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Research Article

Utilizing Lesson Study in Improving Year 12 Students' Learning and Performance in Mathematics

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Abstract
This study investigated the use of Lesson Study to improve Year 12 students' performance in conditional probability through Inquiry-Based Learning (IBL) lessons. In total, 66 students comprised of three Year 12 classes of similar abilities, and their three respective teachers from a government junior college participated in the study. The instruments used to collect the relevant data in this study were teachers' reflective journals and students' achievement tests. The collected data were then analyzed and interpreted quantitatively using the SPSS. The analysis of the students' pre- and post-tests concluded that as the lesson plans were gradually refined and enhanced, their performance in solving conditional probability questions steadily improved.

Keywords: Statistics education, Conditional probability, Lesson study, Junior College students' performance.

1 Introduction

In the past few years, the Ministry of Education of Brunei Darussalam initiated a major curriculum reformation which led to the implementation of the National Education System for the 21st Century, or in the Malay language, *Sistem Pendidikan Negara Abad ke-21 (SPN21)*. This education reform called for a pedagogical shift from teacher-centered classrooms to student-centered classrooms in order to develop technologically, scientifically and environmentally literate members of society who are able to keep up with the demands of the current technology saturated world (Ministry of Education, 2013) [1]. Therefore, it is crucial that teachers are innovative in their teaching approaches. Despite so, implementation of new

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teaching approaches can be complex and unpredictable and when not executed properly, could lead to confusion for both teachers and students involved (Briede, 2016) [2].

Lesson Study is a form of teacher professional development that originated in Japan and has been cited as a key factor in the improvement of their Mathematics and Science education (Stigler & Hiebert, 1999) [3]. Isoda (2006) [4] defined Lesson Study as "an authentic activity for enabling teachers to conduct their classrooms. It includes discussions of subject matters, why they teach, how they teach and what students can learn" (p. 35).

Lesson Study has been widely researched in many countries. For example, Yoong (2011) [5] in Singapore; Leung and Yuen (2007) [6] in Hong Kong; Vui (2007) [7] in Vietnam; Sukirman (2007) [8] in Indonesia; Groves et al. (2015) [9] and Widjaja et al. (2016) [10] in the Australian context, and also from the perspective of Brunei (Suhaili, 2010 [11]; Ahmad, 2011 [12]; Suhaili & Khalid, 2011 [13]; Suhaili et al., 2016 [14]). The results from these researches showed that it uncovers both students and teachers' conceptions of approaches to learning (Yoong, 2011) [5], and also improves students' performance in Mathematics (Leung & Yuen, 2007) [6]. Vui (2007) [7] and Sukirman (2007) [8] both concluded that one of the products of Lesson study is that it helps students improve in learning motivation, skill-process, knowledge, enthusiasm about engaging in cooperation, and good communication.

In 2010, at the World Association of Lesson Studies or WALS conference held in Brunei, a local presenter responded that her team, after two cycles of the Lesson Study process, had improved students' performance in scores on quadratic formulae from 30% to 80% (Koo, 2010) [15]. In the same year, another local researcher, Suhaili (2010) [11] also reported in his investigation on Lesson Study in primary Mathematics classrooms in Brunei that "as the research lessons were progressively refined and polished, the impact on students' learning was positive" (p. 89). Subsequently, Ahmad (2011) [12] carried out a research in Brunei on using Lesson Study to improve teaching and learning in congruency for Year 9 students and he concluded that students' understanding and learning achievements has also increased. Although there is extensive research on Lesson Study done both locally and internationally, there has been few researches reported on Year 12 students' performance in Mathematics, particularly in the learning of conditional probability through Inquiry-Based Learning or IBL lessons. In the context of Brunei, Year 12 corresponds to the 11^{th} grade in American schooling.

Thus, this study aims to discover if the cycles carried out in Lesson Study will improve students' performances through IBL lessons, with three Year 12 Mathematics teachers having the opportunities to collaborate and share ideas on improving the learning experiences of their students. This accords to Lewis and colleague's call to engage in more research on "iterative cycles of improvement" in the field of Lesson Study research (Lewis et al., 2006 [16], p. 3) in order to avoid evaluating "an immature innovation without first doing all we can to improve it" (p. 6).

