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IMPLEMENTING INQUIRY-BASED LEARNING AND EXAMINING THE EFFECTS IN JUNIOR COLLEGE PROBABILITY LESSONS

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Abstract

This study examined how Year 12 students use their inquiry skills in solving conditional probability questions by means of Inquiry-Based Learning application. The participants consisted of 66 students of similar academic abilities in Mathematics, selected from three classes, along with their respective teachers. Observational rubric and lesson observation checklist were used as the data collection instruments. The results obtained were analyzed and then quantitatively reported. Findings from the observational rubric revealed that Year 12 students were able to understand most of the questions during the activity, but they only select and use one previously learned method to solve the questions during the activity. In addition, these students rarely seek and asked probing questions during the activity. They only used words, diagrams and numbers to interpret the solutions to the questions and make connections between them but with few mistakes detected.

Keywords: Statistics Education, Conditional Probability, Inquiry-Based Learning, Students' Performance

Abstrak

Kajian ini meneliti bagaimana pelajar-pelajar Tahun 12 menggunakan kemahiran siasatan mereka dalam menyelesaikan soalan-soalan *conditional probability* melalui pelaksanaan Pembelajaran *Inquiry-Based*. Peserta terdiri dari 66 pelajar dengan kemampuan akademis yang sama dalam Matematika, dipilih dari tiga kelas, bersama dengan guru masing-masing. Daftar periksa rubrik dan observasi pengamatan observasional digunakan sebagai instrumen pengumpulan data. Hasil yang diperoleh dianalisis dan kemudian dilaporkan secara kuantitatif. Temuan dari rubrik observasional mengungkapkan bahwa pelajar-pelajar Tahun 12 dapat memahami kebanyakan soalan semasa aktiviti, tetapi mereka hanya memilih dan menggunakan satu kaedah belajar sebelum ini untuk menyelesaikan soalan semasa aktiviti tersebut. Di samping itu, pelajar-pelajar ini jarang mendapatkan dan meminta menyelesaikan sesuatu soalan semasa aktiviti tersebut. Mereka hanya menggunakan kata-kata, gambar rajah dan nombor untuk mentafsir penyelesaian kepada soalan-soalan dan membuat kesinambungan antaranya tetapi dengan terdapatnya sedikit kesilapan.

Kata kunci: Statistik Pendidikan, *Conditional Probability*, Pembelajaran *Inquiry-Based*, Pencapaian Pelajar

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The demand for students' sustainable development calls for teachers to be innovative in their teaching approaches. Despite so, conventional mathematics education remains teacher-centered whereby students are reliant on the teacher for information. In Brunei Darussalam, it is the norm for students to display unquestioning acceptance of what the teacher teach particularly in Mathematics. Students tend to memorize and regurgitate mathematical formulas needed to answer standardized assessments. This resulted in students facing difficulties when confronted with situations requiring the application of

knowledge, the discovery of new knowledge, or the exercise of creativity (Prahmana, Zulkardi, & Hartono, 2012). For example, majority of the Year 12 students in Brunei misuse the formula for conditional probability when solving problems. This is due to their lack of understanding in the concept of conditional probability (Chong & Shahrill, 2014), which leads to the occurrence of misconception. Previous studies on school and college level probability conducted in Brunei also commented that students possess weak conceptual understanding of said topic (Ang & Shahrill, 2014; Toh, 2010; Tsang & Shahrill, 2015).

Inquiry-Based Learning (IBL) and Students' Performance in Mathematics

Inquiry-Based Learning (IBL) is a constructivist pedagogical approach where students are presented with the opportunity to control over their learning process through exploration, discovery, constructing knowledge and understanding, reflect and thinking critically (Santrock, 2001) instead of teacher dictation (Huziak-Clark et al., 2007). Previous studies have found that the IBL approach motivates students to seek for answers and generated increases in affective and cognitive outcomes (Herman & Knobloch, 2004; Slavin, 2006). As agreed by Baker et al. (2008), IBL requires students to explore and urges them to think and seek actively, as opposed to the act of memorizing repetitively. Hmelo-Silver et al. (2007) commented that middle school students who adopted an inquiry-based mode of learning has been found to achieve better results in their tests. Ismail (2008) also noted the improvements in the students' problem-solving abilities when using inquiry directed texts. Brune (2010) conducted a study on middle school students in the United States in which he used IBL and traditional approach to teach Geometry to different groups of students. His findings indicated that students who participated in Inquiry-Based lessons have improved retention rate and enhanced ability to solve problems. Moreover, the students also demonstrated "better performance on decontextualized mathematical problems than their peers who were taught in the traditional fashion" (Brune, 2010, p. 45).

