. Cooperative learning is a type of active learning which has also been used in this study. It involve a small group of students that work together to complete task, solve problem and attain a common target. Numerous studies have indicated a positive impact of cooperative learning on students. For instance, (Ebrahim, 2012) study demonstrated that the students' achievement and social skills had significantly improved when cooperative learning method was used instead of a teacher-centered approach.

In the SRLE class, the information technology is utilized because it can foster statistical reasoning. For the last few decades, a surge has been observed in the incorporation of information technology into the teaching and learning processes; the modern classroom is no longer restricted to conventional approaches anymore (Chen *et al*., 2012). This study utilized a dynamic mathematical program called GeoGebra. This can be downloaded free-of-charge from the official website since it is from an open source (Hohenwarter and Peiner, 2007). By using the GeoGebra spreadsheet, the students can explore and manipulate the data as well as construct the graphs easily to visualize the abstract statistical ideas.

Besides that, classroom discourse is encouraged in the SRLE classroom to foster deeper conceptual understanding among the students. This is done by using good questions to trigger students' reasoning without restricting them to merely one accurate solution, for example 'What would happen i and 'What do you think?'. Furthermore, they are encouraged to explain their reasoning, clarify their opinions and illuminate their solutions in the class (Garfield and Zvi, 2009).

Assessment is an essential aspect in the teaching and learning procedure as it enables instructors to scrutinize student's reasoning and conceptual knowledge (Lin, 2006). There are various types of alternative assessment such as tests, projects, open-ended problems, portfolios, article critiques, written reports and so forth. The present design of alternative assessment has been paralleled with current curriculum to allow students to exhibit their aptitude and assess their learning from many areas.

The underlying theory for SRLE model is social constructivism which is strongly influenced by the research of (Vygotsky *et al*., 1978). This theory supports that students' knowledge are being constructed when there is a social interaction between them and their instructors and their cognitive development will be promoted. This development is affected by the culture and language as well (Eggen and Kauchak, 2007). In more specific terms, student's zone of proximal development is supported by scaffolding during the social interaction (Powell and Kalina, 2009).

On the other hand, the discrepancies between the SRLE classroom and traditional classroom are abundant. Firstly, traditional classes are teacher-centered where instructors explain and inform the students. Unlike traditional class, the instructors in SRLE classrooms are student-centered where students develop their understanding by conducting discussion and activities. Secondly, in the traditional class, the questions are answered by the instructors; in the SRLE class, the questions are posed by the instructors and answered by the students. Thirdly, procedures and skills are stressed on in the traditional class while big ideas are emphasized in the SRLE class. Fourthly, formulas, computations and definitions are the main focuses in the traditional classroom's assessments, but reasoning and thinking are underlined in the SRLE classroom's assessments. Fifthly, small data sets are utilized in traditional classes but real and rich data sets are utilized in the SRLE classes. Lastly, in the traditional class, technology is only applied to compute or prove the answers; in the SRLE class, technology is used to explore data, generate simulations and test assumptions (Garfield and Zvi, 2008).

In this study, the four constructs of Jones *et al.* (2000), i.e., describing data, organizing and reducing data, representing data and analyzing and interpreting data were adopted. According to Shaughnessy *et al.* (1996), these four construct are important for data handling, however they are difficult to be mastered by the students. Hence, they are employed to construct the statistical reasoning assessment instruments in the present study in order to overcome this problem. Describing data refers to the precise reading of raw data or data displayed in the tables, charts or graphs (Jones *et al.*, 2000). Organizing and reducing data entails classifying, arranging or uniting data into a summary form (Moore, 1997) and reducing data uses measures of central tendency and variability (Jones *et al.*, 2000). Meanwhile, representing data involves exhibiting the data graphically with, but not limited to, fundamental conventions such as title and axes. Identifying patterns, trends and forming assumption or inference from the data is regarded as analyzing and interpreting data (Jones *et al.*, 2000).

MATERIALS AND METHODS

Research design: In this study, a quasi-experimental in the form of pretest-posttest non-equivalent group design was employed. There were 67 participants from the 10th grade involved. They were assigned randomly into two groups which were experimental group and control group. The experimental group was exposed to SRLE and the control group was not. Since the intervention was not allowed in the school, the control group was not taught on how to solve the statistical reasoning questions. However, the presence of control group is very important to inspect whether there are threats that influence the internal validity of the experiment, for instance testing effect and history effect (Lodico *et al.*, 2010). The instruments utilized were pretest and posttest. The usage of pretest and posttest is to explore the effects of SRLE on the statistical reasoning ability for these Grade 10 students. Technology-based statistical reasoning tasks were also employed to enhance student's statistical reasoning ability. The results of pretest and posttest served as the quantitative data and were analyzed using inferential statistical analyses.

