Science Education International
Vol. 17, No. 2, June 2006, pp. 109-121

International Council of Associations in Science Education

Using Constructivist Teaching to Improve Upon an Unproductive Didactical Contract during Chemistry Learning

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ABSTRACT *Didactical contracts research by Brousseau and Warfield highlights that teachers and students in a classroom situation often reach unofficial agreements to exhibit certain desired behaviours. These accords influence the classroom environment as well as students' learning. The aims of this study were to modify students' behaviour to overcome an unproductive didactical contract in a science class by using a constructivist informed teaching method, and to improve students' satisfaction and achievement in science. Data on students' expectations on the teaching method to be used by their teachers (a didactical contract), their satisfaction on constructivist informed teaching method, and their achievement in the course were collected from 27 students enrolled in a lower secondary certificate program at the University of Brunei at Darussalam. The results of the study revealed that, by the end of the semester, the constructivist informed teaching method modified the didactical contract, and about 80% of students wanted their lecturer to follow a constructivist informed teaching method that was not in line with their previously expected method that involved being given explanations and notes to copy. Moreover, their satisfaction towards constructivist teaching as well as achievement in the chemistry course improved significantly. Further research is recommended to verify the claims of this research using students from other age groups. It is also recommended to investigate the effects of teaching science with a constructivist informed teaching method on other unproductive didactical contracts.*

KEY WORDS: *Didactical contacts, constructivism, learning outcomes*

Introduction

"Didactical contract" is a set of specific teacher behaviours that are expected by the students and the set of student behaviours that are expected by the teacher. Didactical contracts research by Brousseau and Warfield (1999) highlighted that teachers and students in a classroom situation often reach an unofficial agreement to exhibit certain desired behaviours. These accords influence the classroom environment as well as classroom teaching and learning. Didactical contracts studies in mathematics and science classes have attracted researchers' attention internationally (Brousseau & Warfield, 1999; Hiebert & Stigler, 2000; Khoo, 2001; Lim, 2000; Monaliza, 2001; Norlina, 2002). Hiebert and Stigler (2000), who carried out a video study in 1994–1995 for the Third International Mathematics and Science Study (TIMSS), analysed 231 eighth-grade lessons in randomly selected classrooms in schools within the United States, Germany, and Japan. They reported that in eighth-grade geometry lessons in schools across the United States, a similar pattern

existed in almost all of the lessons. The steps in this pattern are reviewing previous material, demonstrating how to solve problems for the day, practicing and correcting seatwork, and assigning homework.

Monaliza (2001) and Norlina (2002) have identified some of the didactical contracts in lower secondary science classes and upper secondary biology classes respectively in Brunei. One of the didactical contracts highlighted in these studies was that students expected their teachers to follow the same teaching method in every science lesson. Classroom observation data revealed that the teaching method used by teachers in the science classes included teachers listing the topic on the white board, asking a few questions about the previous lesson, explaining the topic, and then writing notes for the students to copy, followed by some homework similar to class work. This method hereafter is referred to as a traditional teaching method. This pattern of teaching science in Brunei is similar to the one used in mathematics lessons in U.S. schools, as described by Hiebert and Stigler (2000). However, research indicates that the practice of presenting concepts through stand-alone examples and repetitious practice sets does little to foster understanding or to affect transfer of learning to other areas (Resnick & Ford, 1981).

The studies by Monaliza (2001) and Norlina (2002) revealed that the teachers were trying to teach the way students expected them to do. However, the benefits of traditional teaching methods are not clearly understood. It may be advantageous for teachers to teach this way; it appears to minimise classroom discipline problems, because the students are busy copying notes from the white board. However, when teachers taught students using traditional teaching methods, the post-teaching mean achievement score data for lower secondary science students (Monaliza, 2001) and for secondary mathematics students (Lim, 2000; Khoo, 2001) showed very little improvement. Moreover, the improvements were of no educational value, which means that students post-teaching mean achievement scores were far below the pass level (50%).

Contrary to this, Norlina (2002) reported that students' post-teaching mean achievement scores improved significantly. However, it should be taken into account that in Norlina's study only high achieving biology students improved their achievement scores significantly. The low achieving biology students' post-teaching mean achievement score improved significantly, but it was less than 40%, which means it was of little educational value. The didactical contracts honoured by teachers while teaching science to students were therefore seen as being unproductive (Dhindsa & Monaliza, 2003).