2 Methodology

2.1. Participants

The participants involved in this study consisted of 66 Year 12 students of similar academic capabilities in Mathematics, and three teachers with at least ten years of mathematics teaching experience from the same co-education junior college. For this study, we only focused on the Year 12 students mainly because conditional probability is taught in this year group only, and it also to fit in the time frame for us to implement the IBL lessons using Lesson Study practice. From the 66 students involved, 20 were from Class A, 24 from Class B and 22 from Class C. The teachers teaching Class A, Class B and Class C (referred to as Teacher A, Teacher B and Teacher C respectively) were involved in the procedure of the Lesson Study which includes planning, designing the lesson, teaching and observations of the lessons as well as discussion sessions to reflect and critique on the lessons. Prior to carrying out the research, the

teachers involved were briefed by the first author on the procedure of Lesson Study. Video recordings of Lesson Study were also shown to the teachers involved.

2.2. Instruments

This study utilized a pen and paper pre-post tests as instruments of data collection to measure the extent in which the use of Lesson Study could improve the students' performance in solving conditional probability problems. Additionally, a lesson observation's checklist was used to find out the progress of the IBL lessons conducted in the three cycles of Lesson Study. Descriptive Statistics and one-way ANOVA was used to analyze the differences of the lessons based on the evaluation and measurement by the observers using SPSS 20.0.

All the observers who were present during the IBL lessons were asked to evaluate the lesson by using the lesson observation checklist adapted and modified from Suhaili's (2010) study. The observers were asked to respond to a 5-point scale; which were (1) not at all, (2) low, (3) moderate, (4) high and (5) very high for each item in the lesson observation checklist. Besides that, the teachers' reflective journals (reported in Chong and Shahrill (2014) [17]), together with the discussions from the meetings were used in this study to provide suggestions for further improvement of the lesson plans for the subsequent cycles.

2.3. Procedure

The aforementioned pre- and post-tests consisted of four test items. The selections of questions were in accordance with the syllabus content of the topic conditional probability extracted from past year papers of Probability and Statistics within the Advanced Level Cambridge International Examinations. The marking schemes were created for both pre- and post-tests based on the scheme from Cambridge International Examinations for the Advanced level Mathematics. The students were given one hour to complete the test items. Both the pre- and post-tests were developed simultaneously and therefore consist of questions that were parallel with each other.

Each teacher from the sample site checked the face validity of the pre- and post-test items. They commented that all the items in the pre-test and post-test cover both basic probability and conditional probability questions. They also verified that the level of difficulty for both the tests were similar and were appropriate to be administered for this study. The duration for both pre-test and post-test papers was an hour each. The test items in the pre-test and post-test were determined in terms of its internal consistency using SPSS version 20.0. A pilot study was conducted in another junior college before implementing the test items to the junior college students in present study site. The Cronbach alpha reliabilities for the pre-test and post-test based on the responses of 48 students from the pilot study were calculated to be 0.799 and 0.745 respectively. George and Mallery (2009) [18] stated that a Cronbach's Alpha greater than 0.7 is considered acceptable. Therefore, this indicated that the test items in both papers had acceptable reliabilities.

This study adapted and modified the steps for collaborative Lesson Study by Stigler and Hiebert (1999) [3]:

1. *Define a problem during the first meeting*. The research team consisted of the first author, Teacher A, Teacher B and Teacher C and they decided to work on introducing the concept of conditional probability because the analysis of the Pre-test results implied that majority of the students can solve basic probability questions but they do not have prior knowledge on the concept of conditional probability. Therefore, the learning objectives of the research lesson focused on developing the concept of conditional probability as well as using the concept to solve problem.
2. *Plan the lesson*. Four days with a total of 5 hours was used to plan the lesson for Year 12 students on the concept of conditional probability. An exploratory activity was designed by the research team in which groups of students were to solve three questions first by predictions using previously learned methods in probability and after that using the materials prepared to play the game so as to compare

the answers from the predictions as well as outcomes of the game. Then, they are to make a connection between the solutions to form the concept of conditional probability. In the activity, "Two Colours Game", three identical boxes were used. The first box contains two orange balls, another box contains one orange and one white balls and the last box contains two white balls. Students first select one box from the three boxes. From the selected box, the student then picked a ball without replacement followed by selection of another ball. The student wins if both of the balls picked are orange. This lesson plan was then called Lesson Plan 1.

