INSTRUCTIONAL STRATEGIES AND SCIENCE ACHIEVEMENT OF FORM 2 STUDENTS IN MALAYSIA: FINDINGS FROM THE TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS) 2003

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The present study used data from the Trends in International Mathematics and Science Study (TIMSS) 2003 to look at the trend in instructional strategies in science teaching and its effect on the science achievement. Based on the analysis, the strategies used by most science teachers were demonstration, practical work and the lecture method. Among these strategies, the most commonly used in Malaysia was the lecture method where more than 90% of the teachers involved in TIMSS used this strategy. Students in classes where their teachers demonstrated experiments, where students perform experiments and also where students listened to lectures performed significantly higher in the TIMSS science achievement. It was also found that students were more likely to give explanations to their observations than to design their own experiments. These findings suggest that ample opportunities should be given for students to design their experiments which include formulating hypotheses, making predictions and giving explanations to the outcomes of their experiments.

Introduction

Teachers use various approaches and strategies in science instruction aiming at developing students' creative and critical mind. The Malaysian Science Curriculum (Ministry of Education, 2003) recommends several approaches and strategies in order to provide teachers with guidelines for effective science instruction. The Curriculum basically promotes a pedagogical shift from a teacher-centred to a student-centred instructional paradigm. Among the approaches recommended in science education include the inquiry-discovery approach, constructivism, mastery learning and the science, technology and society (STS) approach. Several strategies and methods are also outlined in the Curriculum. These strategies include experimentation, group discussion, simulations and uses of technology in science teaching.

The purpose of this study was to identify the trend in instructional strategies in science teaching and its effect on the science achievement based on the results of the Trends in International Mathematics and Science Study (TIMSS) 2003.

Teaching Approaches and Strategies in Science Instruction

One of the factors that could affect students' achievement are the instructional approaches and strategies that science teachers employ. Teaching approaches and strategies refer to the ways teachers go about their teaching in achieving a set of targeted learning outcomes. Since science is a way of looking at the world and seeking explanations, one of the recommended teaching approaches in science is the inquiry and discovery approach. Through this approach, learners create their own investigations, with teacher as a facilitator, and the inquiry should relate to the real-life experiences of the learners (Edwards, 1997). Research on this approach has shown that it enhances students' learning (Sherman & Sherman, 2004). Other studies have shown that students who underwent inquiry-based science instruction achieved higher scores in their science as compared to their counter-parts in the control group (Amaral, Garrison, & Klentschy, 2002; Faridah, 2000).

There are a number of strategies for inquiry-based instruction. Common strategies in science instruction are experimentation, demonstration, discussion and project work. Experimentation is usually associated with laboratory work and it is an essential component of science instruction. However, experiments could be carried out outside science laboratory as well. To many educators, laboratory work is the essence of science instruction. Laboratory activities allow learners to pursue learning autonomously (Tobin, Tippins, & Gallard, 1994). Research indicates that the experience of carrying out these activities can provide learners with valuable insights into scientific practice and can increase interest in science and motivate them to continue its study (Jakeways, 1986; Woolnough, 1994). Experimentation also promotes the development of cognitive abilities such as critical and creative thinking (Shulman and Tamir, 1973) and this cognitive development enhances science learning. However, there are some concerns that experimentation has often failed as the most important objective of learning in the laboratory. Various factors need to be considered in order to make laboratory work meaningful; namely student engagement in science inquiry processes, student manipulation of experimental materials, and the experiential teaching of specific scientific concepts (Leonard, 1989).

Demonstration is another commonly used instructional strategy and Chiapetta, Kobala and Collette (1998) reiterated that one of the factors that a teacher needs to consider is whether the strategy is the best way to address a certain topic. For instance, it would be inadvisable, to perform a demonstration to test the pH of selected water samples, when laboratory experience is inexpensive, safe and visible to all students. Demonstrations can be meaningful if during the demonstration, the teacher engages students in guided discussion. Such discussion stimulates students' thinking and is necessary to promote scientific understanding of a science demonstration (Shepardson, Moje, & Kennard-McClelland, 1994)

Experimentation and project work are commonly done in groups. Group work transpires social interaction among learners and this in turn mediates learning. This is in-line with the Vygotskian perspective that sees learning as a social construction of knowledge. Knowledge is constructed through engaging socially with their teacher and peers, in conversation and activities of common concern. In group settings, learners cooperate, collaborate or compete with each other. As learners interact with peers, they articulate their views, argue with each other, make critiques on peers' ideas and reflect as they try to achieve mutual understanding. They will then build on each other's contributions and meanings can be co-constructed, and these processes appear to be particularly critical for students' learning in science (e.g. Mercer, 1996; Crook, 1998; Tao & Gunstone, 1999; Mueller & Fleming, 2001.)