The basic problem with the traditional teaching method appears to be that teachers' explanations are understood differently by different students, and that students feel confident in their understanding during the explanation stage. However, when teachers describe their cognitive structures of the taught concepts in the written format (notes) on white board for students to copy, all students are expected to learn the same complex description of the concepts, which is in fact the understanding of their teachers. Many teachers often write descriptions of concepts from a textbook on the white board for students to copy. In these cases, the descriptions are much more complex and deviate greatly from the teacher-given descriptions. This makes it more difficult for students to cope with what they have

learnt and what they copied for from the white board. Moreover, it has been observed that teachers use smaller sentences with one idea per sentence, when they give descriptions of concepts orally in a classroom. However, the sentence length becomes about double (or 2.5 times) with more that one idea per sentence, when they write descriptions of the concepts on the white board (Dhindsa, 2003). Contrary to approaches using the traditional teaching method, it may be useful for those intelligent students, who are lazy to collect additional information about the concepts taught in the class, but who can cope with differences in oral and written descriptions, as well as with longer sentences with more than one idea per sentence. When there are differences in what students have learnt in a classroom and copied for future reference, there is a high probability of conflict and confusion in their minds, thus affecting their achievements in the subject. This confusion may be responsible for little improvement in students' achievement scores when taught using traditional teaching method. We therefore felt a need to modify the learning environment and break a didactical contract, that is, to modify students' expectations from their teachers to teach by traditional methods (giving explanations followed by notes on the white board), and thus to improve their academic achievement.

Constructivist learning that requires students to build on their prior knowledge at their own pace, followed by group discussions to converge student's individual understanding of the concepts to the expert's understanding, has been recently reported to be the most successful method (Bodner, 1986; Dhindsa, 2000; Tekkaya, 2003). Group discussion is the heart of constructivist teaching and learning method. We believe that if the group discussion in constructivist-informed learning is integrated into collaborative learning, it may not only help students' improve their achievement, but also modify their learning behaviours, including a change in their expectations from their teachers on the teaching method (didactical contract). There is ample research available on improvement of students' achievement scores when students are taught using constructivist-informed (Bodner, 1986; Dhindsa, 2000; Tekkaya, 2003) and cooperative learning (Lim 2000; Nichols, 1996; Tingle & Good, 1990). However, it is not very clear if these teaching approaches, or their mixtures, help students modify their expectations (behaviour) in addition to improving their achievement.

In this study, we, therefore, decided to break a didactical contract on teaching with a traditional method between students and teachers, by employing a mixture of constructivist and collaborative learning approaches, and examine their overall achievement scores. The mixture of these approaches is hereafter referred to as constructivist teaching method. This method is described in detail in the method section of this manuscript. We were aware that students might be resistant to changes in teaching method. However, we felt that this new teaching approach may help the students to modify their expectations and help them enjoy the new learning method over the time. We assumed that a mixture of constructivist-informed and collaborative learning could help students to modify their expectations from their teachers on traditional teaching method and to improve the students' mean achievement score.

Objectives

The major aim of this study was to modify students' behaviour in terms of their expectations from their teachers on traditional teaching method by the use of a constructivist teaching method. The constructivist teaching method that was not in line with students' expectations presented a new learning environment in an attempt to bring a behavioural change in these students. More specifically, the study was designed to answer the following research questions.

1. Were the students taught in the school using traditional teaching methods? Did the students expect their lecturer to teach the course using traditional teaching methods?

2. Did the constructivist-informed teaching method help students to modify their behaviours in terms of their expectations from their lecturer on teaching with the traditional teaching methods?

3. Did the students enjoy the constructivist teaching method?

4. Did the students' achievement improve significantly after learning chemistry content with the constructivist teaching method?

Method

Subjects

The subjects of the study were 27 students enrolled in a certificate of lower secondary science teaching program in the Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei, Darussalam, Brunei. The language of instruction was English; the students first language was Malay. Data for two students were partially incomplete, and therefore the number of subjects reported in various sections of the study vary from 25 to 27. The basic but there were some students who have enrolled in the program after passing A-level in secondary school. Some of the students did not have any upper secondary science background, but all have learned general science during their lower secondary school education. The median age of the students was 17 Years. The data werer collected when students were in semester two of their six-semester program. During this program, the students are required to take science content as well as methods of science teaching courses.

