Applying the Thinking Aloud Pair Problem Solving Strategy in Mathematics Lessons

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ABSTRACT

In 'Thinking Aloud Pair Problem Solving' (TAPPS), students work in pairs to solve the mathematics problems. One student (the problem solver) is required to read the problem and think aloud during the problem solving process. Another student (the listener) attends to the problem solver's thinking and reminds him/her to keep saying aloud what he/she is thinking or doing, while also asking for clarifications and pointing out errors being made. This study explored the effectiveness of applying TAPPS on students' mathematics performance in Brunei Darussalam. A Year 9 class from one of the secondary schools participated in this research study. The students' problem solving behaviour and mathematics achievement were investigated to see any significant differences after learning using the TAPPS method. Data reported were mainly collected through mathematics achievement tests, questionnaire surveys and classroom observations. The study revealed that there was a significant improvement in students' problem solving behaviour especially in understanding the problem. Although TAPPS did not help in improving students' conceptual knowledge in mathematics rather, it required the students to have a strong grasp of the conceptual knowledge beforehand in order to be able to devise a plan to solve the problems.

Keywords: Problem solving strategy, secondary, students' mathematics performance, Brunei Darussalam

INTRODUCTION

Learning mathematics is often linked to using one's problem solving skill. While strong conceptual understanding is important in learning mathematics, it is also essential for the students to learn how to use their knowledge effectively in solving mathematics problems. Different problem solving strategies have been described in literatures but some suggest that students tend not to use strategies with too many stages (Jeon et al., 2005). In this study, we mainly used a well-known example of problem solving strategy proposed by Polya (1945), which consists of the following four stages: (i) understanding the problem, (ii) devising a plan, (iii) carrying out the plan, and (iv) looking back over the process.

Thinking aloud pair problem solving, which was first developed by Arthur Whimbey, aims to better understand thinking among the students *(*Whimbey & Lochhead, 1999*)* and to develop students' cognitive processes associated with problem solving (Kotsopoulus, 2010). Thinking aloud pair problem solving is mainly based on thinking aloud and listening (Jeon et al., 2005). As the name suggests, this involves students working in pairs. One student (the problem solver) is required to read the problem aloud and think aloud during the problem solving process, which includes verbalizing everything they are thinking and doing. Another student (the listener) attends to the problem solver's thinking and reminds him/ her to keep saying aloud what he or she is thinking or doing, while also asking for clarifications and pointing out errors being made. It is important to highlight that listeners are not allowed to attempt to solve the problems or give correct answers. Instead of merely imitating worked examples, this instructional method focuses on helping the students learn by being aware of their thinking process in tackling mathematics problems. Students are not always able to express their mathematical understanding in detail. Often, answers from the students were given in the form of one word or sometimes, keywords. Thinking aloud during problem solving may reveal much more about the students' personally constructed understanding compared to assessing them from their written works (Watson, 2002). However this may also be restricted to how well the students are able to express their thinking process verbally.

In this study, we investigated the effects of conducting Thinking Aloud Pair Problem Solving (hereafter, referred to as TAPPS) in a mathematics classroom on students' mathematics achievement in Brunei Darussalam. We also explored whether thinking aloud has any significant effects on students' problem solving performance.

LITERATURE REVIEW

Whimbey and Lochhead (1999) mentioned that thinking aloud during problem solving aims to ensure that students "do not skip steps in their reasoning, nor miss facts in drawing conclusions" (p. 23). This procedure may also help in identifying different kinds of students' weaknesses, errors and strategies in problem solving (Montague et al., 2011). It is able to provide more information inaccessible through examining students' written work for example, through students' explanations.

Jeon et al. (2005) observed in their investigation on the effectiveness of TAPPS in improving problem solving performance of high school chemistry students that students in both the individual and TAPPS groups performed better in problem solving compared to the control group. They found that students in the individual and TAPPS groups performed better in recalling the related law and mathematics execution. The students in TAPPS group also performed better than the others on conceptual knowledge. Jeon and colleagues (2005) also stated that the verbal interactions between the solvers and listeners could help the students be "more cognizant of both their own thinking and the thinking of other students" (p. 1564). However, they discovered that listeners seemed to gain more benefits from TAPPS than the problem solvers. They found that listeners' 'pointing out' behaviour showed the greatest correlation with their own problem solving performance; listeners' 'agreeing' behaviour to the solvers' statements was also positively correlated to the listeners' problem solving performance. They also discovered that there was a negative correlation between the listeners' 'pointing out' and the solvers' problem solving performance.