Several studies offer empirical proof for the suggestion that intellectual discourse contributes to improvement of conceptual understanding (e.g. van Boxtel, van der Linden & Kanselaar, 2000; Light, Littleton, Messer & Joiner, 1994). Such an active engagement strategy is better as evidence has shown that lecture-type explanations are relatively ineffective instructional tools for promoting conceptual change (Knight & Wood, 2005). A productive peer interaction is not only characterized by the use of domain specific concepts, ways of reasoning and by elaboration, but also by the co-construction of knowledge.

Science Instruction Practices

Experts recognize the vital roles of teachers in science learning (Marzano, Pickering & Potllock, 2001; Harlen, 2000). Harlen (2000) identified three main aspects of teachers' roles and one of them was organizing instructional activities. These activities should be of relevance to learners and ample opportunities should be given for them to have direct contact with the materials to be investigated.

Instructional materials are also commonly employed by teachers in their teaching. Such instructional materials include exercises and quizzes. Exercises can be given as homework to reemphasize their teaching. Homework can be defined as tasks or assignments given to students by school teachers that are meant to be carried out during non-class time. Different researchers have gathered different evidence on the effects of homework. Some found that homework has positive effects on achievement (e.g., Austin, 1979; Keith, Keith, Troutman, Bickley, Trivette & Singh, 1993), others (e.g. Barber, 1986) found homework to have negative effect on students' achievement, and some (e.g. Friesen, 1979; Epstein, 1983) found homework to have an inconsistent effect.

The inconsistencies in these findings might be due to the different grade levels of the students being investigated. (Muhlenbruck, Cooper, Nye & Lindsay, 2000) and Cooper (2001) found that there is an association between grade level and homework's effectiveness. There is more impact with students at junior than with high school students. According to Cooper (2001), the time spent on homework also relates to higher achievement but again this is dependent on grade levels.

Data and Methods

A total of 50 countries participated in the Trends in International Mathematics and Science Study (TIMSS) 2003 and TIMSS was designed to measure mathematics and science achievements across participating countries. However, this study will only focus on the science component of TIMSS. The science assessment framework for TIMSS 2003 consisted of two dimensions, namely the content and cognitive aspects. There were five content domains: life science, chemistry, physics, earth science and environmental science and three cognitive domains: factual knowledge, conceptual understanding, and reasoning and analysis. TIMSS has also developed a generalised scoring guide for both mathematics and science items and a few scores were derived from the generalised scoring guides. One of them was the plausible values which were suitable for making international comparisons. In TIMSS 2003, Malaysia was ranked twentieth from the 50 countries that took part with a mean score of 510. The international mean score was 474 (Martin, Mullis, Gonzalez, & Chrostowski, 2004).

In Malaysia, TIMSS 2003 involved a total of 5314 Form 2 students and 150 science teachers from schools all over the country (Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, Kementerian Pelajaran Malaysia, 2004). TIMSS involved a science achievement test and three types of questionnaire. The questionnaires were given to students, teachers and the schools. For this study, we use responses from students for analysis. Some of the data compiled were information regarding instructional activities, student characteristics, family characteristics, learning resources and science achievement.

There were three specific types of instructional activities (watch teacher demonstrate an experiment or investigation, conduct an experiment or investigation, and listen to the teacher give a lecture-style presentation) that were included in the questionnaire. Some other items have been included in the analyses but were subsumed under the three main instructional activities or strategies. These items have been included under the strategy 'conducting experiment': (1) formulate hypotheses or predictions, (2) design or plan an experiment or investigation, (3) write explanations about what was observed and why it happened, (4) work in small groups on an experiment or investigation, and (5) present your work to the class. Items (1) relate what you are learning to your daily life, (2) present your work to the class, (3) review your homework, (4) work problem on your own, (5) begin your homework in class, and (6) have a quiz, have been included under the category instructional practices. All of these variables use four categories of response scale namely, 'Every or almost every lesson', 'About half the lesson', 'Some lessons' and 'Never'. Finally, the dependent measure used in this study was the TIMSS International Science achievement score, which is the average of five plausible values generated by the TIMSS study. Several science content areas were included in this achievement test (earth science, life science, physics, chemistry, and environmental issues and the nature of science).