Science Content and Available Teaching Time

The science content that students learned during the semester was divided under 12 major headings. These headings included Matter, Resources from Earth, Compounds and Kinetic theory, Atomic structure (I, II, III), Acids, Bases, and Salts, Atmosphere, Water, and Electrolysis (I, II, III). This content was taught in a 14 weeks semester. Four contact hours (two for theory and two for practical work) were available to teach this course. The first and the last weeks were used for introduction and end of semester evaluation. In the remaining 12 weeks, the above stated topics were covered. In addition to content learning, each student completed six content-related experiments. Each topic was summarised under 10 ± 2 questions. A set of questions covering acids, bases, and salts topic is listed in Figure 1.

Acids and Bases

S. No.	Questions
1.	What are the characteristics of acids and bases?
2.	Make a list of acids and bases?
3.	What do you understand by the terms strong/weak acids as well as bases?
4.	What do you understand by the term pH?
5.	Define an acid or a base in terms of pH.
6.	What are the relationships between pH and pOH?
7.	What is the relationship between $[H^+]$ and pOH?
8.	Convert the following concentrations to pH. 0.001M HCl, $2x10^{-5}$ M NaOH; 5M KOH, 2 M sulphuric acid.
9.	What do you understand by the term salt? How do we prepare sults
10.	Can salts be acidic, basic, and neutral? Describe?
11.	Fertilisers can change the pH of soil. Explain the action with examples.

Figure 1. A Set of Weekly Questions Given to the Students.

Instruments and Data Collection

Students' Satisfaction: This instrument consisted of five questions divided into two parts. The first part consisted of two questions that it was administered to the students at the beginning of the semester, and the second part consisted of three questions and it was administered twice during the semester. The seventh and fourteenth weeks. The questions in the first part included: (1) Describe the way that you were taught science at school? (2) Describe the way that you are expecting the lecturer to teach the course? In the second part, the students were asked the following questions: (3) Do you like the way this course is taught? Yes ___, No ___, (4) Why did you like or dislike it? (5) Would you like to change from this method (constructivist teaching method) to some other method, or to propose improvements to the existing (constructivist) teaching method?

Students' Academic Achievement Test: The achievement test consisted of seven short answer questions. Each question consisted of two-three parts. The test questions covered almost all the topics taught in the semester. Answers to the test questions and marking schemes were written by the first author before administering the test to the students. Students were allowed two hours to complete the test and most of them completed it in 1.5 to 2 hours. The test was administered to the students in the first and last week of the semester. The students' achievement scores are reported as a percentage.

Traditional Teaching Method

Using this approach, the teacher (a) wrote the topic on the white board, (b) asked few questions about the last lesson, (c) explained the concept (topic) written on the white board orally (mostly), (d) wrote notes on the white board for students to copy for future reference, and (e) gave homework similar to classwork.

Constructivist-informed Teaching Method: Steps and Procedure

Steps. Students (a) received a set of questions, (b) recorded answers to the question from various sources, books, internet, etc., (c) discussed their responses to the question in a group, (d) discussed their responses to the question in a reorganised group consisting of students from other groups, (e) received lecturer's input, and (f) modified their answers.

Procedure. All students attended two hours session per week during which answers to a set of questions were discussed. This session is hereafter referred to as the lecture session. During the two hours per week practical session, the students were divided into two groups A and B, due to limited seating space in the laboratory. The students completed the same experiment on alternate weeks. When group A students were doing the experiment, group B students were asked to go to the library and complete answers to the questions assigned for that week and vice versa. All students were asked to write answers to the questions, which they did. However, during discussion more input was expected from those students who were given time to go to library to find answers to the questions.

During the lecture session, the students from both practical groups (A and B) were randomly divided into five groups, so that each group had students from both groups (A and B). The three groups with five and two groups with six students were given 40 minutes to discuss answers to the questions within their groups. The groups were then reorganised, so that at least one student was present in each of the new groups from the previous group. The students in these groups were given 20 minutes to rediscuss answers to the questions and integrate information from the previous groups to the new groups. During the discussion, the lecturer was available to answer questions raised by the students. Then, the lecturer stood in front of class and started asking students their responses to the questions and added his input, including extensions to the answers, links between different parts of a question, or between questions.

Results

In this section, the results are discussed under five headings. First and second headings cover the teaching methods students used in schools and their expectation that the course-lecturer should continue with it. The second heading deals with changes to students' behaviour in terms of their expectations from the lecturer on the particular teaching method (a didactical contract). The third and fourth headings deal with if and why the students liked/disliked the constructivist teaching method. The fifth heading reports the pre- and post-treatment students' achievement scores for the course. These headings relate to the to four research questions answered by the study.