In addition, Kotsopoulus (2010) highlighted in her study on examining instances of talking aloud during peer collaborations in mathematics that it is important to teach the students both on how to express their thinking and their learning needs and how to attend to each other's thinking and learning needs in such settings. She mentioned TAPPS as a possible suggestion to achieve this. Ericsson and Simon (1980) argued that thinking out loud does not affect the cognitive processes or performance speed, but instead, it does help students to identify and monitor their own thinking process.

PURPOSE AND SIGNIFICANCE OF THE STUDY

TAPPS is used with the intention to reduce the chance of students attempting mathematics problems impulsively as well as to strengthen and clarify students' understanding of the concepts. At the same time it also aimed to promote a student-centred learning environment in the classroom as stated in the new education reform system in Brunei known as *Sistem Pendidikan Negara Abad ke-21* or translated to English Language as the National Education System for the 21st Century (and better known as SPN21) (Botty & Shahrill, 2014; Kani et al., 2014; Mahadi & Shahrill, 2014; Ministry of Education, 2013; Matzin et al., 2013; Mundia, 2010, 2012; Salam & Shahrill, 2014; Shahrill & Clarke, 2014; Yatab & Shahrill, 2014). Incorporating TAPPS in mathematics learning is expected to improve the effectiveness of the classroom learning activity.

This study aimed to critically assess the effectiveness of having TAPPS in a mathematics classroom in Brunei on students' learning and problem solving skills. In order to actualise this aim, we investigated the impact of TAPPS on students' mathematics problem solving behaviour as well as mathematics achievement. This study was guided by the following research questions:

1. Are there any differences in students' mathematics problem solving behaviour before and after learning using TAPPS?
2. Are there any differences in students' mathematics achievement before and after learning using TAPPS?

METHODOLOGY

Participants

The participants for this study were the Year 9 students (mean age of 14 years old) in one of the schools in the Brunei-Muara District. The students participating in this study were amongst the students with intermediate ability doing Mathematics at the International General Certificate for Secondary Education level (or IGCSE Mathematics). There were 21 students (12 boys and 9 girls) in this class. However, since there were some absentees during the data collection period only data from 16 students were taken into account for the Problem Solving Behaviour questionnaire.

Instruments

Recordings of the Lessons

There were three different focus groups chosen throughout the data collection period and their interactions were audio recorded for follow-up analyses. In addition, field notes were also written during each lesson where the first author entered her observations that may be useful for further analyses.

Mathematics Achievement Tests

Scores from the pre-test and post-test were collected to assess the students' mathematics problem solving achievement. These tests required students to answer three items on problem solving under the topic Rate, Ratio and Proportions for 15 minutes.

Questionnaire

A problem solving behaviour questionnaire was used in this study. This questionnaire was given to the students before and after TAPPS was introduced. This questionnaire used a 5-point Likert-type scale, ranging from 1 (never) to 5 (always), obtained and modified from Desoete (2007). It consisted of 25 items that aimed to identify the students' problem solving strategy before and after the study. Each student would receive scores on each item in this questionnaire, ranging from 1 to 5, and a total score from 25 to 125. Each item in this questionnaire represents one of the stages in Polya's problem solving strategy. The first stage, which 'understands the question', was represented by 8 items; 'devising a plan' was represented by 4 items, 6 items represented the 'carrying out plan' stage, and 6 items for the 'reflecting' stage.

Data Collection

The pre-test and problem solving behaviour pre-questionnaire were first administered to the participants at the beginning of the lesson. Then, they were introduced to and practised with the problem solving strategy and TAPPS strategy for the remainder of the lesson. They were first assigned partners based on their pre-test mathematics performances and then trained with their roles as the problem solver and the listener during TAPPS. The students were taught and asked to practise on solving some problems using the four-step problem solving strategy, which consisted of i) understanding the problem, ii) devising a plan, iii) carrying out the plan, and iv) looking back over the process.