3. *Teach and observe the lesson in the classroom.* The first author implemented Lesson Plan 1 while the rest of the members observed. The reason why Lesson Plan 1 was taught by the first author and not by the class actual Mathematics teacher (Teacher A) was because he was not feeling well at that time and therefore it was suggested that the first author should teach Lesson Plan 1.
4. *Critique and reflectively discuss the lesson after classroom observations*. After the lesson, the team members spent around one hour critiquing and reflecting on the lesson. The research team shared and discussed issues of pedagogy and students' learning.
5. *Revise the lesson*. Immediately following the critique, the research team spent another hour revising the lesson by incorporating the outcomes of the critique and reflections. The revised Lesson Plan 1 was then called Lesson Plan 2.
6. *Teach and observe the revised lesson*. Teacher B taught Lesson Plan 2 while the rest of the team members observed.
7. *Critique, reflect and revise*. The research team met up to critique and reflects on Lesson Plan 2 and it was further revised then called Lesson Plan 3
8. *Teach and observe the revised lesson again*. Teacher C taught Lesson Plan 3 and the other team members observed.
9. *Final Discussion*. The research team met up to discuss and reflect on Lesson Plan 3 to conclude and identify final refinement made to Lesson Plan 3.

3 Results

To investigate whether Lesson Study practice through IBL lessons improve students' performance in solving conditional probability questions within the three lesson plans, one way ANCOVA was used to analyze the Pre-test and Post-test scores of the students in the three classes, and also paired sample t-test to investigate whether Lesson Study practice improve students' performance in terms of the differences between the mean scores of Pre-test and Post-test of the three classes.

The Cronbach's alpha reliability of the Pre-test items is 0.710 and Post-test items is 0.732 which indicated that both the test items had acceptable reliabilities (George & Mallery, 2009) [18] in terms of its internal consistency. The total marks for Pre-test and Post-test are 30 each. The total marks are then converted to percentage (%) for the analysis of one-way ANCOVA. The unadjusted mean score of the Post-test for Class A is 54.00, Class B is 66.53 and Class C is 70.76. The average mean score of the three classes is 64.14. In addition, the adjusted means for all three classes were also calculated, for Class A is 54.348, Class B is 67.423, while for Class C, the adjusted mean is 69.464. Table 1 shows the analysis of one-way ANCOVA, that when the Pre-test scores on conditional probability was co-varied out, the main effect of Inquiry-Based Learning (IBL) on students' performance after the Post-test was significant ($F262 = 5.304$, $p = 0.007$). The covariate, Pre-test scores had no significant effect on the Post-test scores. The ANCOVA summary table is shown in Table 2.

Table 1: The test of between subjects effects (Dependent variable: Post-test)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6673.971[a]	3	2224.657	8.448	.000	.290
Intercept	52522.100	1	52522.100	199.442	.000	.763
Pre-test	3517.313	1	3517.313	13.356	.001	.177
Class	2793.644	2	1396.822	5.304	.007	.146
Error	16327.376	62	263.345			
Total	294533.333	66				
Corrected Total	23001.347	65				

[a]R Squared = .290 (Adjusted R Squared = .256)

Table 2: ANCOVA Summary for effects of treatment

Source of Variance	Sum of squares	Degree of freedom	Mean Square	F-ratio
Covariate (Pre-test scores)	3880.327	1	3880.327	14.73
Main effect (IBL)	2793.644	2	1396.822	2.78
Residual error	16327.376	62	263.345	

*Significant at 5% level

By comparing the classes' differences between the mean post-test and the mean pre-test scores, we can determine students' performances in each class. Entries in Table 3 show the summary of Paired sample t-test of students' Pre-test and Post-test mean scores in the three classes.

Table 3: Summary of paired sample t-test results for Class A, B and C

			Class A	Class B	Class C
Paired sample statistics	**Pre-test**	M	20.17	19.17	23.17
		SD	13.571	15.765	10.968
	Post-test	M	54.00	66.53	70.76
		SD	18.75	15.306	19.243
Paired samples correlations		Correlation	0.648	0.470	0.155
		Sig	0.002	0.020	0.491
Paired samples test		Mean difference	-33.833	-47.361	-47.591
		SD	14.359	16.001	20.619
		T	-10.538	-14.501	-10.826
		Df	19	23	21
		Sig (2-tailed)	0.000	0.000	0.000

With reference to Table 3, a paired sample t-test was calculated to compare the mean scores of the Pre-test and Post-test of the students in three classes. There was a substantial difference between the scores in Class A (Lesson Plan 1) of the Pre-test (M = 20.17, SD = 13.571) and Post-test (M = 54.00, SD = 18.75) with the conditions; t (19) = -10.538, p = 0.000. These results suggested that the implementation of Lesson Plan 1 in Class A may have had an effect on students' performance in solving conditional probability questions as it was observed that there was a negative mean difference (M = -33.833) between the Pre-test and Post-test. The two-tailed probability value is less than 0.05 (p = 0.000), therefore it can be said that the improvement of students' performance as measured by Pre-test and Post-test was statistically significant.

