Integrating ICT and Learning Study in Teaching Conversion of Travel Graphs

Hjh Siti Hasara Hj Matussin[a], Nor Azura Abdullah[b] and Masitah Shahrill[b]

Corresponding author: masitah.shahrill@ubd.edu.bn

[a]Rimba 2 Secondary School, Ministry of Education, Bandar Seri Begawan, BE 3319, Brunei Darussalam

[b]Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Bandar Seri Begawan, BE 1410, Brunei Darussalam

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Abstract

This study reports on the use of ICT in Cycle Three of a Learning Study. The purpose is to enhance students' understanding on the topic Conversion of Travel Graphs with the integration of ICT in Learning Study and to shift teachers away from the traditional methods of teaching to a more systematic and meaningful learning through the work of collaboration between colleagues. The research lessons, the tests and the rubric were all planned with the collaboration of teachers involved in this Learning Study. A class of Year 9 students in one secondary school in Brunei Darussalam participated in the intervention and sat for both pre-test and post-test. Analysis of the scores, comparing the results and observations of research lessons were among the methods used in this study. From the analyses, it was found that the integration of ICT in Learning Study had an impact to the students' performance. The integration of ICT in Learning Study was also seen as a possible pedagogical tool in teaching.

Introduction

The education system in Brunei Darussalam has been reformed to fulfil the Ministry of Education's mission and vision in providing students with profitable knowledge, language proficiencies and multi talented skills. This implicitly and explicitly calls for improvement of teachers' instructional practices to develop students holistically. According to Elliot (2005), to create an impact on the students, teachers are accountable in designing a lesson that should practically involve students' learning experience. The experiences gain in a lesson should be cognitively active and suits the objectives of the curriculum. Elliot (2005) further adds in his article that Learning Study is about exploring new kinds of pedagogical goals and should focus more on learning rather than teaching.

Learning Study is an approach to professional development of teachers by supporting Japanese lesson study with theoretical laden foundation of variation theory in phenomenography (Pang & Marton, 2003). Based on their paper, Pang and Marton (2003) explain that learning study involve several steps:

- Teachers collaboratively select and confirmed a specific set of learning outcomes;
- Investigate the students prior knowledge or capabilities of students' targeted learning outcomes before the lesson through a pre-test;
- Based on the pre-test outcome, propose a lesson or series of lessons aiming to obtained the desired learning outcomes;
- Put the proposed lesson to classroom practice;

- Assess the lesson or lessons by measuring the students' attained learning outcomes through post-test;
- To share the result of research lesson or lessons.

Learning Study in Brunei Darussalam has become part of the curriculum assigned by the Ministry of Education to be carried out by teachers in the secondary schools. The process is quite similar to that of Lesson Study except for the use of Variation Theory. A particular sub-topic is chosen by a group of teachers. These teachers implement and design research lesson that includes planning the lesson and its content. For the first cycle (Cycle One), one of them will teach in his or her respective class. Colleagues who are involved in this Learning Study will observe the lesson. Pre-test is given to students before the actual lesson is carried out and post meeting will be held as soon as the post test is administered. The discussion among the teachers in the post meeting will later on decide whether the research lesson should be modified or not. If the result is still unsatisfactory, then the process will have to be repeated for the second cycle (Cycle Two) and so on but with a different teacher and a different set of students.

Ever since the education system in Brunei Darussalam has been reformed, the Ministry of Education now promotes a curriculum that allows teachers to explore variety of teaching practices and learning in their classes (Salam & Shahrill, 2014; Shahrill & Clarke, 2014), and at the same time, provides students with profitable knowledge, language proficiencies and multi-talented skills. Furthermore, according to the Ministry of Education, students should be equipped with the 21st century skills required beyond the academic curriculum such as communication, critical thinking, numeracy and Information and Communications Technology, or ICT skills (Ministry of Education, 2013). This contributes to one of the major encouragement in implementing the use of technologies in a lesson.

