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From Elementary to University Students' Ideas About Causes of the Seasons

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ABSTRACT

This research was a cross-age study that sought to determine and compare students' ideas about the causes of the seasons. Toward this aim, the research was carried out with 974 students at different educational levels and across the various age groups. First, the data obtained from the responses to the open-ended question was categorized according to a rubric formulated in line with the goal of the study. The methodology used in analyzing the data derived from the interviews was a grouped categorization of those responses that were construed as having similar intended meanings. Statistically, a significant difference was found between the groups of university students aged 20-22 and the other groups of students who were between the ages of 10-19. In addition, whereas the frequency of encountering some misconceptions decreased with age, on the other hand, the frequency of other misconceptions showed an increase in older students. At the same time, there were some misconceptions which did not vary significantly in frequency across the age groups and still others that did show changes.

Keywords: Cross-Age Study; Causes of the Seasons; Research into Learning.

INTRODUCTION

In recent years, there have been many studies conducted in the field of science education to discover what ideas students have about different concepts (Duit, 2009). These studies have shown that students come to the classroom with different ideas about the concepts about which they will be learning. Since the preliminary knowledge students have when they enter the classroom is based on different sources, such as their daily experiences and what they have learned in the family and in the community, and because their educational backgrounds might be different as well, there will also be differences in their preliminary knowledge. When students' advance information diverges from scientific concepts, the literature refers to this information as misconception (Eaton, Anderson & Smith, 1984, Gilbert, Osborne & Fensham, 1982; Hewson & Hewson, 1984). Although there can be many

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different sources of misconception, some that can be mentioned here are daily experience (Klammer, 1998), language (Klammer, 1998), textbooks (Bryce & MacMillan, 2009; Helm 1980; Ivowi, 1984) and mistakes teachers make in teaching particular topics (Helm, 1980; Ivowi, 1984). The misconceptions students have may prevent the learning of new knowledge (Helm & Novak, 1983). For this reason, there is a need to determine what students' misconceptions are so that activities can be designed to encourage a change toward the adoption of scientific concepts. To effect this change, however, is not an easy process because many misconceptions are hard to comprehend, inconsistent, and in some instances, extremely resistant to change (Windschitl & Andrew, 1998, in cited by Hsu 2008). Studies have shown that misconceptions can continue to exist despite formal instruction (Hewson & Hewson, 1983; Hsu, 2008; Strike & Posner, 1992; Wild, 2010).

A look into the literature on astronomy education reveals that the most frequently encountered concepts studied are the seasons, the phases of the moon, eclipses, distance and size. The causes of the seasons, the topic on which the present cross-age study has focused, has been examined among kindergarten children (Küçüközer & Bostan, 2010), elementary school pupils (Baxter, 1989; Dunlop, 2000; Sharp, 1996), high school students (Hsu, 2008; Sadler, 1992; Tsai & Chang 2005), and university students (Atwood & Atwood, 1997; Küçüközer, 2007). The studies report many misconceptions about the causes of the seasons among different age groups. In these studies a single education level of the sample' ideas are revealed. Unlike this study revealed students' ideas in different education levels from elementary school to university level about the concept of seasons and compared with each other.

The misconceptions cited in the literature about the causes of the seasons as "the seasons are caused by the change in the distance of the Earth to the Sun" and "the seasons occur as a result of the Sun's orbit around the Earth" have been found to exist in studies carried out with all age groups (Atwood & Atwood, 1997; Trumper, 2000; Trumper, 2001; Küçüközer, 2007, Küçüközer & Bostan, 2010; Dove, 2002; Dunlop, 2000; Sadler, 1992; Sharp, 1996; Tsai & Chang, 2005). The misconception, "the seasons are caused by the Earth's rotation around its own axis" appears before us across groups of kindergarten, elementary school and university students (Atwood & Atwood, 1997; Küçüközer, 2007; Küçüközer & Bostan, 2010). The misconception, "the seasons are caused by the change in the distance between the Earth's hemispheres and the Sun as a result of the tilt in the Earth's axis" has been encountered among elementary school, high school and university students (Baxter, 1989; Sadler, 1992; Tsai & Chang, 2005). The erroneous idea that "clouds cause the seasons" has been a misconception found among kindergarten and elementary school students (Küçüközer & Bostan, 2010; Baxter, 1989; Sharp, 1996). Some other misconceptions encountered only in certain age groups were: "changes in plants cause the seasons" (Baxter, 1989; Sharp, 1996) and "the sun warms up in the summer and cools off in the winter" (Dunlop, 2000; Sharp, 1996), encountered among elementary school students; "the gases causing the ocean currents and global warming are what cause the seasons" an idea seen among high school students (Sadler, 1992); and "the seasons occur because the world is orbiting around the Sun and at the same time rotating around its own axis" among university students (Küçüközer, 2007).

It can be said in general that while these studies have exhibited that there are certain misconceptions among students of certain ages, misconceptions that are more frequently encountered are those which usually exist across the age groups. In this context, it can further be said that students graduate with the same misconceptions and non-scientific ideas that they had when they first entered the classroom (Wild, 2010). It is for this reason that most misconceptions show similarity across the different age groups.

Cross-age Studies

Longitudinal and cross-age studies are used to discover what ideas students have at different age levels (Abraham, Williamson & Westbrook, 1994). Compared to longitudinal studies which spend a long period of time on the same group, cross-age studies have a shorter schedule and thus allow the researcher to study different age groups within the same period of time (Abraham et al. 1994; Gay & Airasion, 2000; Thomas, Nelson & Silverman, 2005). Abraham et al. (1994) report that cross-age studies are more useful than longitudinal studies when considering a particular period of time, and Blanco and Prieto (1997), Krnel, Glazar and Watson (2003), and Westbrook and Marek (1991) have obtained successful results in their cross-age research.

Many researchers have used cross-age studies for various concepts in science education. For example, Abraham et al. (1994) have conducted studies with 100 second-tier elementary school, high school and university prep students, Coll and Treagust (2003) with 15 students between the ages 16-24, Çakmakçı, Leach and Donnelly (2007) with 191 students between the ages of 15-19, Çalık and Ayas (2005) with 441 students between the ages of 13-17, Çepni and Keleş (2006) with 250 students between the ages 11-22, Krnel, Glazer and Watson (2003) with 84 students between the ages of 3-13, Özdemir and Clark (2009) with 32 students between the ages of 5-16, and Ültay and Ültay (2009) with 191 students between the ages of 13-17. The basic outcome of all of these studies has been that the frequency of misconceptions decreases with age but those misconceptions still continue to be seen across the age groups, albeit in different proportions. There are few cross-age studies about various astronomy concepts which is one of the science topic. Only Baxter (1989), Dunlop (2000), Agan (2004), and Plummer (2009) did studies that investigate what ideas students of different age groups have about various concepts in astronomy.

One of these is the research carried out by Baxter (1989) in a study of 100 students, ages 9-16, in which the students' notions about the phases of the moon and the seasons were treated. The most commonly encountered misconception about the phases of the moon across all of the age groups was that the Earth's shadow was falling on the moon. It was also reported in the study that students confused the phases of the moon with the concept of an eclipse. As regards the causes of the seasons, younger children were seen to believe that "cold planets take away the heat of the Sun and the heavy winter clouds prevent the Sun's rays from coming to Earth". On the other hand, older pupils thought that "the sun travels to the other side of the Earth in summer". The misconception "the Earth is farther from the Sun in winter and closer in summer" was the most frequently encountered misconception across all the age groups. The results of this study indicated that as age increases, the frequency of encountering misconceptions decreases, but at the same time, misconceptions continue to be encountered in older age groups. Dunlop (2000) carried out a study of 67 students, ages 7-14, in which the objective was to reveal students' ideas about day/night, the phases of the moon, the seasons, and the concept of orbiting, both before and after instruction was given about these topics in school. A misconception that was encountered on the subject of day and night was that "just as the Sun causes the day, the moon causes the night". While students of younger ages explained the reason for the phases of the moon as their belief that the clouds were getting in the way of the moon, the frequency of encountering this particular misconception diminished at older ages. The idea, however, that the moon is somehow being covered up by something and that it is this that causes the phases of the moon to occur was a misconception that continued, even after the subject was taught in school. The frequency of the misconception of believing that the distance of the Earth to the Moon is the reason for the seasons was 9% before the topic was taught and 6% afterwards. This study indicated that younger children had more misconceptions but that misconceptions continued to be seen in older students. It can be seen furthermore that teaching a topic is not completely effective in dispelling misconceptions. Agan (2004) conducted a study with 17 students, ages 14-19, in which the students' ideas were examined about which star is closest to the Earth and the differences between stars and planets. None of the high school first-year students could provide the correct answer that the Sun was the closest star to Earth; students instead claimed that the North Star was the brightest star in the sky. The misconception that stars are smaller than the Sun diminished with age and disappeared among university first-year students. The misconception about how stars change with time to the effect that stars turn into falling stars over time was an idea seen among high school first-year students but not seen in the higher age groups. The misconception that stars are closer than the Sun diminishes too with age and is not seen among university students. Although the conclusion drawn in this study was that misconceptions decrease as children get older, it was also seen that 3rd and 4th-year high school students who had taken astronomy had less misconceptions in their minds than university first-year students. Plummer (2009) studied 60 students ranging between the ages of 6-14 to find out what their ideas were about the movement and orbit of the Sun in winter and summer, the changes in the appearance of the moon, and the changes in the movement of the stars. While it was seen that elementary school children could not draw a picture of more than one shape of the moon, it was noted that students in older age groups were able to explain the phases of the moon more accurately. Fourteen-year-olds understood the movement of the Sun but students in younger groups had many different ideas about this concept. A large part of these ideas are of the nature of misconception. For example, the most frequently encountered misconceptions were "the sun goes to its highest point more than once during the day" and "the sun rises and sets all within 45 degrees". The most accurate response about the changes in the appearance of the moon was mostly received from older students. The misconceptions that the moon changes in appearance in less than one night and that the moon does not come up in the daytime were more prevalent among young pupils. In this study, all of the misconceptions encountered across the age groups were similar but younger students displayed a higher percentage of misconceptions.

In short, similar to the results obtained from the studies in science described above, cross-age research on topics in astronomy also showed that all age groups had misconceptions and that as students got older, the frequency of encountering misconceptions decreased.

The objectives of the present study were to discover what ideas students of different age groups had about the causes of the seasons and to compare the different groups in this context. Another objective was to discover what misconceptions students had about the causes of the seasons and how their misconceptions changed with age. Our two research questions according to study aim were the following:

1- What ideas did students have about the causes of the seasons and how did these ideas change with age?

2- What were the misconceptions students had about the causes of the seasons and how did these misconceptions change with age?

METHODOLOGY

The research was carried out with a cross-age or, as it is generally referred to, a cross-sectional design technique, a type of development research that focuses on making comparisons of ages as one of the methods used in descriptive research. Cross-age studies are effective in uncovering and assessing the ideas students have at different age levels. Mixed method has been determined as a research method. At the research the qualitative data were embedded into the quantitative one. The main data collection technique was an open-ended survey and the responses were quantitatively scored using a rubric and the secondary data tool was interview that served as a support element for the main data.

a) Sample

The sample of the study was a total of 974 students between the ages 10-22. The students comprising the sample were selected by simple random sampling from five elementary schools, five middle schools, four high schools and one university education department located in a midsize city in the north-western part of Turkey. Simple random sampling is subset of a statistical population in which each number of the schools has an equal probability of being chosen. All of schools in the sample are public schools. Deciding the age groups starting from the 4th grade class began taking science lessons with the three class range of students were selected. At the university level all students were included in the science education department from the faculty of education. At university level the sampling divided two groups because third and fourth class students have been take formal astronomy instruction before the research. Table 1 displays the class levels of the groups, the number of students and the range of ages involved.

Table 1. *Characteristics of Sample Groups*

Group	Class Level	Number of Students	Range of Ages
Group 1	Elementary 4th and 5th grades	260	10-11
Group 2	Middle 7th grade	250	13
Group 3	2nd year high school	223	16
Group 4	1st and 2nd year university	110	18-19
Group 5	3rd and 4th year university	131	20-22

All of the students in the sampling had received formal education about the causes of the seasons. In this study, the researchers did not give the student groups any special instruction about the study subject. The aim was to have the students answer the question on the basis of what they had already learned in school. The sampling was divided into five groups of different ages and educational levels. In determining the age groups, the researchers considered which class the students were in at the time of the study and in which class they had last received instruction on the causes of the seasons. The classes in which the students in the different age groups had received formal instruction on the seasons were in 4th grade elementary school for Group 1, 6th grade middle school for Group 2, and 1st year high school for Groups 3 and 4. Because Group 3 was made up of high school and Group 4 comprised university students, these students were divided in two separate groups. The students in Group 5 had additionally received formal instruction in their 4th semester astronomy class and for this reason were separated from the students in Group 4.

b) Collection of Data

To explore the ideas students of different age groups had about why the seasons occur, the students in the sampling were asked a written question: “What causes the seasons?”. The scientifically acceptable answer expected as a response to this question was the tilt of the Earth’s axis while orbiting around the sun. They were asked to explain to their responses in writing. Determining misconceptions between the responses of the students were utilized the misconceptions related to causes of the seasons in the literature. Two researchers have analysed the 50 open-ended questions independently and researchers’ consistency was calculated as .89 percent. In addition, a semi-structured interview was conducted with a randomly selected volunteer from each age group. Interview form has been prepared by the two researchers together and was examined by two science educators to get an expert opinion.

Semi-structured interviews were held with 18 students from Group 1, with 12 students from Group 2, with 8 students from Group 3, with 8 students from Groups 4 and 5 taking average 10 minutes. The interviewer (the first researcher) talked to the students on a one-to-one basis. The interviews were conducted in order to support the data obtained from the open-ended question and to elicit more in-depth information.

c) Data Analysis

The explanations students offered about the causes of the seasons were fitted into a five-category rubric (Table 2) that was created based on the studies of Atwood and Atwood (1997), Barnett and Morran (2002) and Tsai and Chang (2005). Each category was scored and analysed. Thus, the data arranged in this way facilitated the comparison of the responses of students across the different age groups. The content of the rubric is briefly explained in Table 2.

Table 2. *Code and Score Legend for Calculating Questionnaire Scores*

Score	Categories	Explanation of Categories
4	Correct answer	In this category, students gave an answer that may be considered scientifically accurate and were able to correctly explain the reason for their response. Example: *The seasons occur because of the tilt of the Earth's axis while orbiting around the Sun.*
3	Correct answer + misconception	In this category, the answer given to the question is correct but the explanation contains a misconception. Example: *Because the Earth's axis is tilted, the distance between the hemispheres and the Sun changes and this causes the seasons.*
2	Misconception	Only explanations containing misconceptions were included in this category. Example: *In summer, the Earth is closer to the Sun and that's why the weather is warmer. In winter, the Earth is at a further distance from the sun and therefore benefits from it less and the weather becomes cold.*
1	Couldn't be encoded	In this category, students' answers are either unrelated to the topic or there are statements that were incomprehensible to the researcher.
0	No response	In this category, students did not offer any comment on the question.