Were the students taught in the school using traditional teaching methods? Did the students expect their lecturer to teach the course using traditional teaching methods?

The analysis of students' responses to question 1 revealed that almost all students were taught by traditional teaching methods. The steps used in these methods are described in the methods section of this study (see Traditional Teaching Method). These steps are similar to the ones noted in mathematics lessons in U.S. schools by Hiebert and Stigler (1999). Writing notes on white board for students to copy appears to be an important aspect of the traditional teaching method.

Moreover, the students expected the course lecturer to follow the traditional teaching method indicating that they expected the course lecturer to honour the didactical contract that was also honoured by their science teachers in schools. These findings are similar to those reported by Monaliza (2001) and Norlina (2002) that students expected their teachers to follow the same teaching method, the traditional teaching method, every lesson.

Did the constructivist teaching method help students to modify their behaviours in terms of their expectations from their teacher on teaching with the traditional teaching methods?

Data on students' responses to questions 2 and 4 are summarised in Table 1. These data reflect changes to students' expectations from their lecturer on the teaching method during the semester. At the beginning of semester, about 96% of students expected the lecturer to follow the traditional teaching method, whereas the percentage dropped to about 52% in seven weeks and to about 19% by the end of the semester. These results indicate that the constructivist teaching method was successful in modifying the students' expectations (behaviour). It implies that, at the end of this intervention, only about 20% of students expected their lecturer to teach with traditional teaching methods (to give explanation and then write notes on the white board for them to copy). Moreover, a comparison of post-intervention data in Tables 1 and 2 show the comparable percentages of students who liked the constructivist teaching method (76.9%) and those who did not expect their lecturer to teach with traditional method (about 81%) were compatible. In summary, the constructivist teaching method helped the students to modify their expectations from their teacher about the teaching method.

Table 1

Data in Percentage Showing Variations in Students' Expectations during the Semester

Preferred Teaching Method	Students Distribution and Time in Semester		
	Beginning (%)	Middle (%	End (%)
Teach with Traditional Method	96.3	-	-
Change to Traditional Method		51.9	19.2
Continue with Constructivist Method	-	48.1	80.8
Others[1]	3.7	-	-
N	27	25	25

Those who preferred to continue with constructivist teaching method proposed some changes, such as add more experiments/ demonstrations, etc.

Table 2

Students' Responses to the Question: Do you Like the Way This Course Is Taught?

Response	Time in Semester	
	Middle (%)	End (%)
Yes	40.7	76.9
No	51.9	19.2
Others	3.7	3.9
No response	3.7	0.0
N	27	26

Did the students like the constructivist teaching method?

Table 2 shows data on students' liking/disliking of the method of teaching the course at two intervals during the semester. Assuming that the students at the beginning of the semester only accepted the constructivist teaching method on trial bases, it was encouraging to note that by the mid-semester about 41% students started liking the method and the percentage increased to about 77% by the end of the semester. Similarly, the number of students who did not like the teaching method decreased to about 52 % by the mid-semester and to about 19 % by the end of semester. These data indicate that the students' liking for the constructivist teaching method over the semester improved significantly. A summary of the analysis of reasons for liking and disliking the teaching method is reported in Table 3.

What were the reasons for liking/disliking the constructivist teaching method?

It is clear from the data reported in Table 3 that within first seven weeks the students who liked the constructivist-informed teaching method (Yes response) realised that constructivist teaching method helped to increase their understanding of the course content and also they were able to write notes in their own language (Malay). Moreover, these claims were restated at the end of the semester, which indicated that the impact of constructivist teaching method on students was remarkable and unforgettable. The analysis of answers to the questions in post-treatment achievement test revealed that students wrote descriptions in their own language rather than the same answer given by their teachers and rote learned by the students. These students also stated that they have improved interaction with other students and other skills: information finding, discussion, reasoning and thinking skills. They also recognised the values of comparing answers to the questions and improving upon their mistakes.

Table 3
Reasons for Liking and not Liking the Way the Course Was Taught

Middle of Semester	End of Semester
Yes response-teaching method - liked	
* Increased understanding.	* Increased understanding.
* During group discussion, concepts get clear.	* Improved discussion and resources finding skills.
* Improved ability to research information	* Get to know our mistakes.
* Improve interaction with other students.	* More answers are compared.
* Make us think more and more	* Improved reasoning and thinking skills.
* Can write notes in our own language.	* Can write notes in our own language.
No Response-teaching method - not liked	
* Time consuming, makes my life difficult.	* Some students do not do their work.
* Explanations within groups are different, difficult to understand.	* Some questions are complex to find answers.
* Encourage to postpone the work to last minute.	* We are not sure if our answers are correct.
* Difficult to know if answers are correct.	* Notes are not given.