Many efforts have been made to emphasize the integration of technologies in teaching practice and learning in a classroom. The schools in Brunei Darussalam have been heavily funded to ensure that the use of technology is being implemented efficiently and effectively. Computers, Smart Boards, Graphic Calculators and even wireless internet are few examples of what have been provided and fully subsidized by the Brunei Government to each school. In 2012, the Ministry of Education had spent $6 million to acquire iPads to enhance the use of technology in schools (Azaraimy, 2012). Furthermore, one tremendous effort was to establish a flagship ICT project in education called the e-*Hijrah* Programme. According to the report by the Oxford Business Group (2013) on Brunei Darussalam, the e-*Hijrah* plan includes "delivering ICT support services for school and MoE information technology equipment; incorporating ICT into all facets of SPN21 and future curricula; and facilitating an engaging educational experience by way of 21st century pedagogies" (Oxford Business Group, 2013, p.180). In a local study on learning using ICT, the pressure of finishing the syllabus on time (Krestina, 2008) has always been a major excuse used by teachers either to not include ICT or even under utilising the use of ICT in their lessons. Even though we are currently in the new era of technology, as far as is known, the use of ICT is still lacking in schools. Despite all the invested funds by the government, not all teachers are fully committed in supporting the rationale of having or using technology in a classroom just yet. In addition, the implementations of this e-*Hijrah* project in classroom settings and their impact towards teachers' instructional practices and students' performance have yet to be fully explored.

Students' performance in the use of ICT

Studies that relate to the topic in this study mostly use technologies that can detect motions. Such multimedia software programs namely microcomputer-based laboratory (*MBL*), calculator-based laboratory (*CBL*) and calculator-based ranger (*CBR*) are used in classrooms as part of teaching aid to teach the conversion of speed-time graphs to distance-time graphs and vice versa. These technologies produce similar output in which they can be programmed as a motion detector that can produce real-time graphs when objects move towards or away from them. The use of these technologies are not only restricted to detecting motions, they can also be programmed to measure the change in temperature of an object or even determining the frequency or amplitude of a wave. A study by Kwon (2002) reported that students graphing ability and interpreting graphs might be enhanced when using *CBR* activities. Consequently, Urban-Woldron (2011) stated that in using *MBL*, students were able to discover and understand physics concept and develop critical thinking.

In terms of achievement, a meta-analysis research study conducted by Kulik (1994) found that on average, students who used computer-based instruction scored at the 64th percentile on the achievement tests in comparison to students who were without computers who consequently scored at the 50th percentile. Moreover, Mooi (2007) reported a positive finding on using computers to teach the concept of measurement whereby 58.3% of the Secondary One students scored 50% and above, thus demonstrated the understanding on the concepts and skills that had been taught to them. In this study, we used dynamic software Geometer's Sketchpad (GSP) to provide computer-based activities to the student. Although this software is better known as interactive geometry software, it could also be used to teach non-geometry mathematics such as graphing (Moyer, 2006). In his paper, GSP was used to provide visual aids to the concepts of graphing which students can be difficult to grasp verbally.

However, not all reports stated positive indirect effects of ICT on students. Ben Youssef and Dahmani (2008) expressed that ICT-based instruction could restrict the creativity of learner. This was because ICT allowed limited interactions between students that might reduce their abilities in problem solving and creative thinking. Additionally, Schacter (1999) also drew conclusion on the effectiveness of ICT in a lesson. He pointed out that from all of the results of studies he had brought up in his article, it could be seen that the negative findings were due to unclear learning objectives and the diffusion of the focus of the technology.

On the other hand, with reference to Becta (2003), ICT acted as a focal point that encouraged interaction between students, as well as between themselves and the technology. From this, collaboration between students could be enhanced. Generally, this will motivate students further as they are able to interact and disagree at the same time. Clements (2000) added that instant feedback from the computer programmes further helped them to try out their ideas, proved their conjectures and explored the accuracy of this conjectures that they had discussed from such interactions. The informal learning which occurs through interactions, tutoring and editing each other's' works will lead to skills development.

ICT and the impact on teachers' characteristics

Researches on the impact of ICT on teachers were mainly towards their pedagogical practices. The idea of ICT being implemented in a lesson is to provide opportunities for teachers to shift from the teacher-centred approach to a more student-centred approach. Apart from that, teachers can make their lessons fun and interesting. These benefits were recognised by the local teachers based on studies done by Krestina (2008), and Salleh and Laxman (2013) on the teachers' use of ICT in secondary education in Brunei. Not only that, they are

more efficient in managing their time and lesson. Bennett and Lockyer (2008) expressed this in their research findings whereby the pace of lessons was faster as teachers no longer needed to write on whiteboards.

Jarrett (1998) also reported three changes among teachers using technology and they were: raised expectations of pupils, more student-centred approach to teaching and greater willingness to experiment. It can be seen that when teachers accept these changes and include them into their pedagogy approach, a meaningful and informal learning may be achieved. It is from this approach, the integration of ICT benefits both teachers and students.

Apart from that, ICT can take away manual graphing or calculating statistics away from the traditional method. Not only it provides a quicker accurate calculation, it also offers a specific visualisation of the intended object of learning. Using patterns of variation can bring about the object of learning. As reported by Oliver and Trigwell (2005) whereby few teaching media could help students to experience these patterns which eventually would lead students in attaining the object of learning. Therefore, ICT brings about a new dimension in teaching and learning whereby it makes ease on creating graphs or even calculating statistics that needed fixed/accurate solutions.