After the written responses of the students were reviewed by both researchers, a decision was made regarding into which category each of the students' responses would fit. Each student's response was placed in only one of the five categories. The percentage of students responding to each category of the rubric from the various age groups was calculated. Thus, the researchers were able to find the frequency of each response of the students in the different age groups in each category and also make a cross-age comparison. Each category in the study was given a score and a qualitative analysis was carried out. The

SPSS 12.0 package program was used for the qualitative analysis of the data. In order to be able to make a quantitative comparison between groups, each category of the rubric was assigned a score in descending order (4-0) and the total score of the various age groups was calculated to find out whether there was a difference between groups. The score corresponding to the category in the rubric into which the student's response fit was entered into the SPSS program and the same program was used to calculate the total score of students in each group. Before ANOVA test applied, it was determined that data showed a normal distribution. The ANOVA test was used in the comparison of group scores to determine whether there were significant differences between groups. If the results of the ANOVA displayed a significant difference across the age groups, the "Tukey Post Hoc" test was used to determine between which groups the difference lay.

The misconceptions encountered in the study were fitted into the misconception category of the rubric and the frequency of these misconceptions was calculated. In this way, not only were the misconceptions revealed but the frequency of encountering these misconceptions in the various age groups was also determined. The results of the frequency calculations made it possible to compare how misconceptions changed in the various age groups. The Results section uses the data obtained from the semi-structured interviews set forth in the section following the categories of misconceptions. The interviews were recorded and transcribed after the completion of the sessions. The methodology used in analysing interview data was a grouped categorization of those responses that were construed as having similar intended meanings. The categorizations were mostly based on misconceptions that had been reported in previous studies. (Each student interviewed was given a group number to indicate which group he/she belonged to and then each student in the group was given a code number. For example, the 5th student in Group 2 was given the code number S2-5).

To increase reliability of the data analysis, randomly selected sample of students' answers to the questions were analyzed by a science educator and response categories are placed. Reliability between scores from the researches and outside researcher involved in the study was calculated as 0.92.

FINDINGS

a) Results of Responses to Research Question 1

This section deals with the responses to the question about the causes of the seasons offered by students who were divided into 5 groups on the basis of their ages and educational levels. First of all, the students' responses were imposed in the appropriate category in the rubric and then a total frequency was calculated for each age group represented in the various categories. Table 3 below shows the categories representing the responses of the different age groups and the frequencies recorded in these categories.

Table 3. *Categories of Responses by Group and Frequency*

Response Categories	Group 1	Group 2	Group 3	Group 4	Group 5
	n (%)				
Correct answer	4 (1.5)	1 (0.4)	9 (4.0)	3 (2.7)	65 (49.6)
Correct answer + misconception	15 (5.8)	2 (0.8)	24 (10.8)	5 (4.5)	30 (22.9)
Misconception	225 (86.5)	214 (85.6)	187 (83.9)	94 (85.5)	31 (23.7)
Couldn't be encoded	15 (5.8)	31 (12.4)	3 (1.3)	7 (6.4)	5 (3.8)
No response	1 (0.4)	2 (0.8)	0 (0)	1 (0.9)	0 (0)
Total	260	250	223	110	131

As can be seen in Table 3, the percentages of the correct answer that the cause of the seasons is the tilt of the Earth's axis while orbiting around the sun, with the exception of Group 5, very low and very close to each other across the ages. However, almost half of Group 5, made up of students who had taken a class in astronomy at the university, gave the correct answer. The high rate of correct responses in the students in Group 5 may be explained by the impact of the university-level course on the students. Below are presented excerpts from the interviews held with one of Group 5 students who gave correct explanation.

I: Can you say something about what you were taught in your astronomy class?
S5-4: We had the support of computers in most of the lessons. The instructor used animations. Also, we discussed our ideas with each other in class.
I: Did the teaching have an impact on your ideas?
S5-4: Of course. First of all, I learned a lot that I didn't know and I saw that some of what I thought I knew was incorrect.
I: What were your thoughts on the causes of the seasons before the instruction?
S5-4: Before the instruction, I used to think that summer occurred as the Earth neared the Sun and winter happened when the Earth drew away from the Sun.

The students in Group 5 stated in the interviews that the class had been taught with the help of various computer programs and that animations were also used. Teaching was further supported with class discussions. The students said that computer-supported teaching had an impact on their ideas. However, as seen in Table 3, the students in Group 5 were still unable to dispel all of their misconceptions and as a result, after the formal teaching, close to half of the students continued to have their previous misconceptions.

In the 'correct answer + misconception' category, different percentages were encountered in the different age groups. The most frequent response in this category was "because the Earth's axis is tilted, the distance between the hemispheres and the Sun changes and this causes the seasons". While the simple answer was the tilt of the Earth's axis, the misconception was formulated around the idea that the tilt of the axis caused a change in the distance of the hemispheres to the Sun. The percentages of this category among Groups 1, 3 and 5 are higher compared to Groups 2 and 4. This type of response was mostly seen in students in Group 5. The students in Group 5 knew the concept of the tilted axis because they had received formal instruction in this a short while ago but they were still unable to abandon the misconception about the Earth's distance to the Sun. It was found that students offering this response had been affected by the teaching but also had difficulty giving up their misconceptions. A student in Group 5 whose answer fell in this category expressed his ideas as follows.

I: You've explained that the seasons are caused by the change in the distance of the hemispheres to the Sun as a result of the tilt in the Earth's axis. Could you clarify this?
S5-2: The seasons occur because the Earth's axis is tilted. And because of this, the distance of the hemispheres to the Sun changes. For example, in summertime, the northern hemisphere is closer to the sun whereas it's farther away in wintertime.

In the 'misconception' category, the percentage corresponding to Group 5 students was 23% while that corresponding to the other age groups was approximately 85%. Although however, there was an increase in the percentage of correct answers in Group 5, the students who had received university instruction, the frequency of their misconceptions diminished. In the other groups, it can be said that their formal teaching did not have much of an impact on their producing the correct answer. In Group 5, the computer-supported program of teaching gave rise to an increase in the percentage of correct responses and also caused a reduction in misconceptions.

The ANOVA results showing the relationship between the different age groups in terms of their responses to the question about causes of seasons are shown in Table 4.

Table 4. *ANOVA Results across the Groups*

Source	Sum of Squares	df	Mean Square	F	p
Between Groups	142,011	4	35,503		
Within Groups	302,375	969	,312	113,773	0,001
Total	444,386	973			

* p<0.001

As seen in Table 4, there are significant differences between age groups in students' responses to the question about the causes of the seasons at the p<.05 level for the five groups [F(4, 969) = 113,773, p= .001)]. The results of the "Tukey Post Hoc" test carried out to determine between which age groups there were significant differences is given in Table 5.

A look into Table 5 shows that the "Tukey Post Hoc" test results indicate that there was a significant difference between the scores of Group 5 students who had taken a course in astronomy and the scores of students in all the other age groups; the difference favored the scores of students in Group 5. There was also a significant difference in favor of Group 3 students between the scores of Group 2 and Group 3 students. There was no other significant difference between the other groups.

Table 5. *Tukey Post Hoc" Test Results*

		Mean Difference	Std. Error	p
Group 1	Group 2	0,155	0,050	0,017
	Group 3	0,143	0,051	0,042
	Group 4	0,014	0,064	0,999
	Group 5	1,053*	0,060	0,000
Group 2	Group 1	0,155	0,050	0,017
	Group 3	0,298*	0,052	0,000
	Group 4	0,169	0,064	0,066
	Group 5	1,208*	0,061	0,000
Group 3	Group 1	0,143	0,051	0,042
	Group 2	0,298*	0,052	0,000
	Group 4	0,129	0,065	0,279
	Group 5	0,910*	0,062	0,000
Group 4	Group 1	0,014	0,064	0,999
	Group 2	0,169	0,064	0,066
	Group 3	0,129	0,065	0,279
	Group 5	1,039*	0,073	0,000
Group 5	Group 1	1,053*	0,060	0,000
	Group 2	1,208*	0,061	0,000
	Group 3	0,910*	0,062	0,000
	Group 4	1,039*	0,073	0,000

* $p<0.001$

b) Results of Responses to Research Question 2

Table 6 displays the misconceptions about the causes of the seasons and the frequency of these misconceptions among the various age groups. The 'correct answer + misconception' category was included in the misconceptions listed in Table 6 because, as mentioned before, this category encompassed misconceptions in addition to the right answers. The calculation of the frequencies in Table 6 considered the total of the 'correct answer + misconception' and 'misconception' categories.

Although the misconceptions about the causes of the seasons which were encountered within the various age groups were similar, the frequency of encountering these misconceptions displayed differences across the age groups. The frequency of some of the misconceptions dropped with the increase in age; that of others increased, while still others showed almost no difference or differences within the particular age group.

Table 6. *Misconceptions about the Causes of the Seasons*

Misconception	G. 1 (n=240)	G. 2 (n=216)	G. 3 (n=211)	G. 4 (n=99)	G. 5 (n=61)
	% (n)				
-The Earth orbits around the Sun	67.1 (161)	60.2 (130)	71.6 (151)	55.5 (55)	36.1 (22)
-The change in the distance to the Sun of the Earth's hemispheres	6.3 (15)	5.6 (12)	16.1 (34)	5.1 (5)	11.5 (7)
-Earth's distance from the Sun changes as it orbits around the Sun	4.2 (10)	6.9 (15)	7.1 (15)	27.2 (27)	49.2 (30)
-The rotation of the Earth around its own axis	10.4 (25)	9.3 (20)	1.9 (4)	2 (2)	1.6 (1)
-The Earth's orbiting both around the Sun and around itself	4,6 (11)	7.9 (17)	2.4 (5)	8.2 (8)	1.6 (1)
-The Sun's orbiting around the Earth	6.6 (16)	8.8 (19)	0.9 (2)	2 (2)	-
-Clouds cause the seasons by blocking the Sun	0.8 (2)	1.3 (3)	-	-	-

Two examples of the misconceptions that were less encountered as age increased were "the rotation of the Earth around its own axis" and "the clouds obstruction of the light rays of the Sun". Figure 1 shows the frequency percentages across the age groups of the misconception "the seasons are caused by the Earth's rotation around its own axis" which decreased as age increased.

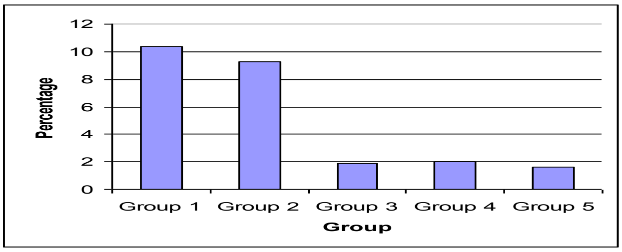

Figure 1. *Frequency Percentages across the Age Groups of a Misconception That Was More Encountered at Small Age Groups and Less Encountered at Old Age Groups*

The frequency of the misconception "the seasons are caused by the Earth's rotation around its own axis" was seen to drop as age increases. This misconception was most encountered among the students of Group 1 and 2 and the decreasing frequency seen in the students of Groups 3, 4 and 5 was observed to ultimately approach each other. Similarly, the misconception that seasons are caused by the obstruction of the light rays of the sun by clouds appeared before us only in the students in Groups 1 and 2, being nonexistent among students of older ages. The students in Group 1 with this misconception expressed their ideas as follows.

I: Why do the seasons occur?
S1-8: The seasons occur because of the clouds.
I: How do the clouds affect the seasons?
S1-8: In wintertime, you can see that the clouds are darker and that's why there are less light rays coming from the sun. In summertime, clouds are white and the sun can reach Earth more easily.

An example of the type of misconception that was seen more as age increased was "the seasons occur because the Earth's distance from the Sun changes as it orbits around the Sun". The percentages seen of this misconception across the age groups are seen in Figure 2.

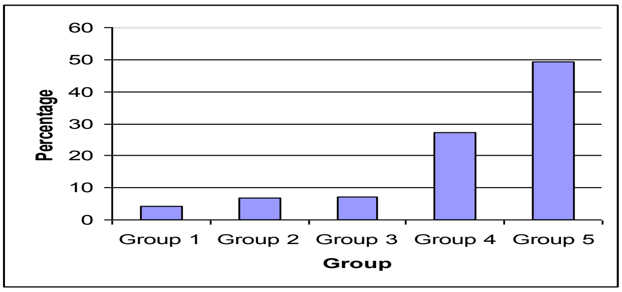

Figure 2. *Frequency Percentages across the Age Groups of a Misconception That Was More Encountered as Age Increased*

As can be seen in Figure 2, the frequency of this misconception rises as age increases. While the percentage of encountering this misconception among Group 1, 2, and 3 students was low, the percentage suddenly rose in Group 4 students. The percentage of encountering this misconception rose even more among Group 5 students, making this the most frequently encountered misconception in this age group. Excerpts from the interview with a student in Group 1 with this misconception and with another student in Group 5 are given below.

I: What causes the seasons?
S1-14: The Earth is closer to the sun in summer and this is why the weather is warmer in summertime. In winter, the Earth moves away from the sun and so it benefits from the sun less and the weather is cold.
I: All right and where did you learn this?
S1-14: This should be right because when we're close to the sun, we're warmer.

I: What causes the seasons?
S5-6: The Earth rotates around the sun in an elliptic orbit. In that orbit, when the Earth gets closer to the sun, it becomes summer and when it gets farther away, we experience winter.

It was observed that students of different ages who had the misconception that seasons are caused by the change in the distance of the Earth to the Sun had different explanations to support this idea. Younger students (Groups 1 and 2) explained the causes of the seasons in terms of their daily experiences, offering the example that we feel warmer the more we approach a source of heat. The students in the older age groups (Groups 3, 4 and 5) tried to explain the causes of the seasons by using the concept of the elliptic orbit to base their idea on the change in distance. Although the concept of the elliptic orbit increased with age, it was mostly observed in Group 5 students, the group who had received instruction in astronomy. Their explanation was that because the Earth rotated around the Sun in an elliptical orbit, it would be closer to the Sun in summer and farther away in winter. While younger students who had the same misconception said that distances had to change for the seasons to come about, they did not specify what occurrences would change these distances. The older students, however, stated that it was because of the elliptical orbit that distances changed and the seasons came about.

An example of a misconception whose frequency did not display a change as age increased was the misconception that "the Earth orbits around the Sun". The percentages in which this misconception was encountered across the age groups are given below in Figure 3.