The reasons given by those students who disliked the constructivist teaching method included: time consuming process, complex questions to find answers, dif-

ferent answers with the group – confusing, helps to postpone finding answers to the last minute, and notes are not given. It was encouraging to note that at the beginning of the semester, some students realised that there was more than one way to answer the questions. They found it difficult to cope with these differences in students' answers during discussion. Since in secondary school, all students copied the same answer from the white board, they, therefore, might have thought that there is only one way to answer a question. However, by the end of the semester this comment was not restated, because it appears that, by that time, the students have learned to cope with different ways to answer the same question. While considering students' comments under no response (disliked the teaching method), it is clear that most of these comments are associated with students' own problems rather than with the constructivist teaching method. Overall, the comments on constructivist teaching method by students were encouraging.

Selected comments from four students (P, Q, R, and S) are described below. Students P, Q, and R liked the constructivist teaching method, whereas S did not like the teaching method.

Yes – response

Student P – (Student's course grade B)

Because we can broaden our ideas and give our ideas to others. A student who is more knowledgeable than us (in the group) can teach us.

It helps us to understand more about the chemistry that our teachers did not teach us before, where we only memorise all notes given rather than understanding.

Students Q – (Student's course grade C)

By doing this way of teaching, it improves our thinking in the reasoning of something rather than memorising without knowing the scenario.

Improve reasoning, searching for more important topics, interaction with other students and teachers.

Student R – (Student's course grade D)

It gives a chance to search for notes first, rather than being spoon-fed. We put our notes in our own understanding.

The method of teaching being applied by the lecturer is interesting, not using the "old" method, class go to page —, do question —and submit to me on—. The old way is a BORING way to learn and hence the lecturer made me be more interested in science especially as I'll be teaching it in few years.

No – response

Student S – (Student's course grade A)

It is almost towards the end of the course and I think it is OK as it can really help us to think by even applying the basic knowledge of certain terms. However, there are students that did not do their part, and this makes the group discussion a little unsuccessful and difficult. It helped us think, think, and think.

Did the students' achievement score improve significantly after learning chemistry content with the constructivist teaching method?

Data in Table 4 indicate that the pre-treatment mean score for the test was 20% indicating a presence of required prior knowledge to build on while students are

learning using the proposed constructivist learning method. The post-treatment mean score of about 63 % indicates a significant improvement in students' achievement score. Moreover, the improvement in mean achievement scores was of educational value. The mean achievement score was above 50% the pass level.

Table 4
Students Pre- and Post-intervention Mean Achievement Scores and Ranges

Data	N	Pre -			Post-			Statistical values	
Type	N	Mean	SD	Range	Mean	SD	Range	p-	Effect Size
All	25	20.0	10.4	5 – 44	62.7	16.5	24 – 93	0.000	2.23
Male	11	16.7	7.7	5 – 30	54.0	14.5	24 – 72	0.000	3.23
Female	14	22.6	11.7	8 – 44	69.5	15.1	46 – 93	0.000	3.39

* p .001

While considering the improvements in male and female students' mean-achievement scores, it was found that initially both groups were comparable (t = 1.515, $p. > 0.05$, and effect size 0.51) in both groups and the post-treatment mean achievement scores improved significantly as compared to pre-treatment mean scores for both male (t = 7.54, $p.$ = 0.000 and effect size = 3.27) and female male (t = 9.19, $p.$ = 0.000 and effect size = 3.39) students. Moreover, the improvements in both groups (mean scores above 50%) were of educational value. However, a comparison of post-treatment mean achievement scores for male and female students revealed that female students' mean achievement score was significantly higher (t = 2.605, $p. <0.01$, and effect size 1.14) than that of the male students. These differences were also clearly demonstrated in lower and upper range of achievement scores.

In summary, when students learned chemistry with constructivist teaching methods, their mean achievement scores improved significantly. The improvement in mean achievement scores was significantly higher for the girls than for the boys.