Students' performance and learning study

According to Vincent (2011), Learning Study focused on finding an effective way of teaching so that students' learning outcomes would be achievable to individual differences. It was expected that low achievers would benefit most from the project since lessons were designed based on students' difficulties identified prior the actual lesson. Vincent (2011) further reported that from his research on Learning Study, Bruneian students had improved progressively over his three lessons in three cycles with better results on their post-test.

Additionally, Elliot (2004), an independent external evaluator, had reported summarised findings on the Progressive and Innovative Primary Schools (PIPS) project in Hong Kong. The PIPS project involved primary and secondary school teachers to implement Learning Study. Initially, the students' understanding and misconceptions on certain topic was clarified through pre-test and interview. Several cycles had been done and data had been recorded throughout the process. As a result, students were still able to recall and explain clearly what they had learnt in the research lessons. Secondly, students were able to give examples to prove that they were still learning from their daily encounter and making use of what they had learnt to build knowledge and to learn by themselves. These two findings were the results after interviewing teachers and students who were involved in the Learning Study under the PIPS project.

However, not all findings in a Learning Study were conclusive. Tam (2005) used Mathematics Learning Study to cater for students with Special Educational Needs (SEN) to two primary schools in Hong Kong on division of fractions and fraction multiplication. The results from both post-test and interview were encouraging and good understanding was demonstrated on the concept, however some of the SEN students still had difficulty in explaining their answers. This showed that the objects of learning might have not been fully grasped by SEN students.

Teachers' perspective of learning study

The common problem for teachers is mostly on creating an effective lesson so that their lesson will entail meaningful learning to their students. Collaborations between teachers are

rare as they are heavily involved in other school responsibilities. Besides tension can occur as a result of different perspectives from teachers (Adamson & Walker, 2011; Runesson & Gustafsson, 2012), which is another reason why sometimes teachers neglect the idea of working collaboratively.

Furthermore, teachers are found to disagree with the idea of lesson observation as part of any evaluation. According to Gabrielatos (2004), there were two interrelated problems when lessons were being observed. The first dealt with the quantity and quality of an observed lesson, which related eventually to the abilities and professionalism of the teacher. Secondly, it concerns with the psychological effects of the observation on teachers' behaviour during the lesson. Apart from that, teachers underestimate students' ability when learning difficult topic. This leads them to spend less time on the topic and hence will affect students' learning outcomes.

A study done by Lo-Fu (2005) had found that from interviews, teachers were found to have actually gone through a series of critical professional development and that these teachers admitted that they had changed positively through the Learning Study practice. Here, change refers to the different aspects of learning outcomes gained by the teachers in a Learning Study. According to Tam (2005), Learning Study provided opportunities for teachers to recognise the object of learning along with its' critical discerning features. Basically these are the essence of variation, which would eventually become a pedagogical tool in planning the research lessons.

The study

The purpose of this paper is to share the findings on students' understanding on conversion of travel graphs concept with the integration of ICT in a Learning Study and on teachers' development from the traditional methods of teaching to a more systematic and meaningful learning through the work of collaboration between colleagues. The ICT component introduced in the research lesson was the use of Geometer Sketchpad. A dynamic geometry software at which enable learners to explore the possibilities of constructing graphs interactively. One might agree that students will benefit more from meaningful learning as it exposes them to different types of skills such as ICT skills, problem solving, communication skills and many more which will be useful in their future undertakings. Furthermore, students will have the advantage of applying the concept of conversion of travel graphs to subjects like Additional Mathematics and Physics and even apply them in real life context.

In addition, the primary purpose of the study is to discover teachers' perceptions on Learning Study and ICT and to investigate the impact of technology on students' understanding on conversion of travel graphs is to integrate ICT component in the research lesson from the Learning Study that was designed and conducted in the year 2011 in one of the secondary schools in Brunei Darussalam. This study is in its third cycle and will target on its impact on the topic chosen. This Learning Study cycle had three research lessons and the learning outcome for the students is focused on their ability to convert speed-time graph to distance-time graph and vice versa.

It is expected that with the above purposes, teachers will benefit the outcomes of the study. The process of designing and modifying the research lesson in Learning Study helps to develop the collaboration between teachers and improve the standard of the lesson content to a more cognitive approach. Teachers will be able to use the instruments used in this research

as a base in assessing their students when teaching the respective topic. Additionally, teachers will help to promote technology exposure to the students by indirectly teaching students to the use of free software from the Internet.