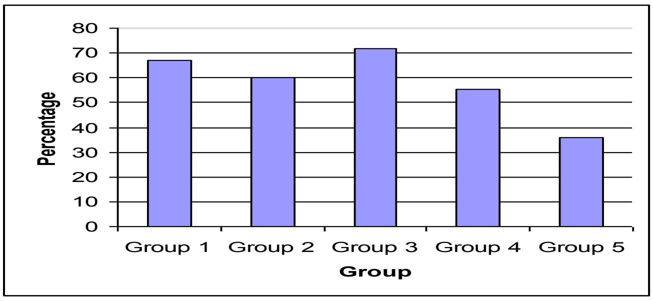

Figure 3. *Frequency Percentages across the Age Groups of a Misconception Whose Frequency did not Change as Age Increased*

The misconception of "The Earth orbits around the Sun" was an idea that was mostly encountered among the students in Groups 1, 2, 3 and 4. The frequency that this misconception was encountered was more or less the same in all the groups and it was also seen that the education received on this topic had not been effective in dispelling the incorrect notion the students in these age groups had. Although the frequency of this misconception among the students in Group 5 had decreased compared to the other groups, the frequency of encountering this misconception in this group was still 36%. The university instruction the students in Group 5 had received had been enough to reduce the frequency but the misconception still lingered. Excerpts from the interview with a student from Group 2 regarding this particular misconception are as follows.

I: Why do the seasons occur?
S2- 10: The seasons occur because the Earth orbits around the Sun.
I: Would you clarify this, please?
S2-10: I don't remember what was said in class but I think our elementary school teacher explained it to us. It seems the Earth orbits around the Sun. I think that's why the seasons occur.

In the interview, this Group 2 student refers as the source of his answer to the instruction he had received. All of the students across the age groups with this misconception similarly pointed to what they had learned in school as the reason behind their ideas. To follow is an excerpt from the interview with a student from Group 5 with the same misconception.

I: What cause the seasons?
S5-30: They occur because of the Earth orbiting around the Sun.
I: I see. How do you know this?
S5-30: It wasn't taught in high school, I may have learned it in elementary school. We learned about the Sun, the solar system, the Earth and its movements in elementary school.

This Group 5 student indicated that it was the instruction he received in elementary school that caused him to have this misconception. It was thus seen that the instruction he had received in the university had not been effective in dispelling the misconception.

Examples of misconceptions whose frequency of encounter changed across the age groups were "the change in the distance to the Sun of the Earth's hemispheres", "the Earth's orbiting both around the Sun and around itself" and "the Sun's orbiting around the Earth". The graph of frequency percentages for the misconception "the change in the distance of the Earth's hemispheres to the Sun" an idea on the basis of which frequency changed as age increased can be seen across the various age groups below in Figure 4.

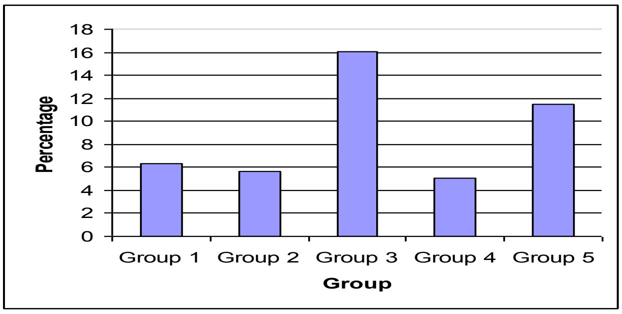

Figure 4. *Frequency Percentages across the Age Groups of a Misconception Whose Frequency Changed as Age Increased*

As can be seen in the figure, the frequency of encountering the misconception "the seasons occur because of the change in the distance of the Earth's hemispheres to the Sun" varies across the age groups. This misconception is most encountered in Group 3, and then in the students in Group 5. The frequency of encountering this misconception is least in Groups 2 and 4. The students having this misconception stated that as a result of the earth's tilted axis, the hemisphere closer to the sun would experience summer and the hemisphere farther away from the sun would experience winter.

The misconception of "the seasons are caused by the Sun's orbiting around the Earth" was mostly seen among the students in Group 2. While percentages of encountering this misconception dropped in Group 3, Group 4 students exhibited an increased percentage when compared with Group 3 students. This misconception was not encountered among Group 5 students, who had received instruction on the topic.

The frequency of encountering the misconception of "as the Earth orbits around the Sun, it also rotates around its own axis and that is why the seasons occur" changed across the age groups. While this misconception was seen more in Group 2 students compared to Group 1, the frequency exhibited a drop in Group 3 students. This misconception however was seen more in Group 4 students as compared to Group 3 students. In Group 5, the frequency of the misconception dropped once more, exhibiting the lowest percentage of the groups.

DISCUSSION and CONCLUSION

It was established in this study that students in different age groups had a variety of ideas about the causes of the seasons. While it was only among the students in Group 5, who had been supported by classroom discussions and computer-based instruction, that the percentage of correct answers was high, in all of the other age groups, the percentage of correct answers was so low as to be considered negligible. The results of the ANOVA test showed that there was a significant difference between the students in Group 5 and all the other groups of students in that students in Group 5 were more successful in results the right answer. At the same time, the frequency of encountering misconceptions in Groups 1, 2, 3, and 4 was considerably high but similar while the percentage was low in Group 5 when compared to these groups. One of the conclusions of the study was that there were no changes in the frequency of encountering misconceptions in Groups 1-4, signifying the age range of 10-19 but that there was a significant drop in frequency in Group 5 compared to the other groups. The reason for the drop in the frequency of encountering misconceptions among the students in Group 5 may be said to have stemmed from the organized instruction that had been geared to make a change in students' conceptual notions at the university level. This instruction, however, was not effective enough to make a complete change in Group 5 students' misconceptions. For example, in the cross-age study conducted by Dunlop (2000) on the concept of the seasons, the frequency of encountering the misconception of "the change in the distance of the Earth to the Sun" was 9% before instruction and 6% after instruction. This result is consistent with the present study, which indicated that instruction geared to bring about conceptual change did in fact reduce the frequency of encountering misconceptions among students but failed to eliminate them altogether, even after instruction.

Most students have various misconceptions about the causes of the seasons. These misconceptions are similar to the examples of misconceptions taken from the literature and presented in the introduction of this work. Cross-age studies of students have shown that the frequency of misconceptions decreases as students get older (Baxter, 1989; Dunlop, 2000; Plummer, 2009). In line with this general belief, in this study too, it was found that certain misconceptions about the causes of the seasons were less encountered as students got older. The misconception of "the seasons are caused by the Earth's rotating around its own axis" can be shown as an example of a misconception that is less frequently seen as age increases. On the other hand, there were certain misconceptions in the study which were more frequently encountered as students' ages increased. An example of this is the misconception that "seasons occur because of the change in the distance of the Earth to the Sun as it orbits on its elliptic path". This is consistent with reports that in certain cases, misconceptions may appear after a program of instruction (Strike & Posner, 1992). In the interviews held with students, it was found that students in Group 4 and especially in Group 5 used the scientific facts that they had learned to support their misconceptions and continued to keep these misconceptions despite their knowledge of the facts. In addition, besides the misconceptions which were more or less frequently encountered as students got older, there were also some misconceptions that were discovered that changed very little and showed different frequencies across the age groups. An example of a misconception that did not change in frequency across the age groups is the answer "the Earth's orbit around the Sun". This misconception was resistant to change, to the point that it was unchanged and difficult to dispel even after formal instruction. In fact, the same misconception is frequently encountered even after a program of instruction geared to instil conceptual change. This result was reported in previous studies that have indicated that some misconceptions continue to exist despite formal instruction (Hewson & Hewson, 1983; Hsu, 2008; Wild, 2010). An example of a misconception where the frequency of encounter changes with age is "the change in the distance of the Earth's hemispheres from the Sun". This type of misconception appears before us in different percentages in each age group, exhibiting no methodical change as age increases. The fact that the frequency of misconceptions changes across the age groups may stem from various reasons.

RECOMMEDATIONS

The conclusions of this study showed that most students across various age groups had misconceptions in their minds. The frequency of some of these misconceptions dropped as age increased while the frequency of others increased. There were also some misconceptions that showed very little or no change across the age groups. Teachers in the classroom have neither the time nor the opportunity to uncover and remedy all misconceptions. For this reason, it is believed that there is no need to devise a special activity to eliminate misconceptions that are less frequently encountered with increasing age; such misconceptions will diminish with time without an activity designed to encourage conceptual change. Misconceptions that are resistant to change and do not disappear as students get older continue to be encountered even though students have been given formal instruction. Misconceptions that are more often seen as age increases are seen to be supported by instruction and become even more frequently encountered after a program of instruction. Cross-age studies conducted at different times and in different countries about the causes of the seasons may be useful in determining which misconceptions increase or remain the same with age. Common misconceptions encountered on the causes of the seasons may be fitted into science and physics course programs so that attention is called to these mistaken notions. In this way, activities to instigate conceptual change may be included in textbooks and teachers may use these activities in the classroom to ensure the eradication of misconceptions that increase or remain the same with age.

Misconceptions that increase, remain the same, or change with age may be encountered in many other science subjects other than the causes of the seasons. Conducting cross-age studies in various topics of science may be beneficial in establishing which misconceptions are more frequently encountered with age, which stays the same, and which exhibit change. Steps should be taken to eradicate these misconceptions.

The present study’s results differ from previous cross-age research in the literature in that some misconceptions were found to be more frequently encountered or to exhibit changes as age increased. Since this was the first time the outcome of higher frequencies at later ages and changes of frequency across the age groups was seen, a comprehensive inquiry into the reasons for this could not be carried out. A topic for subsequent studies might indeed be a more comprehensive exploration into why some misconceptions encountered in younger students increase or exhibit a change as student groups get older.

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Critical Thinking, Real Life Problems and Feedback in the Sciences Classroom

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ABSTRACT

This descriptive and interpretative study was aimed at better understanding how to foment effective feedback in the sciences classroom by implementing an activity based in a real-life problem that was intended to promote critical thinking. Eleven secondary and pre-secondary public school teachers participated in a workshop in the Greater Lisbon area (part of a year-long continuing education project). In one three-hour session, they performed an activity intended to promote critical thinking, based on a real-life problem, and received feedback from a workshop facilitator. Participants responded to two questionnaires concerning the nature of the activity performed and the feedback perceived. Interpretative analysis of responses indicates that the activity performed was perceived as a real-life problem and the feedback was perceived as effective. The outcomes and conclusions contribute to a possible understanding of how such an activity can facilitate effective feedback in the sciences classroom.

Keywords: Feedback; Teacher Education; Critical Thinking; Real Life Problems.

INTRODUCTION

It is widely recognized that feedback is among the most powerful influences on how people learn. According to the scientific literature, frequent and continuous feedback about the level of understanding of the topics under discussion produces gains in conceptual understanding, attitudes and performance (Brookhart, 2008; Hattie, 2012).

The nature of the feedback that students receive from teachers may be influenced by the nature of the proposed classroom activities. Based on the literature, the implementation of activities intended to promote critical thinking is a strategy that facilitates teachers' communication of effective feedback to their science students (Bóo, 1999; Klassem, 2006). But how does this happen? . We seek to understand in what ways teachers' use of effective

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feedback can be facilitated in the sciences classroom by implementing an activity intended to promote critical thinking, embedded in a familiar, every-day life context. Two types of studies guided our literature review: (a) studies focused on defining effective feedback; (b) studies centered on promoting critical thinking and how this intersects with the process of problem solving.

Framework for Effective Feedback

The term *feedback* is defined by Wiggins (2012) as ‘information about what we are doing in our efforts to reach a goal’. Feedback may be given either by observing the effects of our own actions, or it may be provided deliberately and explicitly by other agents. The information received should not be in the form of advice or judgment, but instead, it should be directly related to the effects of our actions. According to Wiggins (2012), feedback is frequently misunderstood. As teachers and parents, we often give advice without confirming that the learner has understood prior feedback. Without prior descriptive feedback, recommendations such as ‘You need more examples in your report’ may be useless. Faced with such advice, students may become increasingly dependent and insecure about their ability to learn, which may have an impact on their achievement (Wiliam, 2009).

Several authors report that teachers rarely tell students what they need to improve, that is, how to get from their starting point to the intended goals (Hattie, 2009; Valente, Conboy & Carvalho, 2009). Students are frequently faced with classroom evaluation and grades that are of little use for what they are learning. In fact, teachers frequently use comments such as ‘Good job!’ or ‘This report is weak’ that classify, praise or criticize what was done. There is little or no genuine feedback here, no useful information that will help students ‘to assess their current achievement and to indicate what the next steps in their learning trajectory should be’ (Black, Harrison, Lee, Marshall & Wiliam, 2010, p. 42). Instead, students are only provided information about their grades and a vague notion of the good or bad results of their effort.

Brookhart (2008), Hattie (2012) and Wiggins (2012) all present theoretical rationales that characterize the essentials of effective feedback. We can synthesize and summarize these essential points by indicating that effective feedback is (a) timely; (b) likely to be used; (c) tangible and transparent; (d) goal-referenced and (e) consistent. Each of these five dimensions is described below.

Timely feedback means that feedback is received shortly after, or while, the task is being performed. It does not mean that feedback should always be received immediately. That will depend on the task that is in progress. In any case, timely feedback, that which is presented just after, or still during the task, appears to be quite effective.

By *Likely to be used* we mean that the feedback provides information that is actionable by the learners, that is, they can act based on that information. It can be given informally during observations of learners doing their work.

Tangible and transparent feedback means that learners should perceive concrete results from their efforts toward the goal they pursue, instead of just hearing talk about the goal. Feedback should be given about topics clearly relevant to the activity encouraging learners both to make connections among their ideas and to carry on the activity without depending on the teacher.

Goal-referenced feedback implies comparing the work in progress with the pre-established learning goals. Task objectives must be stated clearly. Whenever necessary, they should be restated as a reminder, and alternative strategies can be suggested that will help students to figure out how to achieve those goals.

Consistent feedback provides learners with stable and trustworthy descriptions of what they did right, of what could be done to improve and about the gap between the two. Such information, if received by students in a consistent manner over time, helps them to adjust their performance adequately.

These essentials can be used as a framework to describe in what ways classroom discussions, activities and tasks can promote the use of effective feedback. In fact, and according to Hattie and Timperley (2007), feedback about the quality of the work and feedback about the strategies used to do the work are more effective than feedback about students' self-regulation or about the student as a person. As such, it is important to clarify how the use of effective feedback can be facilitated by the nature and type of the classroom activities.

Conceptualization of Critical Thinking

Critical thinking is related to a common core of skills concerning problem solving, decision making, inference, divergent thinking, evaluative thinking, reasoning and transfer. These skills are often referred to as *higher-order cognitive skills* (Leou, Abder, Riordan & Zoller, 2006) or *critical thinking skills*. Among the several definitions that have been proposed since Dewey (1910), Ennis (1987) defines critical thinking as 'a way of reflective thinking focused on deciding what to believe and what to do' (p.10). Ennis classifies a core of critical thinking skills in five basic areas: (a) elementary clarification, (b) basic support, (c) inference, (d) advanced clarification, and (e) strategies and tactics.