METHOD

Inquiry is a strong method for teaching Probability and Statistics. Therefore the aim of this study was to adapt IBL as the new instructional approach to be used in the teaching of advanced level conditional probability, and to investigate how Year 12 students use their inquiry skills in solving conditional probability questions through the implementation of Inquiry-Based Learning.

This present study made use of quantitative methods to investigate the effects of implementing IBL in Year 12 Probability lessons. The main instruments used for data collection are observational rubrics and lesson observation checklists. An observational rubric consisting of four categories was created underpinning the guidelines from Andrade (2000), and was used to investigate how Year 12 students use their inquiry skills when solving conditional probability questions in groups. The observation checklists used in this study served two purposes. Firstly, they are used to analyze the progress of the IBL lessons and find out any difficulties encountered when implementing the lessons. Secondly, the lessons' observation checklists assessing the five criteria: content organization, strategy

used, communication, assessment, and students' behavior, provided information for the researchers and the teachers involved on the progress of the lessons. The ratings were (1) not at all, (2) low, (3) moderate, (4) high, and (5) very high. The results from the ratings also provided feedbacks on how students from Classes A, B and C used their inquiry skills in solving conditional probability questions during the lessons. A rubric consisting of four categories: understanding, prior knowledge, questioning and interpretation were used to measure the students' inquiry skills. Due to the time constraint, inquiry skills in this study only referred to the students' skills in understanding the problem, use of prior knowledge, questioning and interpreting through the exploratory activity. A video recording device was also used while observing the lessons in order to enrich the information collected from the checklist as well as the rubric.

We utilized the SPSS version 20.0, and the descriptive statistics and the one-way ANOVA were employed to analyze the differences of the inquiry skills between Classes A, B and C based on the evaluation and measurement by the research team consisting of the researchers and the three teachers. The significance level 0.05 was chosen for the one-way ANOVA test (Cohen & Holliday, 1979; Gay & Thomas, 1992). The research team was asked to respond on a 4-point scale; which were (1) need improvement, (2) satisfactory, (3) good and (4) excellent for each category. There are a total of four categories in the rubric, which are, understanding, prior knowledge, questioning and interpretation.

Participants and Procedures

The research site was a co-educational junior college (the equivalent of 11^{th} and 12^{th} grades in American schooling) preparing Years 12 and 13 students for the Advanced Level examinations in Brunei. A total of 66 students of similar academic abilities in Mathematics were selected from three classes namely, 20 from Class A, 24 from Class B and 22 from Class C. Coincidently, the classes were originally streamed by the college according to their grades achieved from the General Certificate of Education Ordinary Level for Mathematics Syllabus D and Additional Mathematics (Chong & Shahrill, 2016; Han et al., 2016; Yassin et al., 2015). The teachers teaching Class A, Class B and Class C (Teacher A, Teacher B and Teacher C respectively) were involved in planning, designing the lesson, teaching and observations of the lessons. Besides that, the teachers also participated in discussion sessions to reflect and critique on the lessons taught. All three participating teachers hold a Master Degree with at least ten years of mathematics teaching experience. Lessons Two and Three taught to Class B and C respectively underwent slight refinements to improve the IBL approach undertaken by the teachers based on the reflections and critiques of the first and second IBL lesson implemented.

RESULTS AND DISCUSSION

Quantitative results from the rubric on students' inquiry skills are presented. In each class, students were selected randomly and divided into groups by the research team to complete the activity, with a total of 17 groups of students participated in this study as shown in Table 1. In Class A

and Class B, there were four students in each group whereas for Class C, each group consisted of three or four students. The students' inquiry skills were observed and accessed in groups based on the references for each category in the rubric: understanding, prior knowledge, questioning and interpretation.