Thus the research focus for this study will concentrate on these interrelated aspects namely the impact of integrating ICT in a Learning Study context on students' performance on conversion of travel graphs; and teachers' views on Learning Study and on the integration of ICT in a Learning Study.

Limitations of the study

The limitation of this study is the focus on a small number of samples. Students chosen are of both high and medium achievers. This is because the research lessons will take at least three lessons. Each lesson will take approximately one hour. Students considered as medium to low achievers are not selected. It is thought that it will affect the subject teacher's schedule in following his or her scheme of work. Medium to low achievers are thought to require more time in terms of scaffolding the lesson to them.

Another expected limitation was on the issue of students' absentees. Students' absence has reduced the small number of students that are to be assessed. This in turn will lower the number of students participating in this study. The result may also be affected due to the Hawthorne effect. Students may act differently under the influence of observation by the teachers involved in the Learning Study. According to Draper (2010), the Hawthorne effect is an experimental effect where any positive significant effect has no actual causal basis only because the participants know that they are being studied.

Conversion of travel graphs

The Learning Study is using a subtopic on Travel Graphs entitled 'Conversion of Travel Graphs' which focus on converting speed-time graphs to distance-time graphs and from distance-time graph to speed-time graphs. Students should have learnt the topics listed below as part of their prerequisite:

- Gradient of a straight line.
- Graph of functions.
- Area of polygons (specifically on squares, rectangles, triangles and trapeziums).

The reason behind this chosen topic is because generally students are found to have a difficulty in converting the speed-time graph to distance-time graph and vice versa. Whether in the class or during an exam, students either skipped the question or answered by sketching similar lines to that of the given travel graphs. Hence, this study is to find out more about the students' learning outcomes on conversion of travel graphs with the introduction of Geometer's Sketchpad software in the learning activities.

Methodology

The study followed the process of Learning Study where the teachers will plan and design a lesson. The lesson design focused on students' specific capabilities to be able to convert speed-time graph to distance-time graph and vice versa. Three research lessons were planned to investigate the intended students learning outcomes.

The methodology for this pre-experimental study was designed in accordance to the research focus stated before. On the impact of integrating ICT in a Learning Study context on students' performance on conversion of travel graphs, this study will analyse the pre-test and post-test results. The items in the tests were created from adapting the GCE O Level Examination standard questions on conversion of travel graphs. The allocated time given for the students to answer each test was 30 minutes. Both pre-test and post-test are similar where each comprised of six questions.

Both pre-test and post-test items were structured according to three dimensions and results were assessed with a rubric that follows the 'Brunei Common Assessment Task' rubric. These dimensions are 'Knowledge and Understanding, 'Communication Skill' and 'Problem Solving'. The rubric will help to examine the students' dimensions of achievement, which was needed to evaluate their level of understanding on the topic.

Interviews were done to study teachers' views on Learning Study and on the integration of ICT in a Learning Study. And in this study, two teachers were interviewed. We investigated their views on both Learning Study and Variation Theory, perspectives on the integration of ICT in the lesson and opinions on how to improve the whole study. Semi structured questions were asked to these teachers in order to find out the above perspectives. The teachers' interview took place once the tests had been analysed thoroughly. Data was analysed by using the Statistical Package for the Social Science (*SPSS*) and the interviews were transcribed.

Sample

The sample chosen for this study was the Science stream students in an all boys' school in one of the government secondary schools in Brunei Darussalam. There were 17 students involved in this study. These students were of mixed abilities ranging from high to average achievers. The small number of students was a reason why they were selected for this study. This was because the ICT lab can only fit 25 students and not all of the computers were working. The students are of computer literate so it was easy to assign the Geometer's Sketchpad activities. The research lesson for this Cycle Three requires three lessons with each lesson lasted at an average of 1 hour and 10 minutes duration.

The research lesson

The learning outcome for the students is focused on being able to convert speed-time graph to distance-time graph and vice versa. Three research lessons were planned and lessons went accordingly, all of which being conducted in the school's ICT laboratory. The first and second research lesson was on converting distance-time graphs into speed-time graphs and converting speed-time graphs into distance-time graphs respectively. Initially, students were briefed on the basic knowledge of using Geometer's Sketchpad software. The sketches prepared in each of the student's computer represented activities for the students to work out. Students were then asked to do the activities in pairs and discussion took place as they proceeded from one activity to another. During this discussion, a brief instruction on their activity was prepared with the help of Power Point slides displayed using the Interactive White Board. The third research lesson acted as a summary of the object of learning they learnt from the two previous lessons. They were shown two video clips downloaded from *YouTube* uploaded by PhysicsEH (2011). While the videos were being shown, students were

asked to check their answers from their activity worksheet which they had done prior the video lesson.