Once the students were ready, they were given two worksheets to be done for the rest of the week. In each of the lessons, the first author had chosen different focus groups and recorded their conversations as part of the research data. The worksheets were also submitted at the end of every lesson to be assessed as part of the research data. The problem solving behaviour post-questionnaire was administered to the participants immediately after the students completed their worksheets. Finally, a delayed post-test was also given to the students a week after the intervention lessons.

Data Analysis

In order to answer the first research question, the pre-questionnaire and post-questionnaires were analysed quantitatively using the paired t-test and descriptive statistics to measure any significant difference in their problem solving behaviour before and after TAPPS. For the second research question, results from the pre-test and the post-test were analysed quantitatively using the paired t-test and descriptive statistics to measure any significant difference in students' mathematics achievement before and after TAPPS.

RESULTS AND DISCUSSION

Problem Solving Behaviour

In order to investigate the differences in students' problem solving behaviour before and after learning using TAPPS, the mean scores for the pre-questionnaire and post-questionnaire were analysed using the paired t-test. Table 1 below shows the mean scores of students' problem solving behaviour questionnaire before and after TAPPS. The results indicated that there were significant improvements in students' problem solving behaviour after learning using the TAPPS method for a week ($t = 4.06$, $p < 0.01$).

Table 1. The mean scores before and after TAPPS (N = 16)

	Before	*After*	*t*
Problem Solving Behaviour	85.5 (14.9)	91.8 (15.1)	4.06*

Note. *p < 0.01. Standard deviations appear I parenthesis below the mean scores.

Mathematics Achievement

To investigate the differences in students' mathematics achievement before and after learning using TAPPS, the overall mean scores of the pre-test (2.125) and post-test (1.188) were compared and the difference was -0.937. A paired t-test was computed to find out whether the difference of -0.937 is significant. Table 2 presents the mean scores, the standard deviations of the pre- and post- tests and t-value. The result of the t-test showed that there was no significant difference in the overall mean scores of the pre- and post-test ($t = 1.70$, $p > 0.05$).

Table 2. Mean scores and standard deviations of pre- and post-achievement test and t-value (N = 16)

	Pre-test	*Post-test*	*t*
Mathematics Achievement Test	1.188 (1.721)	2.125 (2.604)	1.70

Note. $p > 0.05$. Standard deviations appear in parenthesis below the mean scores.

The results of this study indicated that the TAPPS method could help improve students' problem solving behaviour. However, it should be noted that this study did not show that using this method alone could help students improve their mathematics achievement. During the intervention lessons, a pair of students who were chosen as one of the focus groups showed that they spent most of their time re-reading all the questions in the worksheet and drawing diagrams in an attempt to understand the questions better. However, no further progress in problem solving was observed in their worksheet. In order to investigate deeper into their problem solving behaviour, the t-test analyses on students' problem solving behaviour were done separately according to the four stages in Polya's problem solving strategy.

It was found that the students improved most significantly in understanding the questions, which is the first stage of the problem solving strategy ($t = 4.30$, $p < 0.01$). However, the students did not show that they have significantly improved at a 5% level in devising a plan to solve the problems ($t = 0.26$, $p > 0.05$). Table 3 below shows the means for students' questionnaire scores on each stage of Polya's problem solving strategy before and after the TAPPS lessons.

Table 3. Mean scores and standard deviations for the four stages in Polya's problem solving strategy (N = 16)

	Before	*After*	*t*
Understanding the problem [a]	26.375 (4.787)	29.625 (4.209)	4.30*
Planning [b]	13.688 (2.496)	13.813 (2.834)	0.26
Carrying Out [c]	23.938 (4.464)	25.500 (4.789)	2.78
Reflecting [d]	21.500 (4.604)	22.875 (4.617)	1.75

Note: [a] Understanding the problem stage was represented by items 1, 2, 3, 6, 7, 8, 9 and 10 in the Problem solving behaviour questionnaire. [b] Planning stage was represented by items 4, 12, 13 and 16 in the questionnaire. [c] Carrying out plan stage was represented by items 5, 11, 14, 15, 17 and 18. [d] Reflecting stage was represented by items 19, 20, 22, 23, 24 and 25.

* $p < 0.01$. Standard Deviations appear in parentheses below the mean scores.