Discussion

It has been reported in the literature that constructivist (Bodner, 1986; Demastes, Good, & Peeble, 1996; Dhindsa, 2000) as well as cooperative (Lim, 2000; Nichols, 1996; Tingle & Good, 1990) teaching and learning help students improve their academic achievement. In this study, we have reinforced the claim that a mixture of constructivist and collaborative teaching and learning also improved students' academic achievement score. Moreover, we found that constructivist teaching method was also useful in modifying students' behaviour. In this study, the behaviour modification was in terms of students' expectations from lecturer (a didactical contract) about teaching science with traditional teaching method. However, readers should note that, in this study, we have evaluated the effectiveness of constructivist teaching method in modifying one contract only. Since, there are many more contracts that have been reported by the researchers (Monaliza 2001; Norlina, 2002; Lim 2000; Kho, 2000) further research is recommended to verify if the use of a constructivist teaching method helps to modify other beha-

viours (or didactical contracts) too. Moreover, we have found that at the end of the semester, there were still about 19 % students who were expecting the lecturer to teach with the traditional method. The analysis of these 19% students' academic performance revealed that there were some of the academically strong students in this group. These good students might represent those students who can make sense of teacher's cognitive structures described on the white board. They, therefore, are looking for ready-made answers and might be lazy to collect information, or pressed by time to prepare for other subjects. Nevertheless, many of the students in this group of 19% were low achieving students, who had language problems. These students find it difficult to express their cognitive structures in a written format on a paper. They, therefore, expected the lecturer to write notes on the white board for them to copy, thinking they can rote learn the notes to pass the examination. However, it is desirable that these students should also benefit from the intervention. The authors believe that one semester may not be enough for this intervention to bring a behavioural change because the students were used to the traditional teaching method for about 10 years. We also plan to modify the constructivist teaching method by moving the teachers' intervention in the middle or at the beginning of two group discussions to optimise the constructivist teaching method to help all the students in the class.

A large number of research studies on students' conceptions of scientific concepts demonstrate that students' conceptions vary (Dhindsa, 2002; She, 2003; Tekkaya, 2003). Moreover, there are more than one ways to describe a concept or to answer a question. The students often do not realise this fact, when they learn the same information (notes) given by the teachers. They often believe that there is only one way to answer the question that is described by the teacher. They therefore, try to rote learn the notes given by their teachers. It was interesting to note that students realised that information students collected to answer the questions varied at large. The students, especially low achieving students, found it difficult to cope with these differences in answering to the same question. They therefore, did not like the constructivist teaching method during the initial stages of the intervention. They struggled to rote learn the description of teacher's cognitive structure of a concept, which is much more complex for the students, especially for low achieving students, than for high achieving students. Moreover, the written notes given by the teachers are mostly copied from the textbooks. This further adds to the complexity in understanding of science for students, because often teacher given verbal descriptions of the concepts and textbook descriptions vary in structural arrangement as well as in explanations of the content. It was interesting to note that this claim (descriptions to questions vary at large) was not restated in the post-treatment comments. It appears that students learned to cope with the fact that concepts can be explained in different ways. However, research is recommended to further re-verify the claim that constructivist teaching method helps the students to realise that there are more than one way to describe a concept, or to answer a question by using different students and content.

Research on cultural learning environment from Brunei has demonstrated that students perceive that they are highly cooperative, indicating a good scope for using cooperative and collaborative teaching and learning techniques in Bruneian schools (Dhindsa, 2003; Dhindsa, & Shanmuganathan, 2002). It is pity that coo-

perative and collaborative learning is often ignored in Bruneian schools. The authors believe that if the school teachers start using collaborative teaching and learning techniques in lower secondary classes, or even earlier than this, then by the time students are prepared for O- or A-level examinations, they will have better understanding of the subject that will improve their academic achievements in science. Moreover, students will learn to be responsible towards their learning and they will get enough time to modify their expectations and behaviours.

The major implications of this research are for teachers, curriculum developers and teacher trainers. Teachers can use this teaching approach to improve students' understanding of scientific concepts as well as their academic achievement. This approach will help the teachers to put learning responsibility on students rather than them doing all the work for students in a classroom. Although, it requires lot of planning in advance, even then the authors believe that it is worth doing. Once the semester is planned, only minor changes are required during years ahead. This study joins in ranks with other studies that show benefits of constructivist and collaborative teaching to improve students' achievement. The curriculum planners, while planning curriculum for a subject at a grade level, should add emphasis to constructivist teaching and learning, and they should plan more collaborative learning activities to improve students' achievement in science. More specifically in countries like Brunei where culture put greater emphasis on cooperation and collaboration, the curriculum planners should take into consideration of the existing situating for the benefit of the students in schools. The teacher trainers can use this approach in training pre-service teachers and also conducting in-service courses for the teachers already working in schools.

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