Validity and reliability of the study

According to Murphy (2011), to enhance a researcher's ability to entail trustworthiness of the analysis, triangulated methods should be implied. He further added that triangulated methods increase the concurrent and construct validity of research. In other words, triangulation provides the credibility and quality of a research. In this study, not only we collected the data by administering pre-test and post-test but also, as mentioned before, interviews and classroom observation were conducted in order to triangulate the methods of data collection.

Pre-test and post-test were further triangulated as the tests were using a rubric to assess the students' performance which later on would be discussed by members of the Learning Study. And this is what we refer to as 'member checking'. In other words, 'member checking' was also employed to increase the concurrent and validity of the study. Furthermore, 'member checking' was not only used for discussing the rubric, the tests and the research lessons, but also for all of the future findings and report. This in turn enhanced trustworthiness on the analysis, increased accuracy and provided realistic data with detail, rich and thick description.

The pre-test was piloted in order to verify its reliability. The reliability coefficient is a numerical index that presents the consistency of reliability ranging from 0 to 1. Reliability coefficient below 0.8 shows that the items have low reliability and more error whilst above 0.8 indicates a very good reliability. The results from the pilot study were analysed by using the same statistical analysis as mentioned before; the *SPSS*. Results were obtained from a pilot study that was conducted in the same school. It was given out to 38 Year 10 students who had participated in Cycle One and Two in the year 2011. From the analysis above, the reliability coefficient was found to be 0.89, indicating that the scale had a good reliability.

However, after a few discussions with members of the Learning Study group, we agreed to improve the test by adding more items. The new pilot test was then distributed to another set of 52 students from three Year 10 classes in the same school. The alpha reliability of the 30 item scale was 0.91, indicating that the scale had a very good reliability.

Results

For better statistical analysis, the students' scores had been converted to percentages. A paired sample *t*-test was conducted to examine the differences between the mean of pre-test and post-test scores for the integration of ICT on Conversion of Travel Graphs. Both Table 1 and Table 2 below showed that there was a significant difference in the scores for the pre-test (M = 29.41, SD = 14.68) and post-test (M = 64.31, SD = 19.75); $t(16) = -8.57$, $p = 0.00$. Furthermore, the Cohen's effect size value ($d = 2.00$) suggested a high practical significance in which this indicates that the mean of the results from the post-test is at the 97.7 percentile of the results from the pre-test.

Table 1: Mean and standard deviation for the pre-test and post-test

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	29.41	17	14.68	3.56
Post-test	64.31	17	19.75	4.79

Table 2: Paired sample test for both pre-test and post-test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-test – Post-test	-34.90	16.80	4.07	-43.54	-26.27	-8.57	16	.00

The mean results for Cycle One and Two were calculated and compared descriptively. The students' scores from Cycle One and Two were converted into percentage for easy comparison to Cycle Three.