The first principle of *elementary clarification* involves focusing a question. In fact, a focus is crucial to know what is relevant. It includes identifying a problem, hypothesis or thesis in the form of a question. *Basic support* includes the ability to judge the credibility of a source. These may be statements made by others, or previous observations. *Inference* is categorized according to interdependent skills such as deduction and induction. The key aspects of *advanced clarification* are the definition of terms and identification of assumptions. The area of *strategies and tactics* involves two skills: 'deciding on an action', which includes steps inherent to the process of problem solving, and 'interacting with others' in discussions, presentations, debates and written text.

Promoting Critical Thinking through Real-life Problems

As pointed out by Ennis (1987), the critical thinking area of strategies and tactics includes essential skills needed to solve problems. As such, considerations dealing with the promotion of critical thinking often involve the development of skills inherent to problem solving.

The NGSS Lead States (2013) presents the promotion of critical thinking and problem solving as indispensable conditions for effective learning in science. These are not only ways to prepare students for subsequent levels of education, but also for future professional careers. According to this document, from the first grade students should be expected to demonstrate '(…) proficiency in planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and obtaining, evaluating, and communicating information' (NGSS Lead States, 2013, p.3).

As a strategy to promote critical thinking in the sciences classroom, several authors recommend the use of activities based on real-life problems as opposed to the routine exercises usually worked (McIntosh, 1995; Pine, et al., 2006; Pizzini, Abel & Shepardson, 1988; Swartz, Fischer & Parks, 1998). Wlodkowvski (2008) considers the use of real life problems as a means for people to learn critical thinking, collaboration, and the essential concepts and professional skills of a particular discipline. In addition, it is often argued that science students frequently have difficulties when developing problem solving processes to face real-life problems because the routine exercises solved in the sciences classroom are typically based on domain-specific knowledge and require unique solutions (Lyons, 2006). Implementing learning activities based in real-life problems is viewed as a potential strategy to bridge the gap between the classroom and the real world (Weber, 2014).

By *real-life problems* we mean activities embedded in personal, community, social or global contexts. Neither the objectives nor the methods to solve these problems are wholly defined, and several plausible solutions may be acceptable. On the other hand, *routine exercises* are activities characterized by definite goals, with sufficient and explicit data provided to reach the solution. These problems imply familiar methods of resolution, involving a unique 'correct' solution. They require a mere application of algorithms in order to solve the task (Wood, 2006).

Real-life problems, by virtue of their multidisciplinary and uncertain nature, enhance students' critical thinking; they help students see the usefulness of learning and provide them opportunities for reviewing and choosing among various options (Newman, Griffin & Cole, 1999; Wood, 2006). In this way, real-life problems stand in opposition to routine exercises that yield correct textbook answers for the teacher to evaluate.

As the effects of feedback depend on the nature of the feedback, we seek to understand how teachers' communication of effective feedback can be facilitated by means of a science classroom strategy based on a real-life problem, intended to stimulate students' critical thinking.

METHODOLOGY

a) Context of the study

The present study was developed in the context of one of the sessions of a teacher education workshop- 'Feedback in the classroom: Dynamics and consequences for students' academic trajectories.' This workshop was structured in eight sessions of three-hours each, distributed one per month. The workshop objectives were for the participants: (a) to understand the concepts of student identity, school engagement, academic trajectories, and feedback; (b) to be able to identify good feedback practices in the education community; (c) to learn how to develop and implement constructive feedback strategies that would promote their students' learning and give meaning to this learning, and; (d) to analyze the feedback strategies they implement in their classes in order to reflect upon, and assess, their teaching practices. The teachers volunteered to participate and their school administrators provided space and equipment as well as assuring teacher availability for the workshop.

Pairs of workshop facilitators guided each session in a team-teaching approach. One of the team was responsible for a particular session and the other assured the continuity and articulation with former sessions. Also, after each session, participants were given assignments involving classroom application of, and reflection about, workshop topics.

During the first session, the facilitators sought to understand the perceptions of the participants on the concepts of assessment, feedback and engagement. Participants then confronted their perceptions with the existing literature, and framed them in the context of the development of student identity and academic trajectories. In the next session, the facilitators promoted an activity in which participants were asked, in groups, to reflect upon previously assigned readings (Brookhart, 2008; Hattie, 2009; Wiggins, 2012). A teaching simulation activity followed in which participants acted as students and then, using a checklist, analyzed teacher (session facilitator) performance in terms of feedback used. As an autonomous assignment, participants were requested to observe a class and write a critical analysis of the feedback used.

The focus of the third session included teaching how to think and relations between different types of feedback and the mental processing they promote in students. As an autonomous assignment, participants were requested to create an activity that would promote student awareness of their own thinking processes during a learning task and apply it in one of their classes.

The fourth session was focused on effective feedback practices according to the models of Hattie and Timperlay (2007) and Brookhart (2008). After this discussion there was a practical application in small groups, where two members of the group performed a task, while another element, acting as teacher, guided the task implementation. Other group members observed and took notes about this interaction. As this session’s assignment, participants observed a colleague’s class, and completed a checklist about the feedback types, strategies and contents they observed.

The fifth session was developed around non-verbal feedback and included role-play activities and discussions about the importance of its application in the classroom, specifically in teacher-student relations and in student-student relations in the context of cooperative work. Self- and hetero-observation of non-verbal feedback was encouraged in the autonomous assignment.

The sixth session, which is the basis for this paper, consisted of implementation of an activity based in a real-life problem taken from a familiar, every-day life context and was aimed at describing and understanding in what ways this kind of activity can facilitate the teacher’s use of effective feedback in the sciences classroom.

b) Participants

Eleven teachers (ten women), from a school in the greater Lisbon area, participated in session six. Participants (mean age 44 years) had more than five years of teaching experience and were from diverse curricular areas including, Mathematics, Physics, and Chemistry. Students of these teachers ranged from the 7^{th} to the 11^{th} grade, and are typically between 12 and 17 years of age.

c) Material

A problem-solving activity was devised with the intention of promoting critical thinking and motivating the workshop participants. The problem was designed so as to be (a) based on a real-life situation; (b) related to simple scientific concepts dealing with everyday human experience; (c) open-ended, appealing and creative; and (d) easily implemented. Material and equipment necessary to accomplish the activity were provided to the participants and included lamps, electrical plugs, supports, rulers, and small samples of window frame material of different colors. The activity is described in detail in the *Procedures* sub-section.

Two data collection tools were used. Participants’ opinions about the nature of the performed activity were collected through the checklist *Nature of the Activity* (NA), adapted from Fiuza (2010), consisting of 15 items intended to verify if the activity performed was perceived as a real-life problem or a routine exercise. Each item was a simple affirmation of a characteristic of real-life problems or routine exercises (for example, ‘In this activity: they asked us to plan experiments; they asked us to execute specific procedures’). These questions were answered on a simple dichotomy, ‘yes’ or ‘no’.

Perceived feedback was measured based on the five dimensions of feedback previously synthesized: (a) *Timely* (Was feedback given immediately or slightly after performing the tasks?); (b) *Likely to be used* (Was feedback actionable while it was possible to act based on it? Was it given informally, during the observation of the performance?); (c) *Tangible and Transparent* (Was the feedback given on topics directly relevant to the activity? Was it enough to continue the activity without help from the teacher? Did it promote understanding of the connections between ideas?); (d) *Goal-referenced* (Did the feedback compare the performance with the pre-established learning goals? Did it include alternative strategies for achieving the goals?), and; (e) *Consistent* (Did the feedback describe what was done right? Did it suggest what could be done to improve?). Perceptions of the feedback received were coded in three categories: frequently, *s*ometimes, and rarely.

d) **Procedures**

The activity, based on Fiuza (2010), is centered on environmental sustainability and, more specifically, color choices and their possible effect on home temperature and comfort. Participants, divided in three small groups, were given the following instructions:

> Materials commonly used in house construction, such as window frames, influence the temperature inside our homes. Making a reasoned choice about the color of frames for our windows and doors is a way to optimize comfort and contribute to environmental sustainability.
>
> 1. Write a plan for conducting one or more experiments that will help you decide which frame materials are the most suitable for windows and doors of a dwelling. (Some material and bibliography are provided for this purpose).
>
> 2. Before conducting the experiments, think carefully and confirm that your planning will enable you to effectively select the most appropriate window/door frames.
>
> 2.1. If you decide to change anything, reformulate the initial plan by including the proposed changes.
>
> 2.2. Justify the proposed changes.
>
> 2.3. If no changes are proposed, write a justification for your decision.
>
> 3. Conduct the experience(s) that you planned and take notes.
>
> 4. Describe the procedures you followed.
>
> 5. Record the data, including any observations about the results.
>
> 6. Organize the data in a way appropriate for the purpose at hand.
>
> 7. Analyze the data. What are your conclusions?
>
> 8. Explain how the conclusions relate to the purpose of the study and the data collected.
>
> Note: In each group, the observer records feedback presented by the workshop facilitator.

While performing the activity, the participants received feedback from the session facilitator and from their peers. Having finished their group work, participants responded individually to the two data collection tools, indicating their perceptions of the feedback received, and their opinion concerning the nature of the performed activity.

At the end of the activity, a group discussion was conducted, which included: (a) exposition and justification of the conclusions; (b) discussion of the nature of the activity performed; (c) the strategies of the feedback received; and (d) reflections about how the nature of the activities can promote the use of effective feedback.

FINDINGS

a) Participants' opinions about the activity performed

Complete data were available from 10 of the 11 participants. Responses to the *Nature of the Activity* checklist were nearly unanimous in considering that the activity demonstrated characteristics of a real-life problem. The participants reported that (a) they were asked to plan; (b) they were provided with diversified sources of information for research; (c) they were confronted with a problem-based question to solve with the help of bibliography and other materials; (d) they were asked to frame problem-solving methodologies; (e) they were encouraged to find out relevant information to carry out the work; (f) they were challenged to find out what they needed to do and to deal with real-life materials. The exceptions to these unanimous opinions were found in three answers, in which participants reported that they were not asked to select appropriate materials to carry out the work.

When asked if they were performing tasks with characteristics of routine exercises, ten participants reported that they were asked neither to perform previously planned work nor to observe and record demonstrations made by the facilitator. More than half of the participants (eight) answered that they were not asked to perform described procedures. Seven indicated that the basic theoretical knowledge to carry out the work was not transmitted in advance and that lists of the work material were not provided. Half of the participants (five) specified that they were instructed about which procedures to follow, and fewer than half (three) declared that they were not given instructions for the next steps while the work was being performed.

b) Participants' perceived feedback

Complete data about the feedback perceived were available from 9 of the 11 participants. Table 1 presents the frequencies of the participants' perceptions of the feedback received according to the three categories: frequently, *s*ometimes, and rarely.

Table 1. *Perceived feedback in five dimensions*

		Perceived		
Dimension		Frequently	Sometimes	Rarely
Timely	Immediate	5	4	--
	Slightly after performance	--	9	--
Likely to be Used	While could Act	2	7	--
	Informally	7	1	--
Tangible and Transparent	Topics Direcly Related	9	--	--
	Enough to Carry on	9	--	--
	Understand Connections	6	2	1
Goal Referenced	Compare Performance with Goals	8	1	--
	Alternative Strategies	--	5	4
Consistent	What was done right	4	5	--
	How to improve	3	3	3

A preponderance of reported perceptions indicates that feedback types were experienced 'frequently' or 'sometimes'. The most often perceived feedback was in the *Tangible and Transparent* dimension, followed by the performance/goal comparison within the *Goal-referenced* dimension. The least reported types of feedback involved *Alternative Strategies* and indications of *How to Improve.*

DISCUSSION AND CONCLUSIONS

The data show that during the session, effective feedback was frequently perceived by the participants while performing the activity. But might this feedback have been facilitated because the activity performed was intentionally devised and implemented as a real-life problem? Results point to the acceptance of this reason as a plausible explanation.

Since the activity is an open-ended problem embedded in a real life situation, it did not include completely defined objectives. All the necessary steps towards resolution of the task were not familiar to the participants and more than one solution was acceptable. As the participants reported, they were asked to define the problem and to plan experiences; so they had to ask each other, and the facilitator, questions that naturally emerged. Therefore, we can infer that participants were required to use their critical thinking skills.

Implementing strategies based on real-life problems is a powerful strategy to enhance the performance on problem solving in the sciences classroom (Caillot, 2006). According to Akçay (2009), 'this approach lets students improve their critical thinking skills, analyze and solve complex, real-life problems, work cooperatively in groups, and communicate orally and in written form' (p. 26). Also, results indicate that tangible and transparent feedback was frequently received from the facilitator and peers during the performance of the workshop activity. This means that participants' perceived feedback was given to them about topics directly related to the activity performed, was enough to carry on the work and allow them to realize connections between ideas. Yet feedback was frequently perceived as goal referenced. That is, learning goals were compared to the work in progress, although alternative strategies for achieving the goals were sometimes, or rarely, included. This perception may be due to the facilitator avoiding the suggestion of specific procedures to be followed. This could also explain why all participants reported having perceived that feedback on what they could have done to improve was given only sometimes or rarely. Feedback describing what they had done right was perceived as happening frequently or sometimes.

Teachers' perceptions about the innovative nature of the activity proposed and the feedback received may have been influenced by their previous beliefs and conceptions.

In the group discussion that took place in the final part of the session, three participants reported that since only the necessary materials to carry out the activity were available, they had no choice to decide about adequate equipment. These teachers considered that the provision of the necessary material on a table was equivalent to presenting a list. This is probably why they answered that lists of the material were provided to them.

Also, some participants declared that they interpreted the feedback received as continuous instructions to proceed with the work. This may explain why seven participants reported that instructions about the next step were given to them during the activity. After reflection, these participants recognized that the feedback received encouraged them to find out what to do, rather than instructing them.

Half of the participants identified the script of the activity as a recipe protocol of procedures to follow, a teaching strategy often used in the sciences laboratory classroom (Kyle, Penick, & Shymansky, 1979; Lunetta, 1998; Roth & Roychoudhury, 1993). Therefore, the differences between a script and a recipe protocol were debated and clarified.

Sessions that diffuse educational strategies which include reflection about science teaching practices, related with critical thinking, and with effective feedback, can be useful in promoting teachers' reflection, leading them to rethink and develop new conceptions and beliefs towards the goals for science teaching and learning. The results of this study, although limited by the number of participants and the brevity of the intervention, reinforce the idea that activities drawn from a familiar, every-day life context and based on real-life problems, that intentionally stimulate the use of critical thinking skills, enhance science learning. The implementation of such activities encourages students to define problem-solving methods, to pursue and assess solutions, and to seek the feedback they need to accomplish their work and move their learning forward. Furthermore, this science teaching strategy, based on the implementation of such an activity seems to have facilitated the provision and perception of feedback that is timely, likely to be used, tangible and transparent, goal-referenced and consistent.