Participants: About 67 students from Grade 10 took part in the present study. They came from two secondary schools, P and Q, in Johor, Malaysia. The instructors from school P were enthusiastic to give cooperation and allowed the researcher to carry out intervention in their class, but the instructors form school Q did not allow the intervention. So, the 35 students of school P were assigned as the experimental group and the other 32 students from school Q were assigned as the control group. There were 11 males and 24 females in the experimental group. The 10 students were Malay, 11 were Chinese and 14 were Indian. The control group comprised of 9 males and 23 females where 9 of them were Malay, 14 were Chinese and 9 were Indian. The ages for all the participants were 16 year old. However, 3 students from the experimental group were absent during the posttest, leaving only 32 students during the posttest. Owing to ethical considerations, the students' permission and voluntary were sought after before they were involved in this study. Their names and identities were also remained anonymous and confidential and such was made known to them. So, pseudo names like S1-S10 were utilized instead.

All the students had learnt about statistics in their syllabus at the point of testing because the present study was implemented after the final examination. In the tenth grade curriculum, a single statistical topic can be found in both general mathematics and additional mathematics' syllabus. For general mathematics, the students are taught the idea of mean and mode of grouped data, the idea of class interval, presenting and inferring data using frequency polygon to solve problem, comprehending the idea of cumulative frequency and comprehending and utilizing the idea of measures of variability to solve problem. For additional mathematics, they are taught to know and employ the idea of measures of central tendency as well as the idea of measures of variability to solve problem. In this study, these topics were taught to all the students within a month using traditional instruction using chalkboards, similar textbooks and paper-and-pencil activities.

Instrumentation: In this study, two major instruments were employed-pretest and posttest. These instruments were created upon the four key constructs from the study of Jones *et al*. (2000), namely describing data; organizing and reducing data; representing data; and analyzing and interpreting data. Students' statistical reasoning ability was determined using pretest and posttest. In both tests, the topics included were topics of descriptive statistics such as measures of central tendency and variability. There were 25 true and false questions; the students had to choose true or false in part A and provide their explanations in part B. The internal consistency reliability of the posttest was examined and the cronbach alpha obtained was 0.813. Since this has exceeded 0.80, the instrument is considered as good according to the definition of (George and Mallery, 2003).

The content validity of pretest and posttest had also been determined by three experts in the statistical reasoning area. These lecturers of foreign universities have given their valuable comments on the content for both tests to ensure that all items match the four constructs and are able to evaluate students' statistical reasoning ability. Expert A and B are the lecturers from University of Minnesota and Illinois State University in the United States. Meanwhile, Expert C is the lecturer from the University of New England in Australia. They have broad experience in teaching statistics and have published numerous papers concerning statistical reasoning in journals, proceedings and book chapters. The communication was done through e-mails. The instruments were sent to the one of the experts and revisions were made based on the comments, responses, views and recommendations before they were sent to the next expert.

Procedure: The duration of the quasi-experiment was 2 weeks. At first, the Malaysian Ministry of Education and the Johor Education Department's approval was obtained to execute the research at the secondary schools. After that the permissions of the headmasters and instructors were fetched to conduct the study at their schools. At the outset of this study, the students from both groups were given a 1 h pretest. Then, an hour briefing was given to the experimental group concerning some crucial statistical ideas and the attributes of the Geo Gebra Software. They were required to install the Geo Gebra Software into their laptops and explored the Geo Gebra Software in order to familiarize themselves with the usage of this software. Next, this group was taught in the SRLE for 3 consecutive days and lasted for around 5 h. During the treatment, the instructors employed the technology-based statistical reasoning tasks to train students on how to solve the statistical reasoning problems. The central statistical concepts for technology-based statistical reasoning were measures of central tendency, distribution and variability. Meanwhile, the real data were embedded into the tasks as well. When conducting those tasks, the students worked cooperatively by sharing a computer and conducting the tasks in pairs. Besides that, some good questions had been used to stimulate students' statistical reasoning throughout the classroom activities including 'What do you think?' and 'What would happen if…'. Students interacted actively in the classroom by asking questions, discussing, defending their dispute and providing feedbacks. In contrast, the control group did not receive any treatment which means that they were not instructed on how to deal with the statistical reasoning problems. Subsequent to the treatment, the students from both groups were administered the posttest. In this study, the pretest, technology-based statistical reasoning tasks and posttest were served as alternative assessments.