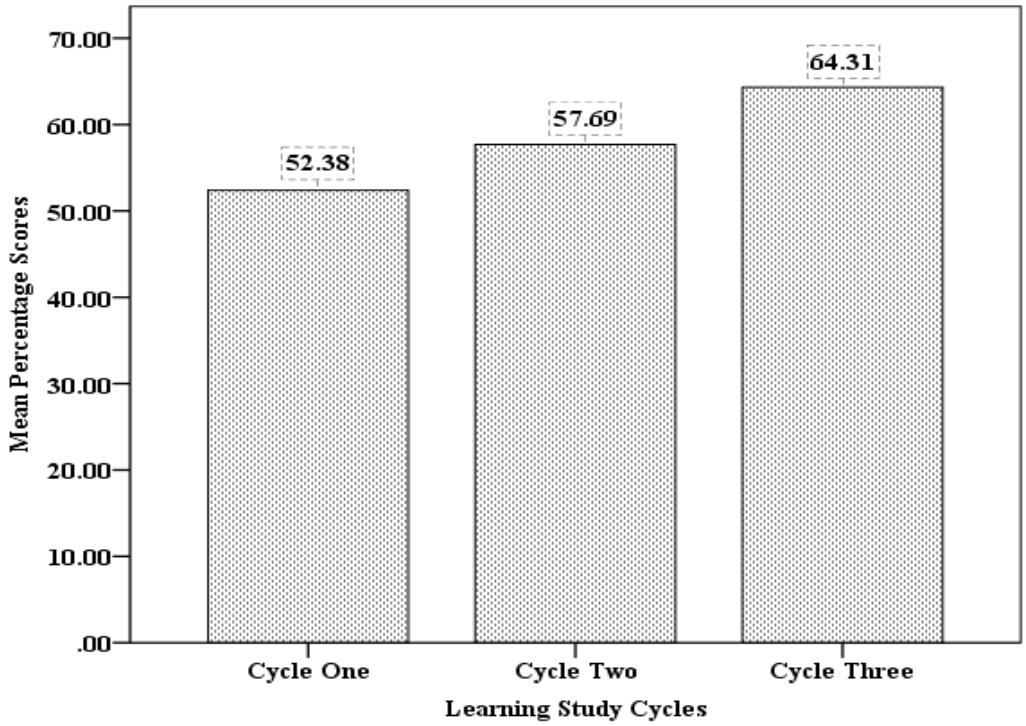

Figure 1: Mean percentage scores for all three cycles for conversion of travel graphs

From Figure 1, Cycle One with N = 19, showed the lowest mean percentage scores (M = 52.38). Since the research lesson was modified and improved in Cycle Two with N = 26, the results increased 5.31% giving a mean percentage score of M = 57.69. Cycle Three with N = 17showed the highest mean percentage scores (M = 64.31) with an increase of 6.62% from the previous cycle.

The rubrics results analysis

With reference to Figure 2, a comparison of mean percentage scores for each dimensions showed that Knowledge and Understanding had the highest mean (M = 34.12) and lowest on Communication Skill (M = 0) on the pre-test results. Similar pattern could also be seen for

the post-test scores. This is when Knowledge and Understanding had the highest mean (M = 68.53) and lowest result was still on Communication Skill (M = 38.24).

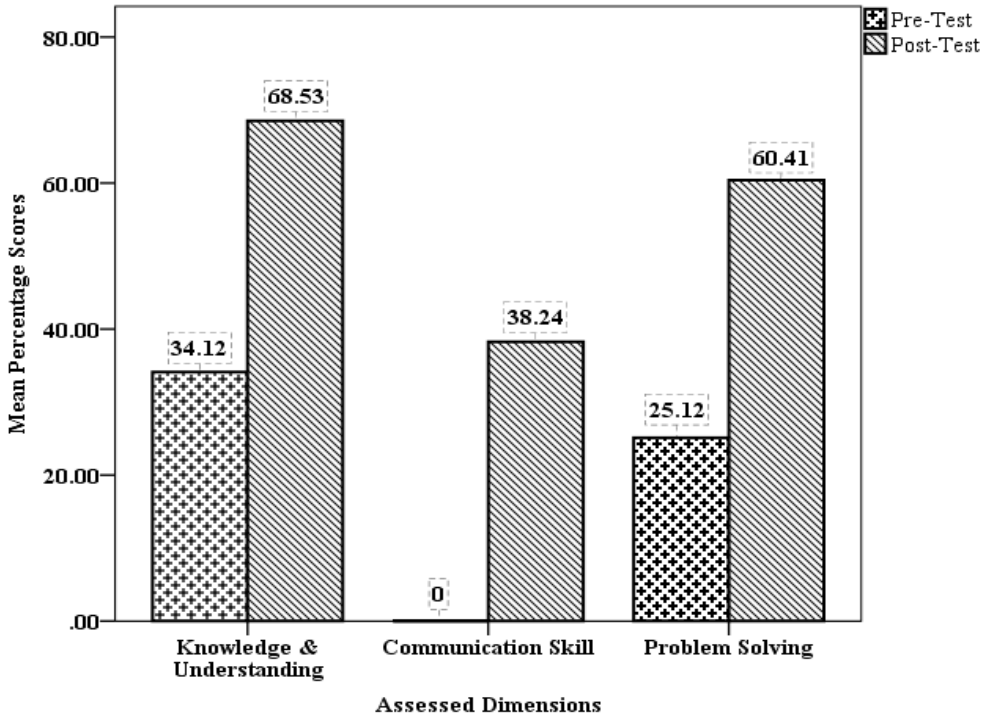

Figure 2: Mean rubric scores for each assessed dimensions from Cycle Three

Teachers' perspectives

Teachers, T1, a male Maths teacher, and T2, a female Maths teacher, both had expressed the need of collaboration between teachers in Learning Study in order to create an effective research lesson. There was also an emphasis on creating a student-centred lesson. It could be stressed out that through stronger collaboration between teachers, any projects could be properly planned. Such collaboration would eventually benefit all teachers where each of them would learn to be responsible, resourceful and more efficient in handling any tasks assigned to them. This in turn could be achieved when teachers are involved in Learning Study.