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Alignment between Turkish Middle School Science Curriculum Standards and High School Entrance Examination

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ABSTRACT

The standards-based approach to science education has been implemented worldwide. The standards-based approach requires developing content standards and examinations to measure students' mastery of the content standards. Alignment between curriculum standards and examinations is crucial for providing accurate information about achievement of students, teachers, schools and educational reforms. The aim of this study is to examine the alignment between Middle School Science Curriculum Standards and High School Entrance Examination in Turkey. In this study Porters' alignment model was used. It was found that there was a moderate alignment between the examination and science curriculum standards. This study indicated that both curriculum standards and examination mostly emphasizes understanding at cognitive level. The examinations generally require higher level cognitive skills such as applying, analysing, and evaluating than curriculum standards. The findings of this study can provide some quantitative evidence and instructive information for Turkish standards based education. Also they can be used to compare curriculum standards and assessment systems in different countries.

Keywords: Alignment; Science Curriculum; High School Entrance Examination; Porter Model.

INTRODUCTION

Science education in many countries all over the world has adopted a standards-based approach for two decades. For example, in the United States No Child Left Behind Act (2001), *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), the *National Science Education Standards* (National Research Council [NRC], 1996) and *Next Generation Science Standards* (NRC, 2013) support a standards-based education. Many countries such as South Africa (Edwards, 2010), Nigeria (Akınbobolo & Afolobi, 2010), China (Ministry of Education of the People's Republic of China, 2002), Canada (Council of Ministers of Education of Canada [CMEC], 1997), Turkey (Ministry of National Education [MNE], 2013) revised or developed their curriculum according to a standards–based education apart from the USA. In standards-based education, the Standards define what students should know and be able to do at each level. All the components of education system such as assessment, instruction, professional development,

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are expected to align with the learning outcomes suggested for the students (Herman & Webb, 2007).

To support implementation of a standards-based curriculum it might be needed to design a standards-based assessment. Standards-based assessment focuses on which learning outcomes defined in the curriculum students attained. Generally, large-scale examinations such as national and/or state wide are carried out in the countries which have adopted standards-based curriculum. The scores students get from the large scale examinations are used either to decide their graduation from the schools or in which school they are going to continue their education. These examinations not only provide information about the students' performance but also they are used to reward the teachers and the schools and evaluate the success of the state or national education reforms. For example, merit pay scheme is offered to teachers in the USA. Merit pay scheme provides a temporary or permanent pay rise for the teachers according to their performances in the class. One of the indicators of teachers' good a performance in the class is the students' state wide test scores (Leigh, 2013). Alignment between curriculum standards and examination is crucial for accurate inferences about achievement of students, teachers, schools and education reforms. Alignment can be defined as "the extent of agreement between curriculum standards and assessment(s) used to measure students achievements these standards" (Bhola, Impara & Buckendahl, 2003:21). In many countries, studying the alignment between curriculum standards and national/state wide examinations has been ongoing for the past decade. For example; Liang and Yuan (2008) examined alignment between Chinese National Physics Curriculum and 12th grade exit examinations. The findings of this study indicated that the Chinese National Physics Curriculum and 12th grade exit examinations mostly emphasized students' understanding of fundamental principles and concepts of physics. Their study also indicated that examinations emphasize high level cognitive skills such as application and analysis more than curriculum. Liu and Fulmer (2008) analysed alignment between New York State core curriculum and New York State Regents Exams. They found that there was a high alignment between New York State curriculum and tests. Liu, Zhang, Liang, Fulmer, Kim and Yuan (2009) compared the alignment between physics curriculum and physics tests among three education systems: Jiangsu (China), New York State (United States), and Singapore. The results of their study show that different education systems have different emphases on both topics and cognitive skills. Also, they found that there was a statistically significant alignment between the New York content standard and the standardized test for physics, but there was not a statistically significant alignment for Chinese and Singapore physics. Edwards (2010) calculated alignment index for physics curriculum and examinations in South Africa. Also the researcher examined alignment between chemistry curriculum and examinations. The researcher found that there was a good alignment for physics, but there was a moderate alignment for chemistry. Another study which was conducted by Lu and Liu (2012) showed that there was a low alignment between the national High School Biology Curriculum standard and the standards-based High School Exit Exam in China. Çepni and Kara (2011) investigated alignment between Turkish Biology curriculum and University Entrance Examination. Their study indicated that the exam questions were not fully aligned with curriculum standards. Most of the alignment studies were carried out for the curricula and the test at high school level. However, students sit for a large scale examination at younger ages in many countries of the world. For example, In England, the students in their last year of primary school take an examination which is called eleven plus exam. In Turkey eighth grade students sit for a national examination. There are very few studies in literature which examine the alignment between exams and curriculum at middle school level. This study examined the alignment between High School Entrance Examination which the eighth grade students sit and was implemented for the first time in Turkey in 2013 and middle school science curriculum. The findings of this study can provide some quantitative evidence and instructive information for Turkish standards based education. Also, alignment studies can be used to compare curriculum standards and assessment systems in different countries.

Turkish Middle School Science Curriculum

The Turkish education system is centralized. All curricula are designed by a committee of experts at the Ministry of National Education. These curricula are implemented across the nation. The middle school science curriculum has been reformed three times since the early 2000s. The latest science curriculum was revised in 2013. Enhancing the scientific literacy of students is the central goal for curriculum. The curriculum standards are concerned with four domains of students' achievement: knowledge and cognition, skills, affective and science-technology-society and environment. The curriculum focuses on students' learning instead of teachers' teaching. Finally, constructivist learning theory has been proposed as a learning and instruction way. Science subjects are taught four hours and each lesson lasts 40 minutes (MNE, 2013).

High School Entrance (HSE) Examination

In Turkey, the schooling consists of four main components: Elementary School (four year), Middle School (four year), High School (four year) and University. The Turkish education system is highly examination centred. The students do not take national wide examination when they finish elementary school and move on to middle school. A student who completes elementary education continues his/her education in any middle school s/he wants. However, students have to sit the national standardized examinations in order to be admitted to the upper educational levels.

Students in Turkey have to take national examinations in the eighth grade. The eighth grade students are about to complete their middle school and move on to high school. There are many types of high school such as science, anatolian, social science, technical in Turkey. However, they can be categorized into two main categories. One of them is the schools which give academic education and the other one is the vocational training schools. Most of the vocational training schools are not popular between the students and their families. Due to the limited capacities of the high schools which give academic education, a competition among the students who want to be accepted to these schools has been continuing for years. In order to be accepted to these schools, the students must attain good scores in a nationwide examination.

The Turkish government announced a new nationwide examination called HSE Examination in 2013. HSE Examination consists of multiple choice questions in the disciplines of Turkish, Mathematics, Science, Foreign Languages, History, and Ethic. Ministry of National Education prepares the exam questions. An item bank included questions written by the assessment and evaluation experts of the Ministry of National Education. Teachers can give their exam questions to this bank. After the questions are analysed by the experts, they could be added to the bank. HSE Examination questions are chosen from this item bank. Eight grade students sit this examination twice (one of them is in the fall term, the other is in the spring term) in an academic year.

The Turkish Ministry of Education determines the schedule of the examinations in the autumn and spring terms at the beginning of the education year. Moreover, they announce content areas and learning outcomes of the science curriculum the examinations in autumn term and spring term will cover. The Ministry of Education also prepares a work programme for the teachers. This work programme includes a syllabus and it presents the subjects and learning outcomes in the curriculum according to the weeks and months when the teachers are required to teach their students. This programme is published on the web site of Ministry of Education. Moreover, this programme is also sent to the schools. You can reach 2013-2014 academic year HSE Examination programme on http://ttkb.meb.gov.tr/www/merkezi-sistem-ortak-sinav-calisma-takvimleri/icerik/188.

The purpose of this study is to explore the alignment between Turkish Middle School Science Curriculum and HSE Examination. The research questions of the study are:

1. What is the alignment between High School Entrance Examination in fall term and Middle School Science Curriculum?
2. What is the alignment between High School Entrance Examination in spring term and Middle School Science Curriculum?

METHODOLOGY

There are several alignment models (e.g. La Marca, Redfield, Winter, Bailey & Despriet 2000 alignment model, Achieve 2001 alignment model, Porter 2002 alignment model; Webb 2007 alignment model) in the literature. Bhola et al. (2003) reviewed the model on alignment. You can see the clear definition and brief summaries for each alignment model in their study. However, Porter's alignment model is the most commonly used model in literature (e.g. Edwards, 2010; Liang & Yuan, 2008; Liu & Fulmer, 2008; Liu et al., 2009; Lu & Liu, 2012). Liu and Fulmer (2008:375) argued that Porter's alignment model has two advantages: (a) it adopts a common language to describe curriculum, instruction and assessment; and (b) it produces a single number as the alignment index.

In this study, Porters' alignment model was used (Porter, 2002). In order to determine alignment between Turkish Middle School Science Curriculum standards and High School Entrance Examination, two tables were designed. One of the tables represents Science Curriculum; the other represents High School Entrance Examination. In these tables, rows represent the topics and columns represent the level of cognitive demands. The cognitive demands categorized into revised Bloom's taxonomy (remembering, understanding, applying, analyzing, evaluating and creating). The cell values in the tables were based on the number of major understanding corresponding to a main topic and cognitive demand. To compare the two tables, all cell values were standardized, that is, converted into ratios totalling to 1. Then Porter alignment index (P) was calculated using the following formula:

$$P = 1 - \frac{\sum_{i=1}^{n} |(X_i - Y_i)|}{2}$$

where *n* is total number of cells in the table and *i* refers to specific table cell, ranging from 1 to n. For example, for a 3 × 4 table, there are 12 cells, thus *n* = 12. *Xi* refers to the i^{th} cell of *Table X* (e.g., the standardized test table) and *Yi* refers to the corresponding cell (i^{th} cell) in *Table Y* (e.g., the content standard table). Both *Xi* and *Yi* are ratios with a value from 0 to 1. The sum of X_1 to *Xn* is equal to 1, so is the sum of Y_1 to *Yn*. The discrepancy between the i^{th} cells of the test table and the standard table can be calculated as *Xi – Yi*. The total absolute discrepancy is then calculated by summing the absolute discrepancies over all cells (Liu et al., 2009:781-782).

Subtotal cells in curriculum and examination tables are not used to calculate Porter Alignment Index. Porter alignment model can provide valuable data for each row to compare content areas emphasised by subtotal curriculum standards and examination. It can also be used for each column to compare cognitive demands emphasized by subtotal curriculum standards and examination. Subtotal values of rows and columns in curriculum standards tables and examination tables can be presented visually, such as using graphics (Porter, Blank & Zediner, 2007).

The Porter alignment index ranges from 0 to 1. If index is closer to 0, it means that alignment is lost. If index is closer to 1, this means that alignment is perfect. However, there is not a clearly defined level to decide whether the degree of alignment is acceptable or not (Näsström, 2008). In other words, Porter has not clearly specified an index in order to assert a good alignment between the curriculum and the examination. The studies conducted state that the value around 0.50 is considered moderate, the value of 0.60 and over is considered high alignment index. For example, Liu and Fulmer (2008) considered 0.60 as high alignment index.

a) Content Areas and Learning Outcomes of Science Curriculum and HSE Examination

This study explored the alignment between Middle School Science Curriculum standards and HSE Examination. In the study, the alignment indexes of HSE Examination in the fall term and HSE Examination in the spring term in 2013-2014 academic year were calculated. The fall term examination was held in November and the spring term examination was held in April in 2013-2014 academic year. Explanations about the science content areas and learning outcomes in HSE Examinations in 2013-2014 academic year were announced with the act of Ministry of National Education dated 13 September 2013 and numbered 68128140/480/2463603. It was stated in this official document that Heredity and Buoyancy subjects in science curriculum would be included in HSE Examination which would be held in the fall term during 2013-2014 academic year. Table 1 presents the sub-themes and the number of the learning outcomes which these content areas include.

Table 1. *2013-2014 Education Year Content Areas for Fall Term*

Content Areas	Sub-themes in Content Areas	Number of Learning Outcomes in Curriculum
Heredity	Mitosis	4
	Mendel Laws	9
	Meiosis	3
	Deoxyribonucleic acid	9
	Adaptation and evolution	4
Buoyancy	Buoyant force in liquid	11

Ministry of Education stated that spring term HSE Examination in 2013-2014 academic year would include six science content areas in science curriculum. These subject areas are: Heredity, Buoyancy, Matter, Sound, Heat and Temperature, Photosynthesis and Respiration. Table 2 presents the sub-themes and the number of the learning outcomes which these content areas include.

Table 2. *2013-2014 Education Year Content Areas for Spring Term*

Content Areas	Sub-themes in Content Areas	Number of Learning Outcomes in Curriculum
Heredity	Mitosis	4
	Mendel Laws	9
	Meiosis	3
	Deoxyribonucleic acid	9
	Adaptation and evolution	4
Buoyancy	Buoyant force in liquid	15
	Pressure	7
Matter	Periodic Table	5
	Chemical Bonds	5
	Chemical Reactions	7
	Acid and Bases	11
	The Chemistry of Water	3
Sound	Sound of Wave	2
	Characteristic of Sound	7
	Musical Instruments	2
	The Energy of Sounds	2
	Speed of Sound	3
Heat and Temperature	Differences between heat and temperature	6
	Heat Transfer	5
	Changing State of Matter	4
	Melting and Freezing	7
	Evaporation	3
	Heating and Cooling Curves	2
Photosynthesis and Respiration	Food Chain and Aerobic Respiration	12

In this study general content areas were used instead of more specific sub-themes to calculate alignment index in this study because general content areas are usually preferred more than specific subjects in alignment studies in literature. Liu et al (2009) explains the benefits of using general content areas depending on three reasons: reliability (analysis of specific subjects can be unreliable), pedagogical (curriculum, instruction, and assessment are likely to focus on big ideas) and practical (general content areas are required to be used so that the results obtained from the alignment studies can be used for international comparisons).

b) Cognitive Demands

The cognitive demands of learning outcomes in science curriculum and science questions in HSE Examination were categorised into revised Bloom's taxonomy. Revised Bloom's taxonomy includes six levels which are *Remembering, Understanding, Applying, Analyzing, Evaluating and Creating.* The following key words were used while learning outcomes and questions into each of the cognitive demands were being categorized (Anderson & Krathwohl, 2001; Krathwohl, 2002):

Remembering: Recognizing, listing, describing, retrieving, naming. For example, listing the most common genetic diseases in human beings is at remembering level.