Since this study was an initial effort in exploring the TIMSS data, only descriptive statistics and ANOVA were employed. ANOVA was used to determine the instructional activities that have significantly different means on science achievement.

Results

The most employed strategy by science teachers was the lecture method. More than 99% of the sample used the lecture method while less than 1% said that they never used this strategy. Slightly more than half (51%) of the subjects employed demonstration as their instructional strategy in almost all of their lessons, whilst slightly more that a third (37%) made their students conduct experiments in every lesson. However, only 14% of the subjects designed their own experiments while almost a third of the subjects designed experiments in some of their lessons. Almost half of the subjects work in groups in doing experiments. The frequency of instructional activities employed by science the teachers are presented in Table 1.

Table 1
Frequency of Instructional Activities Employed

Instructional Activities	Frequency of Strategies Employed			
	Every or Almost Every Lesson	About Half the Lesson	Some Lesson	Never
Demonstration of an experiment	51.1%	32.0%	15.2%	1.7%
Conduct experiment	37.0%	35.2%	24.0%	3.8%
- design experiment	13.8%	32.5%	35.5%	18.3%
- formulate hypotheses	30.3%	39.6%	25.6%	4.5%
- gives explanation to observation	37.0%	35.6%	23.2%	4.1%
- present work to class	13.9%	28.2%	40.8%	17.0%
- work in groups	47.9%	29.4%	19.0%	3.6%
Listen to lecture-style	69.9%	23.1%	6.9%	0.4%

The ANOVA was performed to determine the difference in science achievement score with the different instructional activities employed. The groups were collapsed to two or three when the differences between the groups were found to be not significant.

Generally, the results in Table 2 show a significant difference in the mean science achievement scores between groups that employed demonstration, conduct experiments and the lecture method. It was found that there was a significant difference in the mean of science achievement score for the group which employed demonstration in every or almost every lesson as compared to the group which used demonstration in about half of the lessons or lesser frequencies (mean difference=13.27, p=0.000).

Table 2
Differences Between the Instructional Strategies on Science Achievement

No.	Instructional Strategies	Groups	Mean	*p*-Value
1	Demonstration of an experiment	every or almost every lesson	515.95	0.000*
		About half the lessons, some lessons and never	502.68	
2	Conduct experiment or investigation	every or almost every lesson	524.49	0.000*
		About half the lessons	508.02	
		Some lessons and never	491.44	
	• Design or plan an experiment or investigation	every or almost every lesson	515.04	0.012*
		About half the lessons, some lessons and never	508.65	
	• Formulate hypotheses or predictions	every or almost every lesson	514.89	0.000*
		About half the lessons, some lessons and never	507.08	
	• Gives explanations to observation	every or almost every lesson	524.20	0.000*
		About half the lessons, some lessons and never	500.86	
	• Work in small groups	every or almost every lesson	524.90	0.000*
		About half the lessons	501.59	
		Some lessons and never	487.21	
3	Lecture-method	every or almost every lesson	517.25	0.000*
		About half the lessons	499.30	
		Some lessons and Never	470.74	

*significant at the 0.05 level

The result also indicated that students scored significantly higher in their science achievement test in classes where they designed their own experiments, formulate hypotheses, and gave explanations to their observations in every and most of the lessons as compared to students who rarely (about half the lessons, some lessons and never) do so.

Table 2 also revealed that students working in groups while performing experiments in every or almost every lessons scored significantly higher in the science achievement test than students working in groups in less than half of the lessons (half the lessons, some lessons and never).

Based on Table 2, it can be inferred that the lecture-method was also an effective instructional strategy. Students under this category scored significantly higher in their science achievement test than students whose classes employed the lecture method in half, only in some of the lessons or never employed this strategy in their lessons.

The results in Table 3 showed that students in classes where teachers relate learning to the students' daily lives in almost every lesson performed significantly better than students in classes where it was seldom done or when the learning was not related to their daily lives. The result also revealed that there was a significant difference between classes where students work on problems on their own in every lesson and almost every lesson and in classes where they seldom or never work on problems on their own.