With regards to Variation Theory, T1 and T2 mentioned that they applied such theory into their teaching. T1 tried to give variety of questions to allow students to discern critically the objects of learning on their own. T2 focused more on questioning technique so that she was able to identify her students' misconceptions. In relation to Variation Theory, T2 had shown that she was able to analyse the critical features of a specified learning object through questioning her students as she allowed the transition to be from a general to a more detailed level of learning outcomes when she conducted her lesson.

T2 further added that through Learning Study, she managed to correct her own misconceptions on this topic Conversion of Travel Graphs. Based from the excerpt below, it was through discovering her own misconceptions that she was able to find a better approach to offer the object of learning to the students. These changes of ways of applying different approaches on delivering the object of learning along with the ability to analyse the critical features of specified learning outcomes are the essence in implementing Variation Theory.

Integration of ICT in learning study

When T1 was asked on the advantages and disadvantages of integrating ICT in a lesson, he had commented that ICT did make lessons fun and interesting. T1 also added that through the use of ICT, teachers could save up time by avoiding writing on the board, which could actually speed up the pace of delivering the lesson even though designing ICT lesson is time consuming.

Meanwhile, T2 also claimed that ICT could be one of the pedagogical tools that help to provide a proper visual aid for students. A lot of time could be saved when explanation is given since students would be able to understand certain concepts through visuals. This surely would help to attract students' attention when learning Maths.

Disadvantages of ICT were also discussed by T2 where she pointed out that designing an ICT based lesson is never easy especially when it deals with the use of unfamiliar software. The Internet could also create problems if it has slow or no connection at all. Another drawback mentioned was on the limited ICT equipment, which could also discourage teachers into implementing ICT in their lesson. On the other hand, any problems encountered during the lesson conducted such as computer crash or broken wires could leave the teachers to be unprepared and unfortunately in the end revert to the orthodox way of teaching.

Both T1 and T2 agreed that ICT could be integrated in a Learning Study depending on the topic. This is because not all of the Mathematic topics can be explained by using ICT. Although, one could disagree because, currently, a lot of free software can be downloaded from the Internet that could teach most Mathematic topics.

T1 also further commented that in the future, he might be interested to implement ICT as part of his pedagogical approach. This is similar to T2's perspective however she preferred being given professional development before being able to fully integrate ICT in her lesson. As discussed in the interview, T2 suggested that this ICT professional development should train teachers on certain topics that use certain software so that teachers can be confident in their teaching when using the ICT.

Discussions

The students' results that were discussed previously exhibited significantly higher scores in the post-test. This implied that students managed to grasp the concept from the first research lesson. Moreover, there was an improvement in an overall performance when compared to Cycles One and Two. This improvement might have been the result of the impact of ICT during the lesson.

Analysing further at the rubrics results, students have shown better improvement in their scoring for each assessed dimension after their post-test. Perhaps, ICT might have improved the students' Knowledge and Understanding on Conversion of Travel Graphs. Students also achieved better standards in the Problem Solving dimension although weaker still at their Communication Skill in which they were still having difficulties in reasoning out their own mathematical working.

This study also aims to seek the teachers' perspectives on Learning Study. Based from the interview, it could be concluded that the two teachers have shown positive changes after experiencing all three cycles. Both have emphasised on the need of collaboration between

their colleagues in designing meaningful research lessons in order for Learning Study to be carried on effectively. According to a study by Meng and Sam (2011) where secondary mathematics teachers have positive attitudes towards the use of GSP in a Lesson Study professional development setting.

Teachers' ability in using Variation Theory is also improving; one tried to implement it in his classroom through discerning several of exercises given to his students, the other used it in her teaching to analyse the critical learning features that students tried or developed.

Based from the results discussed earlier, the performance of the students in Cycle Three Learning Study was better than the previous cycles. This has shown that with teachers' collaboration and Variation Theory, a better systematic design research lesson can affect students' understanding of a mathematical concept. Teachers should be aware and understand what Variation Theory is about in order to implement Learning Study. The discernment in the items of the activity of lesson content will help students to conceptualise a general principle. With this, meaningful learning can be encouraged, as Edwards (2006) stated, "We can structure the learning environment to ensure students experience the variations of the information searching experience; by doing so, we may encourage learning" (Variation Theory section, para. 3).

Another perspective that this study had focused on is on the integration of ICT in a Learning Study. Initially, both teachers were asked to discuss the pros and cons where in terms of the disadvantages, both claimed that designing ICT lessons with unfamiliar software are time consuming. Limited ICT equipment and other problems encountered while using computer for example, slow Internet connection and computer crash are few of the drawbacks that they talked about. Many advantages were also mentioned briefly. According to them, ICT saves a lot of time in delivering lessons and that the pace can be sped up as teachers do not have to write the lesson on the board.