Understanding: Interpreting, summarising, paraphrasing, classifying, and explaining. For example, classifying the substances whose pH are well known as acid or base is at understanding level.

Applying: Implementing, carrying out, using, executing. For example, preferring metals for heat transfer is at applying level.

Analyzing: Comparing, organizing, deconstructing, interrogating, finding. For example comparing the similarities and differences between mitosis and meiosis is at analyzing level.

Evaluating: Checking, hypothesising, critiquing, experimenting, judging. For example testing the factors required for photosynthesis is at evaluating level.

Creating: Designing, constructing, planning, producing, inventing. For example, designing and making a simple musical instrument which produces sounds at different frequencies is at creating level.

A 2 x 6 table (2 major topics x 6 cognitive levels) were formed in order to calculate the alignment between science curriculum standards and HSE Examination for the fall term. A 6 x 6 (6 major topics x 6 cognitive levels) table were formed in order to calculate the alignment between science curriculum standards and HSE Examination for the spring term.

The two coders with science education background examined curriculum standards and examination items. The two coders first independently designed their tables. And then they compared their tables. The small differences (less than 5%) between the two coders were agreed via negotiations.

FINDINGS

The findings of the study were presented under two sub-titles. First, alignment between HSE Examination in the fall term and science curriculum standards in 2013-2014 education year were explained. Second, the findings obtained for the alignment between HSE Examination held in the spring term and curriculum standards were presented.

a) Alignment between HSE Examination and science curriculum standards for the fall term

Ministry of National Education announced the content areas of science curriculum which HSE Examination would cover in the fall term at the beginning of 2013-2014 academic year. When these parts of the curriculum were examined, the findings in Table 3 were obtained. Curriculum covers two subjects: Heredity and Buoyancy. There are total 40 student learning outcomes about these two subjects in the curriculum. 29 of the student learning outcomes are from Heredity. Most of the learning outcomes (24) are at understanding level. Seven of the learning outcomes were at analysing level. Four of the learning outcomes are at applying level. Three of the learning outcomes are at remembering level and the other two learning outcomes are at evaluating level. The value in each cell was divided into 40 and the cell values were converted into ratios. In Table 4, the ratios obtained for science curriculum are presented.

Table 3. *Science Content Standard Based on Number of Understandings for Fall Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	2	20	1	4	2	0	29
Buoyancy	1	4	3	3	0	0	11
Subtotal	3	24	4	7	2	0	40

Table 4. *Science Content Standards in Ratios for Fall Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	0.05	0.5	0.025	0.1	0.05	0	0.725
Buoyancy	0.025	0.1	0.075	0.075	0	0	0.275
Subtotal	0.075	0.6	0.1	0.175	0.05	0	0.1

HSE Examination held in the fall term in 2013-2014 academic year consists of 19 science questions. When Table 5 is analysed, it is revealed that more than half of the questions (11) are about Buoyancy. Most of the questions are at understanding level. The six questions are at the analysing level. The three questions require applying cognitive skill. Only one of the questions is at remembering level. There are no questions at evaluating and creating levels. The value in each cell was divided into 19 and the ratios were obtained. Table 6 presents the ratios.

Table 5. *High School Entrance Science Examination Based on Points for Fall Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	1	7	0	0	0	0	8
Buoyancy	0	2	3	6	0	0	11
Subtotal	1	9	3	6	0	0	19

Table 6. *High School Entrance Science Examination in Ratios for Fall Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heridity	0.05	0.37	0	0	0	0	0.42
Buoyancy	0	0.10	0.16	0.32	0	0	0.58
Subtotal	0.05	0.47	0.16	0.32	0	0	1.00

The Porter alignment index was calculated using cell values in the Table 4 and Table 6 for the fall term. The Porter alignment index was found to be 0.67 for the fall term.

Figure 1 presents the comparison between the content areas emphasized in science curriculum standards and HSE Examination.

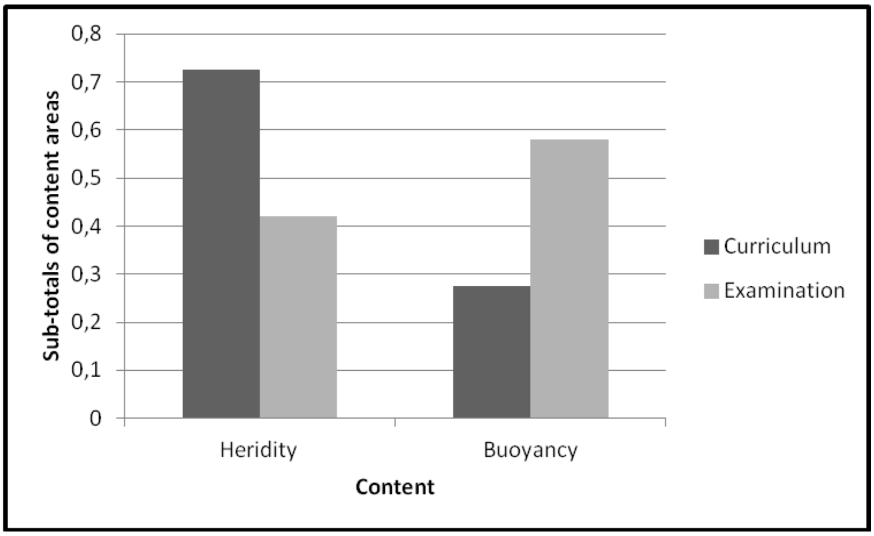

Figure 1. *Comparison between the content emphasised in curriculum and HSE Examination for the fall term*

There are differences between the content areas emphasised in HSE Examination held in the fall term in 2013-2014 academic year and curriculum standards. Although curriculum consisted of more learning outcomes about Heredity, most of the examination questions tested what students learned in Buoyancy. Figure 2 presents the differences between the cognitive domain emphasized in curriculum standards and the HSE Examination.

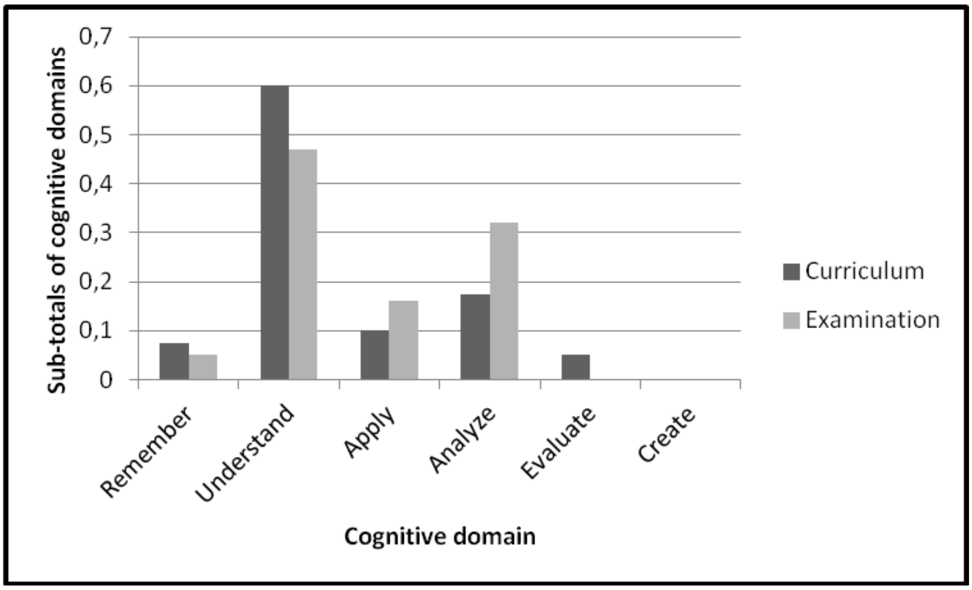

Figure 2. *Comparison between the cognitive domains emphasised in curriculum and HSE Examination for the fall term*

Understanding level was frequently emphasised both in science curriculum standards and the HSE Examination in the fall term of 2013-2014 academic year. Applying and analysing levels were emphasised more in the HSE Examination than in the curriculum standards. Curriculum standards included evaluate cognitive skill at a very low degree, but HSE Examination did not require this cognitive skill. Both curriculum standards and the HSE Examination did not include creating level.

Alignment between HSE Examination and science curriculum standards for the spring term

HSE Examination held in the spring term in 2013-2014 academic year consists of six science content areas. The science content areas are: Heredity, Buoyancy, Matter, Sound, Heat and Temperature, Photosynthesis and Respiration. Student learning outcomes of these six content areas in science curriculum were analysed by the revised Bloom's Taxonomy. The findings obtained were presented in Table 7. The numerical data in each cell of Table 7 were divided into 137 and then converted into ratios (See Table 8).

Table 7. *Science Content Standard Based on Number of Understandings for the Spring Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	2	20	1	4	2	0	29
Buoyancy	5	8	6	3	0	0	22
Matter	13	8	7	2	1	0	31
Sound	8	3	0	4	0	1	16
Heat and Temperature	8	12	2	4	0	1	27
Photosynthesis and respiration	4	4	0	0	2	2	12
Subtotal	40	55	16	17	5	4	137

Table 8. *Science Content Standard in Ratios for Spring Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	0.015	0.146	0.007	0.029	0.015	0	0.21
Buoyancy	0.036	0.058	0.044	0.022	0	0	0.16
Matter	0.095	0.058	0.051	0.015	0.007	0	0.23
Sound	0.058	0.022	0	0.029	0	0.007	0.12
Heat and Temperature	0.058	0.088	0.015	0.029	0	0.007	0.19
Photosynthesis and respiration	0.029	0.029	0	0	0.015	0.015	0.09
Subtotal	0.291	0.401	0.117	0.124	0.037	0.029	1.00

HSE Examination held in the spring term in 2013-2014 academic year consists of 20 science questions. Heat and Temperature was the topic from which most questions were asked. One quarter of the questions was about Photosynthesis and Respiration. Less than a quarter of the questions tests what the students learned about Matter. Table 9 presents the findings obtained from the analysis of science questions asked in the examination according to Bloom's taxonomy. 11 questions out of 20 questions were categorized at understanding level. The three questions were categorized at applying level, and the other three questions were categorized at evaluating level. The two questions were categorized at the remembering level. Only one question was categorized at analyzing level. The numerical data in each cell of Table 9 was divided into 20. Therefore, each cell was converted into ratios. The findings obtained were presented in Table 10.

Table 9. *High School Entrance Science Examination Based on Points for the Spring Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	0	1	0	0	0	0	1
Buoyancy	0	0	0	1	0	0	1
Matter	1	1	1	0	1	0	4
Sound	0	2	0	0	0	0	2
Heat and Temperature	1	4	2	0	0	0	7
Photosynthesis and respiration	0	3	0	0	2	0	5
Subtotal	2	11	3	1	3	0	20

Table 10. *High School Entrance Science Examination in Ratios for the Spring Term*

Topics	Remember	Understand	Apply	Analyze	Evaluate	Create	Subtotal
Heredity	0	0.05	0	0	0	0	0.05
Buoyancy	0	0	0	0.05	0	0	0.05
Matter	0.05	0.05	0.05	0	0.05	0	0.2
Sound	0	0.1	0	0	0	0	0.1
Heat and Temperature	0.05	0.2	0.1	0	0	0	0.35
Photosynthesis and respiration	0	0.15	0	0	0.1	0	0.25
Subtotal	0.1	0.55	0.15	0.05	0.15	0	1.00

The alignment index between science curriculum standards and HSE Examination in the spring term was calculated using the cell values of Table 8 and Table 10. The Porter alignment index was found to be 0.47.

The differences between the content areas emphasised by the science curriculum standards and examination in the spring term in 2013-2014 academic year were presented in Figure 3.

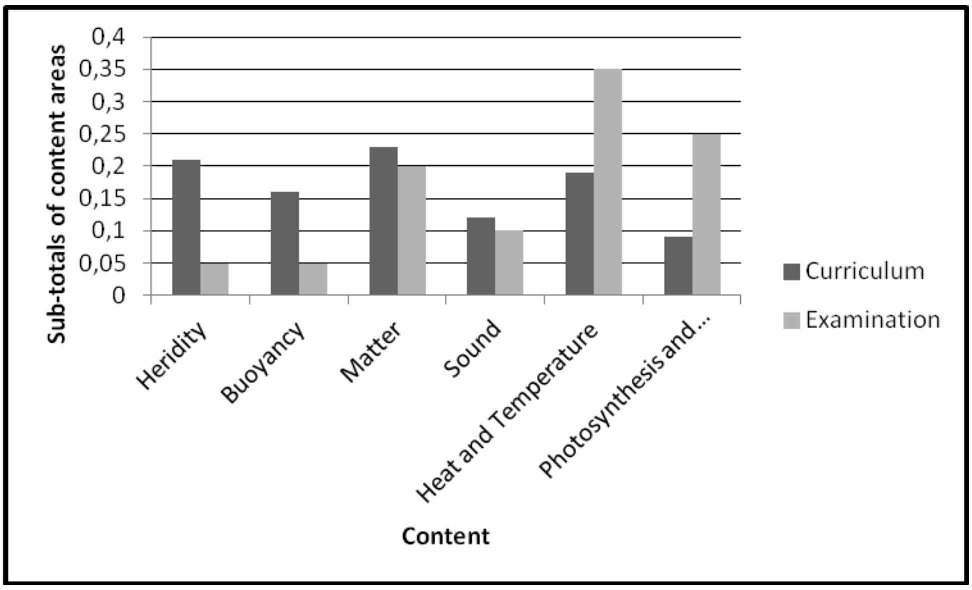

Figure 3. *Comparison between the content areas emphasised in curriculum and HSE Examination for the spring term*

The topics of Matter and Sound were emphasised at similar ratios in curriculum standards and the examination. The examinations mostly emphasise the topics of Heat and Temperature and Photosynthesis and Respiration. Figure 4 presents the cognitive domain emphasised by High School Entrance Examination held in the spring term and curriculum standards.