RESULTS AND DISCUSSION

Statistical reasoning ability of students: srle group versus control group: The two-way mixed design ANOVA was conducted to address the research question 1 and 2. It was found that the main effect of the pretest and posttest was significant because $F(1.62) = 30.920$ and $p = 0.000<0.05$, as displayed in Table 1. It means that the pretest and posttest have remarkable distinction.

Besides that, Table 1, the value of $F(1.62) = 33.226$ and $p = 0.000<0.005$ exhibited that the interaction between tests and groups has been significant as well. Experimental group's changes from pretest to posttest are different from that of the control group. After the SRLE treatment, the scores obtained by experimental group had improved considerably. On the contrary, the scores obtained by the control group were somewhat constant from the pretest to posttest. These two groups were identical since, the mean scores of the experimental group ($M = 17.84$, $SD = 4.112$) and control group ($M = 16.34$, $SD = 4.660$) in the pretest were almost equivalent. This indicates that all the students are equally capable in answering the questions. This is

Table 1: Tests of within-subjects effects

Sources	Type 3 sum of squuares	df	Mean	F-value	Partial Sig.	η^2
Test						
Sphericity	582.258	1	582.258	30.920	0.000	0.333
Assumed	582.258	1.000	582.258	30.920	0.000	0.333
Greenhouse-	582.258	1.000	582.258	30.920	0.000	0.333
geisser	582.258	1.000	582.258	30.920	0.000	0.333
Huynh-feldt						
Lower-bount						
Test*group						
Sphericity	625.695	1	625.695	33.226	0.000	0.349
Assumed	625.695	1.000	625.695	33.226	0.000	0.349
Greenhouse-	625.695	1.000	625.695	33.226	0.000	0.349
geisser	625.695	1.000	625.695	33.226	0.000	0.349
Huynh-feldt						
Lower-bount						
Error test						
Sphericity	1167.547	62.000	18.831			
Assumed	1167.547	62.000	18.831			
Greenhouse-	1167.547	62.000	18.831			
Geisser	1167.547	62.000	18.831			
Huynh-feldt						
Lower-bount						

Table 2: The results of ANOVA from the posttest of students in the experimental group based on the four constructs

Variables	Sum of squres	df	Means square	F-value	Sig.
Batween groups	161.870	3	53.957	0.719	0.546
Within groups	3452.950	46	75.064		
Total	3614.820	46			

imperative to preserve the equality of both groups to eliminate threats and support the study (Gay *et al*., 2009). Furthermore, the mean scores of the experimental group in the posttest was 26.53 with SD = 7.951. Meanwhile, the mean scores of the control group in the posttest was 16.19 with SD = 4.373.

The first research question was to identify the main effect of pretest and posttest between the experimental group and control group. The findings demonstrated that the main effect of the tests was noteworthy and the overall statistical reasoning ability of all students had been enhanced from the pretest to posttest. The second research question was to recognize the interaction between tests and groups. The findings revealed that the interaction was prominent; the development of statistical reasoning ability between the groups was remarkably different where the experimental group had clearly surpassed the control group after the SRLE treatment. Thus, the treatment has great effects on the statistical reasoning ability of students. Such finding coincides with the finding of Sun and Buys (2010) where the critical thinking, research skills and learning of the students administered with the six principles of their STLE model have been improved.

Statistical reasoning ability across four constructs: A One-Way Analysis of Variance (ANOVA) was also performed to answer research question 3. In Table 2, it demonstrated that the findings of posttest are $F(3,46) = 0.719$ and $p = 0.546>0.05$. It implied that there was no substantial distinction on the statistical reasoning ability of students in the experimental group regarding the four constructs, i.e., describing data, organizing and reducing data, representing data and analyzing and interpreting data.

The third research question was to find out whether there was a significant difference on the statistical reasoning ability of students exposed to SRLE with regard to the four constructs. The results recorded no clear distinctions across the four constructs. It means that the proficiency of students were similar in describing data, organizing and reducing data, representing data and analyzing and interpreting data.

CONCLUSION

By and large, the findings of this study showed the significance of Statistical Reasoning Learning Environment (SRLE) on the statistical reasoning ability of tenth grade students in statistics. Unlike other model, SRLE model is a powerful instructional model that integrates six principles and has the potential to empower students' statistical reasoning ability. Hence, the researchers and instructors could apply this instructional model in their statistics classroom. This study provides new empirical evidence and some practical contributions to the statistics education. Future research studies can be implemented for differ grade levels to further support the efficiency of SRLE. Not only that, it may be applicable for different subject matters such as language and science. Diverse types of educational software can also be considered as the technological tool.

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