Table 3
Differences Between the Different Instructional Practices on Science Achievement

No.	Instructional Practices	Groups	Mean	*p*-Value
1	Relate learning to students' daily lives	every or almost every lesson	521.51	0.000*
		About half the lessons	514.94	
		Some lessons	505.29	
		Never	479.74	
2	Students present work in class	every or almost every lesson, about half the lesson	508.53	0.003*
		Never	515.39	
3	Students work problems on their own	every or almost every lesson and about half the lessons	516.32	0.000*
		Some lessons	507.94	
		Never	475.68	
4	Begin homework in class	every or almost every lesson	524.08	0.000*
		About half the lessons	510.14	
		Some lessons and Never	504.34	

*significant at the 0.05 level

The result in Table 3 also indicates that students who begin doing their homework in class in most of the lessons performed significantly higher than those seldom begin doing their homework in class. There was also a significant difference between students who never present their work in class and students who always present their work in class, on science achievement test (mean difference=6.86, p=0.003). Students who never present work in class performed better in science as compared to those who did. Although it was not included in Table 3, analysis also showed that the use of quiz in class and revision of homework by students did not have significant effects on science achievement.

Discussion and Conclusion

The three main instructional strategies discussed in this study were performing demonstration; the lecture method and students conduct experiments. Among these three strategies, the most commonly employed was the lecture method. This strategy was not only common among teachers in this study, but it was also common in most middle school and secondary school science classes (Chiapetta et al., 1998). Based on the results, it can be inferred that the lecture method is an effective strategy and according to Chaipetta et al. (1998), the lecture method has certain strengths that make it useful for science instruction. It is especially effective in conveying information, particularly to students who have difficulty reading textbooks and do not read assigned text materials.

However, students in classes where they themselves performed experiments in most of their lessons had a higher mean score in their science achievement test as compared to students who listened to lectures in most of their lessons. On the other hand, students who observed teachers performed demonstration in most of their lessons have a slightly lower mean as compared to students who listened to lectures in most of their lessons. In addition, this study also showed that the group that employed demonstration, conduct experiment and lecture methods in every or almost every lesson performed significantly better than those who do them rarely or not at all. Laboratory activities such as watching demonstration and performing experiments or investigations allow learners to pursue learning autonomously (Tobin, et al., 1994). Research indicates that the experience of carrying out these activities can provide learners with valuable insights into scientific practice and can enhance their interest in science and the motivation to continue its study (Jakeways, 1986; Woolnough, 1994). In addition, experimentation promotes the development of cognitive abilities such as critical and creative thinking (Shulman & Tamir, 1973).

The result also indicates that students working in groups scored significantly higher in their science achievement than those who did not. This finding is in-line with Vygotskian perspective that sees learning as a social construction of knowledge. Knowledge is constructed through engaging socially, with their teacher and peers, in conversation and activities of common concern. In such setting, learners cooperate, collaborate or compete with each other. Intellectual discourse transpires from these interactions. The discourse will enhance students to build on each other's contributions and meanings can be co-constructed, and these processes appear to be particularly critical for students' learning in science (e.g. Mercer, 1996; Crook, 1998; Tao & Gunstone, 1999; Mueller & Fleming, 2001.)

This study also found that students did significantly better in their science achievement test when the teachers relate students' learning to daily applications and also when the students work on the problems themselves. When proponents of Science, Technology and Society (e.g., Yager, 1996) introduced this movement, one of the reasons was to make science education applicable and meaningful. Through such an approach, students could relate to the importance of science process skills in any investigation, and the application of scientific knowledge in solving problems in their daily lives.

Giving homework to students benefited them, particularly when students attempt to do it during class or school time. This was also one of the findings of this study. Homework was found to have positive effects on achievement (e.g., Austin, 1979; Keith et al, 1993), particularly at this age group as Cooper (2001) found that there is more impact with students at junior to high school students.

One interesting finding from this study was that in classes where students present their work, there was a reverse effect. Their counterparts who never present work in class scored significantly higher than those who presented their work in class. One possible reason to this phenomenon is that the students probably were not interested in listening to other students' presentation. Based on our experience, such experience is also true among university students. Students seem to be busy with their own work such as preparing for their own presentations, when other students were presenting their work during seminars. Thus, presentation as such will not have a positive effect on students' learning. Therefore this strategy needs to be reconsidered in the school science teaching. Furthermore, instructional strategies such as having a quiz or test, asking students to review their homework can also be reconsidered or restructured since these strategies did not give significant effect on the science scores.

These findings have implications on the instructional practices employed in relation to students' science achievement. It suggests that ample opportunities should be given for students to design their experiments which include formulating hypotheses, making predictions and giving explanations to their experiments. Although the lecture method was found to be an effective strategy, it is only suited for certain kind of topics. Items tested in the science achievement test were probably best acquired through lecture method. Demonstration too was found to be an effective instructional strategy and this implies that teachers could have chosen appropriate topics using demonstration and they might have incorporated discussion within the demonstration sessions.

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