Furthermore, ICT can help attract students' attention. This is expected as ICT lessons provide visuals and students find that fun and interesting. Such interactive lessons can be found from the Internet. Moreover, free mathematical software can be downloaded easily and can be used during a lesson so that students will be able to explore the concept of this topic freely in their own time. Many interactive activities, lesson plan and even lesson notes are now made readily available to be shared for teachers internationally on many websites. Teachers can now effortlessly access these lessons with just 'one-click away'.

With the above positive reviews, one might agree with the fact that ICT could be used as a pedagogical tool in a Learning Study. With the current trend of global education reform, teachers are encouraged to implement the use of ICT in their teaching. Oliver and Trigwell (2005) supported the idea of mixing teaching with technologies in which they referred this as blended learning. They stated that, "Blends of e-learning with other media may make it easier to help students experience the variation in the critical aspects of the topic being learnt" (p.23).

This is true to some extent as admitted by the two teachers. They commented that ICT could be integrated in a lesson to certain Mathematics topics only. In this case, it is suitable to integrate ICT when teaching this particular topic. Overall, it could be implied that the teachers are well aware of the importance of ICT. The idea of moving forward in changing their procedural pedagogical approach is in the back of their mind. If these teachers are given

chances to participate in ICT workshops or be trained using any Mathematical software, surely they will be able to divert their ways into creating ICT based lessons and teach confidently and comfortably in a different teaching environment.

Overall, there are four main interrelated themes in this study and they are: Learning Study, technology, meaningful research lessons and the topic chosen, Conversion of the Travel Graphs. It can be summarised that the process of Learning Study may help out in improving teaching and learning of the topic chosen. Meaningful research lessons may also be accomplished through collaboration of teachers in designing the activities. This of course relates to Learning Study as well since it promotes sharing of ideas and experiences. To improve Learning Study with the integration of ICT, teachers should be exposed to series of professional development.

Professional development is essential in supporting the ICT implementation to be successful. Fullan (1991) stated, "continuous development of all teachers is the cornerstone for meaning, improvement and reform" (p.315). Additionally, teachers should also be open-minded in accepting the change in the teaching and learning environment. Positive attitude on the use of ICT in their lesson and being creative in designing the lesson will further help to enhance meaningful learning. As supported by Thorburn (2004), "teachers need to be convinced that whatever change is being proposed will positively impact student learning" (Summary section, para.1).

Professional development is needed so that teachers will be proficient enough to use any technology. This is important because teachers will facilitate students during a lesson especially if they are using ICT incorporated in their teaching. It helps further for teachers to be more confident in designing creative lessons provided that the professional development focuses on pedagogical techniques. Pedagogical approach using Learning Study should also be shared during professional development. With it, teachers will be able to implement Variation Theory so that Learning Study in Brunei can be continued throughout the years to come.

Future recommendations

The results that had been discussed in this study originated from a small number of sample size and thus, must not be generalised for the whole of Brunei. It is recommended that in the future, a further study with a much larger sample with different level of abilities should be taken into consideration in order to investigate the impact of the students' performance after such intervention.

This study can further be improved if the multimedia software programs are readily available. These software programs namely microcomputer-based laboratory (*MBL*), calculator-based laboratory (*CBL*) and calculator-based ranger (*CBR*) were used mainly in many international studies for this particular topic in Mathematics or Physics subjects. It is suggested that, these multimedia can be used in future research lessons. Comparisons of results can be made since there had been many reviews such as from Lapp and Cyrus (2000), Yenni and Heck (2003), Urban-Woldron (2011) and others, written in relation to the use of this multimedia.

Meanwhile students' misconceptions can also be explored further if more students are to be interviewed. This is also suggested by Beichner (1994) where "interviews or transcripts of students 'thinking aloud' might shed light on why students answered as they did." (p.754).

Perhaps, few misconception facts can be ruled out from the list, as the existing ones may only be applicable to the interviewee.

A wider perspective on the teachers' collaboration should also be asked during the interview to avoid any biasness that may lead researchers into thinking that there is only positive action and reactions. Such perspective should fit the six keys of collaboration as stated by Welborn (2012). They are clarity of purpose, individual commitment, time, understanding how to collaborate and communicate, supportive administrators and freedom to explore. In this study, the collaboration was only based on discussions during meeting and sharing of responsibilities while designing the research lessons. It is recommended for further research to investigate whether teachers are able to achieve the six attributes whilst planning the research lessons.

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