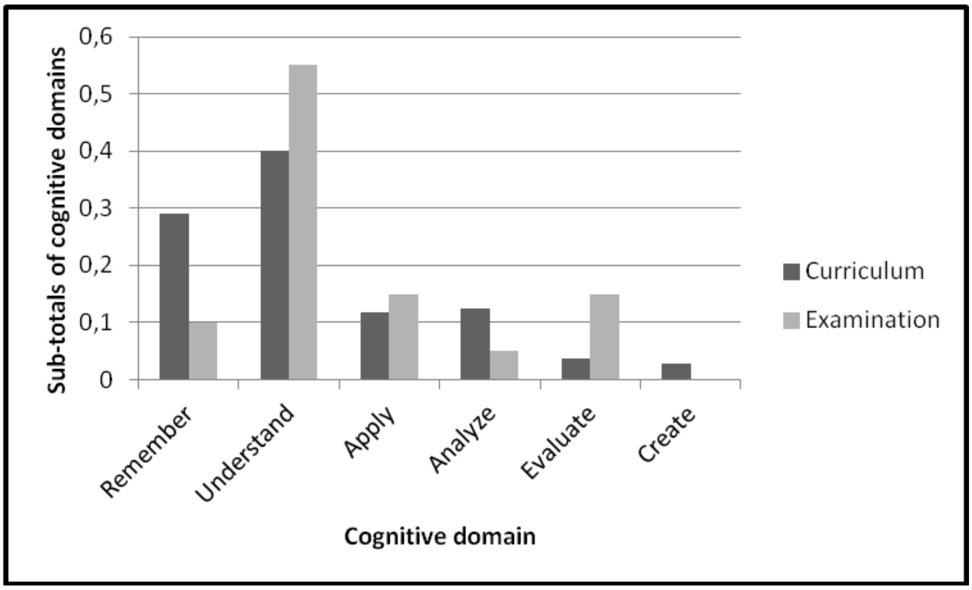

Figure 4. *Comparison between the cognitive domains emphasised in curriculum and HSE Examination for the spring term*

The examination held in the spring term in 2013-2014 academic year and curriculum standards mostly required understanding cognitive skill. The curriculum standards emphasised remembering level more than HSE Examination. Applying cognitive skill was emphasised at a similar degree in both science curriculum standards and HSE Examination. The curriculum standards required analyzing and creating cognitive skills more than examination. The examination emphasised evaluating cognitive skill more than the curriculum standards.

DISCUSSION and CONCLUSION

The Porter alignment index for the fall term examination and the spring term examination has been calculated to be 0.67 and 0.47 for respectively. It can be stated that the alignment between HSE Examination held in fall term and science curriculum is high. On the other hand, the alignment between HSE Examination held in spring term and science curriculum is moderate. The studies in the literature indicate that the USA, China, Singapore, and South Africa provided high alignment between the curriculum standards and large-scale examinations. Moreover, the alignment between the curriculum and large-scale examinations in the USA is much better than the other countries which are mentioned above (Edwards, 2010; Liang & Yuan, 2008; Liu & Fulmer, 2008; Liu et al. 2009; Lu & Liu, 2012). Therefore, it can be implied that Turkey is similar to the countries such as China and Singapore in terms of providing alignment between the curriculum standards and examination.

The findings of this study indicated that Turkish middle school science curriculum and HSE Examination include similar science contents. The examination does not include any topics which are not included in the curriculum. However, curriculum and examination have different emphasis in science content. HSE Examination held in the fall term included the topics of Heredity and Buoyancy in science curriculum. Learning outcomes for Buoyancy is 27.5% of the total learning outcomes. Despite this, 58% of the exam questions test learning about Buoyancy. HSE Examination held in the spring term included six topics. Heredity, Matter, Heat and Temperature subjects were more emphasized in the science curriculum. However, matter, heat and temperature, photosynthesis subjects were more emphasized in the HSE Examination. 19% of total student learning outcomes in the curriculum consisted of Heat and Temperature, although 35% of the exam questions tested students' learning related to this subject. 9% of total student learning outcomes in the curriculum consisted of Photosynthesis and Respiration, although 25% of exam questions tested students' learning related to this subject. The main reason for this situation might be the administration of HSE Examination throughout an academic year just like the examinations carried out by the teachers in their classes. Eighth grade science teachers administer six written exams throughout an academic year in Turkey. Three of these exams are carried out in the fall term and three of them are done in the spring term. In fact, HSE Examination is a national examination. However, these examinations are done as the third exams which each teacher administered in their classes during the fall and spring terms of the academic year. Teachers in Turkey ask a few questions from the previously learned topics but they ask a lot of questions from the recently learned topics. Therefore, the recently learned topics could have been emphasized more in HSE Examinations. The students learned Buoyancy as the last topic in the examination held in the fall term. This topic is emphasized less than Heredity in the curriculum. However, more questions were asked from the topic of Buoyancy in HSE Examination administered in the fall term. Before students sat for HSE Examination in the spring term, they had learnt the topics of Heat and Temperature and Photosynthesis and Respiration. More than half of the questions included in HSE Examination in the spring term tested the learning outcomes from these two topics. Emphasising science contents differently in the curriculum and HSE Examination might result in misinterpretation of student achievement. Some students could have learnt some topics better. A student who could not learn science content well can learn other science content better. It can be stated that some content areas more should be emphasized more according to curriculum standards in the examination which is held at national level and will have an effect on the students' educational life in the future.

Both science curriculum standards and HSE Examinations mostly emphasize students understanding of fundamental concepts and principles of science. However, there are differences between cognitive demands of curriculum and HSE Examinations. HSE Examinations generally require higher level cognitive skills such as applying, analysing, and evaluating than curriculum standards. Emphasising high level cognitive skills differently in the examination and the curriculum causes the degree of alignment to drop. However, positive arguments can be made for the requirement of high level cognitive skills of the examinations. The questions of large scale examinations affect the students' mind because the students get prepared for the examination by studying the questions of the previous years. While low order questions lead the students to memorization, high order questions can support the students to analyse, synthesise, and transfer knowledge (Brualdi, 1998; Liang & Yuan, 2008; Özsevgeç & Çepni, 2006; Vendlinski, Nagashima, & Herman, 2007).

Lower degree of alignment between the curriculum and examinations can cause an inaccurate representation of student achievement (Lu & Liu, 2012). HSE Examination in Turkey does not seem to reveal correctly what the students have learned in their schools. Eighth grade students are about to finish middle school and their scores from this examination are used to make decisions about which high school they are going to attend. Therefore, HSE Examination held in Turkey in 2013 may have brought up the issue of injustice in Turkey.

A big debate has continued about the effects of large scale examinations on teachers' instructional activities. According to Bishop (1998) and Wößmann (2005), these examinations provide useful benefits for the teachers to renew themselves and increase the quality of education they give. Contrary to this belief, some researchers (Bjork & Tsuneyoshi, 2005; Lisle, Smith & Jules, 2005; Youell, 2005) argue that large scale examinations may have negative effects on teachers' teaching methods. Teachers give up student-centred teaching and active learning techniques in order to make their students answer more questions correctly in the national exams and teach them test techniques because teachers' achievements are directly related to how many questions their students answer correctly at the central examinations. However, many teachers know that without understanding real meaning of the concepts, students are able to answer the test questions by memorizing the certain rules. Large scale examinations are one of the obstacles for implementation of curriculum in the class because teachers and students spend most of their time and energy to get prepared for large scale examinations (Kasanen & Raty, 2008). In Turkey many curricula have been accepted unsuccessful due to the same or similar reasons (Ayas, Çepni & Akdeniz, 1993; Çepni & Çil, 2009). The high alignment between the curriculum standards and examinations may help to deal with these problems. If the examination and the curriculum are compatible with each other, teachers can make an effort to teach what are described in the science curriculum to their students. While teachers are designing and implementing their in-class instructions, they can use the curriculum as their guide. It can be stated that there is a need to reinforce the relation between the curriculum and national wide examinations so that teachers can implement the standards-based education reforms in a pleasing way in Turkey.

Large scale examinations provide important information for the policy makers. Hamilton, Stecher and Klein (2002) summarize the benefits of the examinations for the policy makers: Policy makers can use the reports of large scale examination results in order to judge the effectiveness of the education reforms. Large scale examinations can improve the policy makers' ability to monitor the performance of the school systems. Moreover, large scale exam results can enable the policy makers to share the sources fairly. If the relation between the curricula and the examinations are not strong, the test results may provide incorrect information to the policy makers (Lu & Liu, 2012). Thus, item writers must consider alignment concepts further so that policy makers can do correct evaluations and make right decisions in Turkey.

We have very little data about the alignment between the curricula which the middle school students learn and the large scale examinations which they sit in Turkey and the other countries. Therefore, we do not know much about the other countries' curriculum and assessment systems and also we cannot make comparisons between the countries. It can be suggested that more studies should be conducted on this issue.

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Competencies of Science Centre Facilitators

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ABSTRACT

In the era of globalization, the structures of non-formal science education, such as science centre, plays an important role in nurturing interest in science. At the same time, the interactive exhibitions reinforce understanding of science concepts. This is where the science facilitators play a significant role. Thus, the aim of this study was to identify the level of science facilitators' competencies in science centre based on the perceptions of science teachers. This study involved 202 science teachers who completed a survey designed to elicit their perceptions on the level of science facilitators' competencies. The sample was chosen through random sampling. The questionnaire was based on three main domains: pedagogical content knowledge, personal development and learning assistance. Results from the descriptive analysis showed that the level of competencies among the science facilitators was at a moderate level for all domains i.e pedagogical content knowledge (mean = 2.61), personal development (mean = 2.78) and learning assistance (mean = 2.78). The findings from multivariate analysis of variance (MANOVA) showed that there was no difference in the perceptions between the teachers who had visited and who had never visited the Science Centre towards the level of competencies of the science facilitators. This suggests that science centres need to improove the competencies of the science facilitators based on the three domain.

Keywords: Science Facilitators; Competencies; Non-Formal Science Learning; Science Centre; Pedagogical Content Knowledge; Personal Development; Learning Assistance.

INTRODUCTION

The National Philosophy of Science Education in Malaysia states that 'In consonance with the National Education Philosophy in Malaysia, it nurtures a science and technology (S&T) culture by focusing on the development of individuals who are competitive, dynamic, robust, resilient, and are able to master scientific knowledge and technological competencies' (Malaysian Ministry of Education (MOE), 2011). Thus, science curriculum has been designed to instil and develop children's creativity through learning experience and scientific investigation to acquire scientific knowledge, thinking skills, scientific attitudes and values.

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According to Eshach (2007), science education involves two types of learning processes, namely at school (formal) and outside school which can be divided futher categorised into informal and non-formal science learning. Learning science in school is focused in the classroom, and thus, due time conntrains might not fully develop students' cognitive abilities and scientific skills (Aziz & Said, 2011). Therefore non-formal science learning should be implemented to complement the formal learning that takes place in schools.

Science education in Malaysia is seen as the vehicle to develop the country's economic development. Recognising the importance of this role, the MOE introduced the 60: 40 Policy (i.e Science and Technical Stream: Arts Stream) since 1970 and the policy still continues to date (MOE, 2012a). However, the goal of this policy has not been fully achieved, where the percentage of students taking science at both school and University levels is only 29%. In addition, the achievement of science and interest of students towards science has also decreased. The quality of science education has also decreased as shown in the TIMSS result where Malaysian obtained an average score of 492 in the 1999 TIMSS, 510 in 2003, 471 in 2007 and 426 in 2011 (MOE, 2012b; IEA, 2008, 2012).

Exposure and experience in the field of S&T need to be enhanced in nurturing the desire and interest of students in S&T. Learning process based on experience involves a variety of hands-on activities and on-site learning, and this process needs to be strengthened. Non-formal learning has been introduced in the education system in Malaysia so that contextual and meaningful learning can be carried out. At the same time, it can enhance the interest of students towards science since research has shown that the interest towards science has decreased (Osman, et al., 2007; Iksan, et al., 2006). Studies showed that children spent 80% of their time outside the classroom (Eshach, 2007). Learning activities outside the classroom can have significant impact on the learning process. Hence, the non-formal science learning is experience based, inquiry based, and hands-on activities are part of learning process that can improve science literacy (FriedHoffer, 2007). Non-formal science learning also enables students to learn from the environment. Therefore, this exposure has proven that non-formal learning outside the classroom also has an important role in addressing the issue of declining students' interest in science (Mirrahmi, et al., 2011).

Non-formal science learning can also be obtained through various agencies or organizations that carry out training, in-service courses, seminars, workshops, and other planned activities. Eshach (2007) states that the non-formal science education occurs in places like science centres/museums, botanical gardens, zoos, aquaria, planetarium, industrials, interactive exhibits, and many more. Falk and Dierking (2010) found that the main source of scientific knowledge in the United States is not from school, but from the structure of non-formal education, such as science centres (museum), aquaria, mass media, and various resources involved in the exploration of science.

However, non-formal learning is often marginalized by teachers of science in Malaysia mainly among others due to the beauracracy. According to Eshach (2007), most of the non-formal learning experiences is ineffective because students were not prepared before they embarked on the trip. In particular, they were not given proper guidance during the learning process. There is no further action done by the teacher after the learning process (Dillon et al., 2005; Kahn & Rockman, 2002). In addition, time constraint is also a cause for non-formal learning to be conducted widely and not to expose students to new experiences (Cox-Petersen et al., 2003). Thus, in order to overcome this situation, non-formal science education requires facilitators or professional educators to make sure that the learning process effective.

Agencies and organizations involved in non-formal science education typically use the services of volunteers or facilitators for all programmes organized. Hogan (2005) defines the facilitator as an individual with various skills and knowledge of people, process, technical, and experience to help a group reach the learning targets and objectives. Hamdan et al. (2007) defined facilitator or facilitators as a special person entrusted with the responsibility of carrying out their duties diligently. Facilitator refers to as an individual who acts as a leader and manager to a specific group, talented, experienced, knowledgeable, and disciplined in carrying out his/her responsibilities well. (Kadir et al., 2006; Arip et al., 2008; Schwarz, 2002; Abdullah, 2003). In addition, facilitators act as advisors whereby their focus is mainly on the learning process rather than the content of learning (Hunter et al., 2005; Paulsen, 2004; Schwarz, 2005; Thomas, 2010) Therefore, they must possess competencies to ensure their task done effectively. Competencies are defined as the basic features of an individual with knowledge and skills to work effectively and give the best performance in their tasks (Jelas et al., 2006). Competence also refers to the skills and abilities of a person should possess to perform a task (Ibrahim, 2007; Siraj & Ibrahim 2012). Thus, every facilitator must have skills and high competences or competencies to create a quality of non-formal learning environment. However, studies related to facilitators and their level of competences in Malaysia is still limited (Fairuz, 2014). Therefore, the purpose of this study was to identify the competencies level of the science facilitators from the perspective of science teachers.

Hence, in order to achieve these objectives, the research questions were as follows: (i) What are the perceptions of science teachers, who visited the science centre, towards the competencies of science facilitators?, (ii) What are the perceptions of science teachers, who had never visited the science centre, towards the competencies of science facilitators?, and (iii) Are there differences in the perceptions of science teachers who have and have not visited the science centre, towards the competencies of science facilitators?

Conceptual Framework

Non-formal learning is an approach to provide learning processes, which involves experience and reflection on concrete experiences in real situations. This reflection of the learning experience is a type of knowledge gained from outside of the classroom environment. The knowledge consists of self-exploration, experience, and linguistic concepts (Szczepanski, 2008). According to Dillon et al. (2005) non-formal learning involves students to collaborate with each other and to develop various personal skills. The acquired experience encompasses knowledge, understanding, attitudes, feelings, values, beliefs, self-development, and social development (Dillon et al., 2005; Rickinson et al., 2004).