The findings in Table 3 also suggested that the overall students' performance in Class B (Lesson Plan 2) as measured by the Pre-test and Post-test show improvement from the mean scores in Class A (Lesson Plan 1). It can be seen that students' performance in Class B was higher and better than students of Class A. There was also an improvement in the mean difference of Lesson Plan 2 (difference between Pre-test and

Post-test mean scores): t (23) = -14.501, p = 0.000. It is now clear that the improvement of students' performance as measured by Pre-test and Post-test was statistically significant (p = 0.000). The improvement was likely due to the implementation of Lesson Plan 2 of the Lesson Study. It is important to note that the mean difference between the Pre-test and Post-test in Class B (M = 47.361) is larger compared to the mean difference in Class A (M = 33.833).

Further consideration of Table 3 showed that the overall mean score for both Pre-test and Post-test of Class C was slightly higher than the mean scores of students in Class B. It was also observed that there was improvement in the mean difference of Lesson Plan 3 (difference between Pre-test and Post-test mean scores): t (21) = -10.826, p = 0.000. It is clear that the improvement of students' performance as measured by the mean difference between the Pre-test and Post-test was statistically significant (p= 0.000). The improvement was likely due to the implementation of Lesson Plan 3 of the Lesson Study. It is important to note that the mean difference between the Pre-test and Post-test of Class C (M = 47.591) is slightly higher than in Class B (M = 47.361). It can be deduced that students' performance in solving conditional probability questions as a result of the quality of lesson plan in Class C is higher than in Class B.

It can be concluded that students' performance which was measured by the mean differences of the Pre-test and Post-test of all students improved in each lesson plan. However, the degree of improvement of students' performance from each lesson plan was more likely to be influenced by the extent of refinements made on the lesson plan. It is important to note that as the lesson plans were gradually refined and improved, students' performance too steadily improved. This can be seen clearly by making comparison between students' performance in the Post-test as well as the mean differences between Pre-test and Post-test of students in Class A (Lesson Plan 1) and Class C (Lesson Plan 3).

4 Conclusions and Recommendations

The results from the quantitative procedure using one way ANCOVA on the Pre-test and Post-test of the three classes indicated that, following the removal of the covariate (Pre-test), there was a significant difference between the means of the three classes as the significance level is 0.007 which is less than the 0.05 critical value and so is statistically significant (F = 5.304, p = 0.007). Therefore, it can be concluded that Year 12 students' performance had improved after the classes were taught using Lesson Plan 1, 2 and 3 respectively. It was worthwhile to examine the mean score for the Post-test that has been adjusted for the effect of the Pre-test of the three classes (effect of the Pre-test has effectively been removed). Lesson Plan 1 which was conducted in Class A reported that the mean score of the Post-test was 54.00 (out of 100). There was an increase of the Post-test mean score (M = 66.53) for Lesson Plan 2 conducted in Class B. In Lesson Plan 3 taught in Class C, an increase in the Post-test mean score (M = 70.76) was reported.

A paired sample t-test was also used to compare the mean difference of the Pre-test and the Post-test which can be used to determine the students' performance in solving conditional probability questions in each of the three classes. The results stated that there was an increase of the mean difference of both test from 33.833 in Class A (Lesson Plan 1) to 47.361 in Class B (Lesson Plan 2). It was further observed that the mean difference of both tests from Class B (Lesson Plan 2) to Class C (Lesson Plan 3) increased slightly from 47.361 to 47.591. Therefore, from the analysis of students' Pre-test and Post-test using ANCOVA and paired sample t-test, it can be concluded that as the lesson plans were gradually refined and improved, students' performance in solving conditional probability questions were steadily improving. The findings are similar to Suhaili's (2010) study, which stated that the effect on students' learning was positive as the lesson plans were progressively improved through the use of Lesson Study.

To the best of our knowledge, this is the first study conducted in teaching conditional probability to Year 12 students through the use of Lesson Study. Instead of using the pervasive "chalk and talk" method of teaching conditional probability, this study can provide teachers an insight into how Lesson Study and IBL were implemented at the Year 12 level. It should be noted that the conclusions drawn from this study are

based on the particular sample, topic and tests used and as this study is exploratory as well, it is suggested that its findings to be taken tentatively rather than conclusively. We recommend Mathematics teachers to be trained on using Lesson Study to tackle topics that are confusing for students. The Lesson Study practice can be introduced to Years 12 and 13 Mathematics teachers through intensive workshops and courses so that they can work collaboratively to come up with a lesson plan that will improve students' performance in the respective areas in Mathematics. In addition, the teachers from the Ministry of Education may want to collaborate with our local university experts to organize Lesson Study professional development courses that are suitable for these Mathematics teachers to attend.

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