Table 1. Number of Groups of Students in Classes A, B and C

Class	Number of students	Number of groups
A	20	5
B	24	6
C	22	6
Total	66	17

In order to focus on how each group of students used their inquiry skills when solving conditional probability questions, each observer was assigned to observe one to three groups for each class. The teacher teaching the respective class i.e. one of the researchers in Class A, Teacher B in Class B, and Teacher C in Class C, was not involved in assessing the students' inquiry skills during the lesson so that the respective teacher can focus on guiding and assisting the students during the group discussion. Table 2 shows the number of groups observed by each observer in Classes A, B and C. It should be noted that Teacher A was not involved in observing and evaluating students' inquiry skills in Class B because he had to leave the lesson 20 minutes earlier due to unforeseen circumstances.

Table 2. Number of Groups Observed by Each Observer in Classes A, B and C

Class	Number of Group(s)	Observer
A	1	Teacher A
	2	Teacher B
	2	Teacher C
B	3	Researchers
	3	Teacher C
C	2	Researchers
	2	Teacher A
	2	Teacher B

In order to investigate on how Year 12 students use their inquiry skills in solving conditional probability questions within the three cycles of Lesson Study (reported in Chong et al., 2017), firstly we analyzed the descriptive statistical data and then one way ANOVA to measure students' inquiry skills in group activity during the lessons using the four categories in the rubric: understanding, prior knowledge, questioning and interpretation. In each category, there are four references, and the observers provided a rating based on the references. The ratings were (1) need improvement (2) satisfactory (3) good and (4) excellent. The Cronbach's alpha reliability of the four items is 0.734 that indicated that the items had acceptable reliability in terms of its internal consistency.

Table 3. Descriptive Statistics for the Four Categories in the Rubric

Skills		Understanding	Prior Knowledge	Questioning	Interpretation
Class	n (%)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
A	5 (29.4)	2.80 (.447)	2.20 (.447)	2.20 (.447)	2.40 (.548)
B	6 (35.3)	3.33 (.516)	2.67 (.516)	2.33 (.516)	3.00 (.632)
C	6 (35.3)	3.50 (.548)	3.00 (.000)	2.50 (.548)	3.00 (.632)

Table 3 above shows the descriptive statistics for the four categories in the rubric: Students' understanding, prior knowledge, questioning and interpretation in each class. It was evident that students in Class A and Class B were able to understand most of the questions in the activity, with the mean scores of 2.80 and 3.33 which are within the range of good. As for Class C, the students have the highest mean score of 3.50, which shows that they understood all of the questions. In all three classes, it was evident that students understood most of the questions in the activity as the mean scores are within the range of good. The mean score of prior knowledge for Class A was 2.20, within the range of satisfactory. This shows that students select and use one previously learned method but with small mistakes to solve the questions. As for Class B and Class C, students also select and use one previously learned method and managed to solve the questions correctly as indicated by mean scores of 2.67 and 3.00. The mean scores for students' prior knowledge in all the three classes implied that students did select and use only one previously learned method to solve the questions in the activity. As for questioning skill, in all of the three classes, it was evident that students rarely seek and ask probing questions to solve the questions in the activity as indicated by the mean scores which are all within the range of satisfactory. These findings resonate correspondingly to those reported by Salam and Shahrill (2014), Shahrill (2009), and Shahrill and Clarke (2014).

Meanwhile, the mean scores for students' interpretation skill indicated that students used words, diagrams and numbers to interpret the solutions to the questions in the activity and make connections between them but they encountered small mistakes while trying to interpret and figure out the connection. The mean score for Class A was 2.40 in this category is in the range of satisfactory. This shows that students used words, diagrams or numbers to interpret the solutions to the questions in the activity but were unable to make connections between the solutions. As for Class B and Class C, they both have a mean score of 3.00, which shows that students used words, diagrams and numbers to interpret the solutions and manage to make connections between them but with small mistakes. This may then resulted in the students having difficulty in forming a relationship between the solutions.