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

The findings of this study showed that the use of TAPPS method helped students in being aware of their thinking process and improve their problem solving skills, especially in understanding the problem solving questions prepared in this study. However, it did not help improve students' conceptual knowledge. If students' conceptual understanding were weak to start with, the problem solving strategy would not help much during the exercise. This is consistent with the findings by Jeon et al. (2005) which reported that "the problem solving strategy did not improve students' conceptual knowledge more than conventional methods" (p. 1563). They also reported that the TAPPS method was "..more effective than individual use of the problem solving strategy at helping students become aware of their knowledge, process, or skill and those of their fellow students" (p. 1563). Due to lack of planning strategies, students then tend to stop halfway through their problem solving as was reported by Jeon et al. (2005). Therefore, it may still not be enough in helping to improve students' mathematics achievement in problem solving. It is essential that the students have a strong conceptual knowledge (that is required to tackle the particular mathematics problems) beforehand to work with during the learning activity using TAPPS. Subsequently, TAPPS could then help them be better in applying their knowledge to devise a plan for solving the problems at hand.

Another reasonable explanation might be that students were finding it hard to understand some of the questions due to their weak command of the English language. When the students found the exercise questions difficult, they tended to give up and get distracted easily. As reported by Fan and Yeo (2007), "students' ability in their command of the language (English) was a crucial factor in determining their ability to perform well in oral presentation tasks" (p. 94). This may be the case for the participants in this study. Although students have to practice speaking about mathematics in English with the correct use of terminologies, it is important for the students to be able to express their own understanding in the language they are comfortable with first. As the students get more comfortable with this process, the teacher may then introduce some rules with using the appropriate language and terminologies.

Students generally showed positive perceptions and attitudes towards learning mathematics using the TAPPS method. However, during the TAPPS activity, the first author came across some students who were shy and reluctant to think aloud even though they were able to write and use mathematical notations. Students were also reluctant to ask what they were struggling with as a group unless they were approached and asked directly if they were having any problem. Similarly, Henjes (2007) in her study on the use of the think-aloud strategy to solve word problems with her sixth-grade students. She reported that students would not use the think aloud strategy as they were not familiar with the process and "had not yet taken ownership of the think aloud strategy" (Henjes, 2007, p. 16).

Apart from the challenge of getting used to expressing themselves verbally, students did not have a problem with accepting TAPPS in their mathematics learning. Students agreed that the TAPPS method could help with their mathematics learning. This was consistent with the results in the study by Gan and Hong (2010) where the students in the peer-tutoring group had a more positive perception of the interactive activity compared to the control group. Students' preferences of learning techniques could contribute into how effective it is. Apart from that, encouragement from the teacher is also a key factor "to better give confidence to students who were engaging in something that was not previously the focus in their learning" (Fan & Yeo, 2006, p. 94).

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The results in this study contradicted the results found by Jeon et al. (2005). Since the number of participants and time were limited during the data collection period, this study suggests more research to be done in the future in investigating the effects of TAPPS on students' mathematics achievement for a longer period of time or with a sample that is representative of the Brunei secondary level students. In addition, without any extensive revision lessons done on the Rate, Ratio and Proportions topic before the TAPPS lessons, students found it hard to remember the concepts in order to solve the problems given. This has resulted in the students not knowing which information from the questions that should be considered as important or relevant. Therefore a suggestion for future research would be to carry out the TAPPS lessons on a certain topic immediately after they have learnt it and to investigate the improvement in their mathematics achievement and problem solving behaviour.

In this study, we investigated on how well students were able to use TAPPS in their mathematics classroom by examining whether there were any significant differences both in their problem solving behaviour and their mathematics achievement before and after TAPPS. Future research on other disciplines in the Brunei context should also be done, as it may be a better learning method in other subjects that involve problem solving besides mathematics. Jeon et al. (2005) did their study on the effectiveness of TAPPS method in the context of chemistry lessons and have found that TAPPS "improved students' conceptual knowledge and increased success rates on solving problems" (p. 1564). The students in their study were better at recalling related laws and executing meaningful mathematical expressions with the help of TAPPS. This could also be the case for other subjects, especially in science. It is also important for any teacher or researcher to gradually introduce TAPPS to their students. The teacher or researcher may begin by firstly providing an environment that the students are comfortable with. After a familiarisation period, a more challenging task may then be given to the students.

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