The one-way ANOVA test was then analyzed to investigate whether there are differences in students' inquiry skills when solving conditional probability questions within the three classes. Entries in Tables 4, 5 and 6 show the results of students' inquiry skills in each class based on the mean scores obtained from the rubric.

Table 4. Descriptive One-way ANOVA for Students' Inquiry Skills in Classes A, B and C

Class	n (%)	Mean (SD)	Std. Error	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
A	5 (29.4)	9.40 (1.342)	.600	7.73	11.07
B	6 (35.3)	11.00 (1.265)	.516	9.67	12.33
C	6 (35.3)	11.83 (1.169)	.477	10.61	13.06

Table 5. One-way ANOVA for Students' Inquiry Skills in Classes A, B and C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.437	2	8.219	5.222	.020
Within Groups	22.033	14	1.574		
Total	38.471	16			

Table 4 indicates Class C has the highest mean score for students' inquiry skills (M = 11.83, SD = 1.169) compared to Class A (M = 9.40, SD = 1.342) and Class B (M = 11.00, SD = 1.265). From Table 5, using one-way ANOVA, the F-ratio for the between groups effect (i.e. the effects of students' inquiry skills in each class) is 5.222, which has an exact significance level of 0.020. Since $p < 0.05$, this means that the between groups effect is significant. Overall the means for the students' inquiry skills in the three classes differ significantly.

In Table 6, at $p < 0.05$, using Tukey HSD test, the results indicated that there was no significant differences between the mean score of students' inquiry skills for Class A and Class B ($p = 0.124$) as well as between Class B and Class C ($p = 0.500$). However, there was significant difference between the mean score of students' inquiry skills for Class A and Class C ($p = 0.016$).

Table 6. Post Hoc Test Using Tukey Between Students' Inquiry Skills for Classes A, B and C

Class (I)	Class (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-1.600	.760	.124	-3.59	.39
	C	-2.433*	.760	.016	-4.42	-.45
B	A	1.600	.760	.124	-.39	3.59
	C	-.833	.724	.500	-2.73	1.06
C	A	2.433*	.760	.016	.45	4.42
	B	.833	.724	.500	-1.06	2.73

*The mean difference is significant at the 0.05 level.

Comparing between the mean scores of students' inquiry skills in each class as in Table 6, it can be concluded that students in Class C (M = 11.83, SD = 1.169) have the best inquiry skills when solving the conditional probability questions compared to Class A (M = 9.40, SD = 1.342) and Class B (M = 11.00, SD = 1.265).

CONCLUSION

In this study, only one IBL lesson was conducted in each class. Therefore, Year 12 students only experienced learning by inquiry in the duration of one lesson. In addition, this is also the first time they have encountered learning and solving conditional probability questions using inquiry. Due to the limited amount of time spent, they may not be accustomed to this new learning experience and this maybe the reason that Year 12 students' inquiry skills were not as promising as those studies done internationally (Brune, 2010; Ismail, 2008). Similarly, Vahey et al. (1999) also mentioned that not all inquiry-based activities are guaranteed to lead to productive learning in Probability and Statistics.

Meanwhile, quantitative analysis using one-way ANOVA on the rubric of the three classes indicated that there was significant difference between the mean scores of Year 12 students' inquiry skills in the three classes ($F = 5.222$, $p = 0.020$). From the mean scores, it can be concluded that the students in Class C ($M = 11.83$) have the best inquiry skills when solving the conditional probability questions compared to Class A ($M = 9.40$) and Class B ($M = 11.00$).

It should be stressed that this study is explanatory as well as exploratory and its findings should be viewed as tentative and suggestive rather than conclusive. The conclusions drawn from this study are restricted to the particular sample used, the topic included as well as the tests used. Appropriate recommendations are made to improve this study with suggestions for future research based on these conclusions. This study provided Year 12 students the opportunities to be responsible for their own learning by constructing new concept through inquiry. The overall findings from this study revealed that Year 12 students' performances in conditional probability have improved. And we believe that teachers need to be creative in their teachings and show students there are more than one ways of learning. Creativity in this study focused on encouraging student-centered learning in the classroom. These include exploring the meaning of conditional probability through activity and then relate it to real life problems.

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