Science facilitators working in science centres should have good competencies to produce effective non-formal learning processes. One of the main roles of a science facilitator is to reveal knowledge and concept of science to students. Therefore, it is very important for facilitators to master pedagogical content knowledge (PCK). PCK was introduced by Shulman (1987). PCK is a construct that is used to describe the integration of teacher content knowledge and pedagogy (Guzey & Roehrig, 2009; Halim & Meerah, 2002; Aziz & Said, 2011). PCK is knowledge that enables the teachers to transform the content in ways that is accessible to students. It is knowledge and skills of an effective teacher.

A science facilitator should also have good self-efficacy since they are also models to the students. Erdem, and Ozcan (2007) state self-efficacy is important in aspects of classroom management, course management, and effective communication with students. Moreover, self-efficacy in science facilitators can also increase students’ motivation to learn and affect students' behaviour (Tschannen-Moran & Hoy, 2001).

In addition, a facilitator’s competence is not limited to only intrapersonal skills, but it also includes interpersonal. Thus, each facilitator should encourage the participation of all students and has good relationship with the students so as to establish trust and mutual understanding with each other. Establishing this relationship will reduce the students from feeling isolated and marginalized within the group (Hogan, 2005; Hunter et al., 2005;

Paulsen, 2004; Thomas, 2005). In this respect, acquiring interpersonal competencies should be emphasized on science facilitators so as to create an effective learning environment for students. In the context of this study, self-efficacy theory (Bandura, 1977), the conceptual framework of management (Ebersöhn et al., 2007) and PCK (Shulman, 1987) were the main references in explaining the justification of the three domains chosen in the conceptual framework. The domains were adapted from the conceptual framework introduced by Bernhardsson and Lattke (2011) and Fairuz (2014).

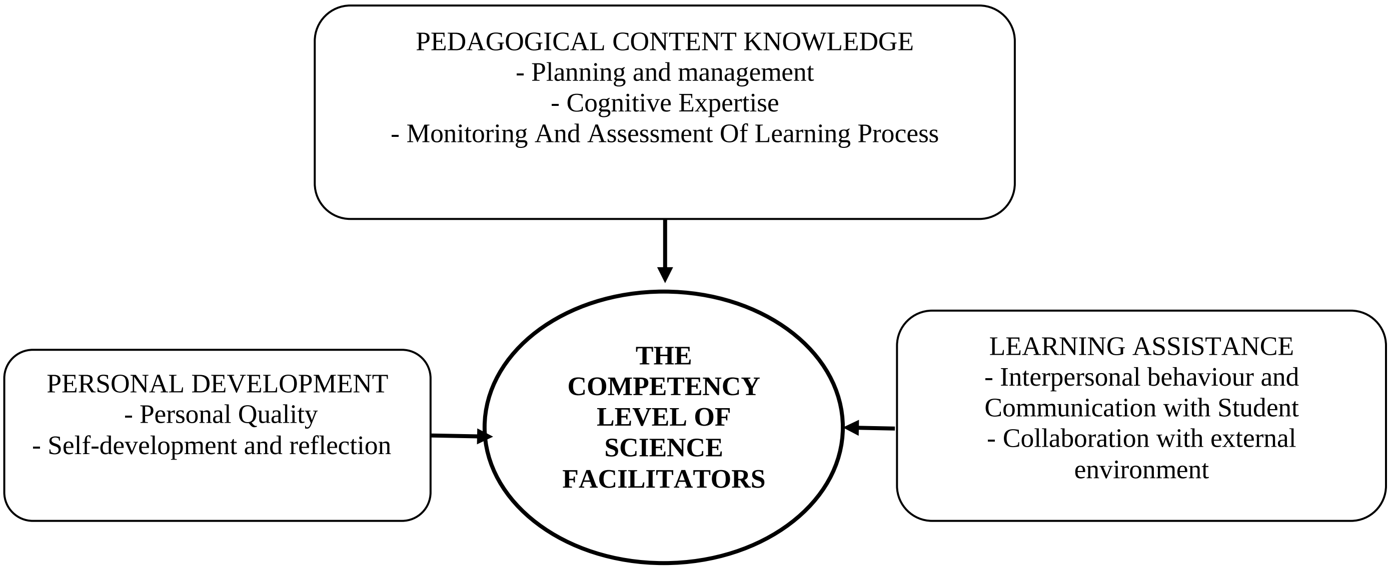

Figure 1. *Conceptual Framework* Bernhardsson and Lattke (2011) and Fairuz (2014)

METHODOLOGY

This survey research used a questionnaire as the instrument. A total of 201 science teachers from 101 primary schools and 100 secondary schools were selected through random sampling. The questionnaire consisted of three domains: pedagogical content knowledge, personal development and learning assistance. Reliability of the instrument was measured using Cronbach Alpha. Overall, the value of the Cronbach Alpha was high for each domain: pedagogical content knowledge ($\alpha = 0.870$), personal development ($\alpha = 0.954$) and learning assistance ($\alpha = 0.914$). The questionnaire used Likert scales with one (1) strongly disagree; (2) strongly disagree; (3) agree; and (4) strongly agree. In order to determine the level of competency, the mean score value was further divided into three categories: a) low level – 1.00 to 1.99, b) moderate level- 2.00 to 2.99, and c) high level- 3.00 to 4.00 (Ahmad, 2002; Chua, 2006). To identify the perceptions of science teachers towards the competencies of science facilitators, two statistical analyses were used: descriptive statistics, and inferential statistics mainly Multivariate Analysis of Variance (MANOVA). Descriptive statistics were used to answer the perceptions of science teachers of the science facilitators, while MANOVA inferential statistics was used to whether there was any differences in the perceptions towards science facilitators between teachers who had and who had not visited the science centres according to the three domains of competencies.

FINDINGS and DISCUSSION

This study aimed to determine the competencies of science facilitators from the perspectives of teachers. The samples that assessed the competencies of facilitators consisted of two groups of teachers. The first group was teachers who had visited science centre with students (140 teachers), while the second group was teachers who never led any student trip to any of the science centres (61 teachers) (Table 2). The results indicated that more than 50 percent of the samples had visited the science centre with students. The places they visited are either close or easily reached by the schools. Although the schools in the study were considered to be located in rural areas, the schools were found to be close to the science centre facility.

Table 1. *The number of teachers who had visited and never visited the science centre with students*

Visit Science Centre	Numbers Of Teacher	Percent
	N	%
Had Visited	140	69.3
Never Visited	61	30.7
Total	201	100

In this study, the level of competencies of science facilitators from the perspectives of teachers was measured based on three main domains: (1) the pedagogical content knowledge; (2) personal development, and (3) learning assistance. The mean score and standard deviation of the perceptions of teachers who had visited and had never visited the science centre towards the competencies of science facilitators is shown in Table 2.

Table 2. *Mean scores and standard deviation of the competencies of science facilitators according to the perceptions of science teachers*

Competencies of Science Facilitators	Perceptions of Science Teachers			
	Had visited		Had never visited	
	Mean	S.D	Mean	S.D
Domain 1: Pedagogical Content Knowledge	2.38	0.67	2.36	0.63
Domain 2: Personal Development	2.50	0.58	2.51	0.59
Domain 3: Learning Assistance	2.56	0.57	2.56	0.59

Overall, the perceptions of science teachers toward the level of competencies of science facilitators were moderate (Table 2) for both groups of sample; those who had visited or had not visited the science centre. This showed that with or without visiting to the science centre did not affect the perceptions of science teachers. It also indicates that teachers are not confident in science centres providing effective and meaningful science learning. Table 3 shows the level of competencies of science facilitators in detail based on the three domains.

Table 3. *The competencies level of science facilitators from the perceptions of Science teachers*

Competencies of Science Facilitators	Perceptions of Science Teachers											
	Had Visited						Had Never Visited					
	Lower		Intermediate		Excellent		Lower		Intermediate		Excellent	
	N	%	N	%	N	%	N	%	N	%	N	%
PCK	15	10.7	57	40.7	68	48.6	5	8.2	29	47.5	27	44.3
Personal Development	6	4.3	59	42.1	75	53.6	3	4.9	24	39.3	34	55.7
Learning Assistance	5	3.6	52	37.1	83	59.3	3	4.9	21	34.4	37	60.7

It is interesting to note that the level of PCK of science facilitators is perceived to be moderate and low for both teachers. Alternatively, the competencies related to Learning Assistance appear to be seen as a competency that is highly acquired by science facilitators. As argued by Cox-Petersen et al., (2003) science centres are seen more as playing an entertainment role rather than focussing on providing learning to students.

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) is an important aspect to be mastered by a science facilitator. According to Spencer, and Spencer (2008), a science facilitator should have knowledge about the curriculum or the basic concepts of certain area. Overall, the level of competencies among science facilitators for this domain was moderate with mean scores 2.38 and 2.26 (Table 4). Generally, studies have shown that museum facilitators are academically well trained and experts in their fields (Tran, 2007; Kidd, & Kidd, 1997). With the knowledge and understanding of the subject, it is assumed that the facilitators would be able to give a clear example of any abstract concepts and relate to students' daily lives. However, Shulman has argued that subject matter specialists are not necessarily good pedagogue. In addition, when analysed by sub-constructs, it also showed that the level of competencies among science facilitators was moderate. This domain consisted of three sub-constructs: planning and management, cognitive expertise, and monitoring and assessment of learning process.

Planning and Management

There were four items in this sub-construct. The results showed that all items were at a moderate level (Table 4).

Table 4. *Mean score and interpretation of planning and management domain*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Adapt teaching to the needs of the target group	2.89	Moderate	2.87	Moderate
Lesson plans based on available resources (time, place, and other equipment)	2.99	Moderate	2.84	Moderate
Teach the concepts based on student achievement	2.78	Moderate	2.87	Moderate
Monitor and review the delivery of quality teaching	2.79	Moderate	2.80	Moderate
Overall Mean Score	2.86	Moderate	2.84	Moderate

Table 4 shows that the third item, 'Teach the concepts based on student achievement' had the lowest mean score according to teachers who had visited science centres. This means that the science facilitators did not take into consideration of the students' achievement during learning process and this may be due to lack of experience and pedagogical training. The fourth item, 'Monitor and review the delivery of quality teaching' also showed the lowest mean score from the perspective of teachers who had never visited science centres. They felt that the science facilitators did not monitor and evaluate their teaching quality. Therefore, competencies for these items with moderate level should be emphasized and given attention.

Cognitive Expertise

There were six items in this sub-construct. The results showed that most of the items were at a moderate level (Table 5).

Table 5. *Mean score and interpretation of cognitive expertise domain*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Have expertise in the field of science teaching	2.93	Moderate	2.89	Moderate
Have knowledge of disciplines related to their own expertise	2.90	Moderate	3.00	High
Using special teaching methods in the field of teaching	2.81	Moderate	2.85	Moderate
Enable students to apply what they have learned	2.96	Moderate	3.03	High
Constantly update their knowledge and skills	2.93	Moderate	3.02	High
Update the domain-specific knowledge and skills at their own initiative	2.88	Moderate	2.97	Moderate
Overall mean score	2.90	Moderate	3.00	High

Table 5 shows that the third item, 'Using special teaching methods in the field of teaching' had the lowest mean score according to the teachers who had visited the science centres. This means that the science facilitators were perceived not using specific teaching technique that was suitable with the students' achievement and this might be due to lack of knowledge in teaching methods. Therefore, a science facilitator should have knowledge in pedagogy in order to use teaching method according to students' abilities.

Monitoring and Assessment of Learning Process

There were six items in this sub-construct. Overall, the findings showed that all items in this sub-construct showed a moderate level (Table 6).

Table 6. *Mean score and interpretation of monitoring and assessment of learning process construct*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Assessing students' needs	2.61	Moderate	2.57	Moderate
Analyze barriers to student learning	2.58	Moderate	2.54	Moderate
Monitor the learning process	2.70	Moderate	2.57	Moderate
Assessing learning outcomes	2.58	Moderate	2.61	Moderate
Diagnose students' learning capacity	2.56	Moderate	2.59	Moderate
Diagnose students' learning attitude	2.53	Moderate	2.61	Moderate
Overall mean score	2.60	Moderate	2.58	Moderate

Both group of teachers felt that the Science facilitators had moderate level of competencies in monitoring and assessment of learning process. Item on 'Diagnose students' learning attitude' had the lowest mean score according to the teachers who had visited the science centres, and item 'Analyze barriers to student learning' from the teachers who had not visited the science centres. Thus, the science facilitators should increase these competencies to generate meaningful learning. Competencies in monitoring and assessment of learning process are very important constructs for all facilitators to assess learning process and the learning outcomes.

In summary, the facilitators need to be exposed to educational training and professional development courses to enhance their pedagogy. Trainings should also emphasize on inquiry approach to encourage active learning. Continuing education for facilitators can be carried out through courses, seminars, and workshops, as well as the involvement of experienced teachers in helping to improve the competencies.

Personal Development Domain

Personal characteristics of a competent facilitator are possessing the capability of organizing and having foresight (Bernhardsson, & Lattke 2011; Stewart, 2006). This includes having high intellectual agility seen as quick thinking on their feet and understanding information quickly. They should gain high levels of trust from the clients and groups, self-confident with strategies to manage their weaknesses, very emotionally resilient and stress tolerant (Stewart, 2006). Bernhardsson, and Lattke (2011) characterize the personal qualities based on the ability of having a steady emotion, one that is resistant to pressure, open-minded, able to analyse barriers to student learning and proceed wisely on structured learning. The findings showed that the level of competencies among science facilitators under personal development domain was at a moderate level, whereby the mean score for both categories of teachers were 2.50 and 2.51 (Table 2). The analysis based on the sub- constructs also showed that the competencies levels were moderate and high for all the sub-constructs in this domain. There were two sub-constructs for this domain, i.e. personal quality, and self-development and reflection.

Personal Quality

There were five items in this sub-construct. The results showed that two items reached high level and three items were at moderate level (Table 7).

Table 7. *Mean score and interpretation of personal quality construct*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Have humour	2.73	Moderate	2.62	Moderate
Pay attention to the visitors	2.99	Moderate	2.92	Moderate
Friendly	3.04	High	2.98	Moderate
Willing to help/answer questions asked by students easily	3.17	High	3.16	High
Emotionally stable (not irritable, always smiling, etc.)	3.01	High	3.00	High
Overall mean score	3.00	High	2.94	Moderate

Table 7 shows that the first item, 'Have humour', had the lowest mean score according to the teachers who had visited and never visited the science centres. This means that the science facilitators did not have any sense of humour during the learning process and this may be due to lack of teaching skills to make the learning process interesting. Elements of humour in teaching sessions are important to attract students' interest, and at the same time, to make sure that non-formal learning is effective. Roberts, and Antioch (2004), and Grenier (2005) state that a good facilitator should have character and personal qualities, such as kindness, humour, patience, responsibility, confidence, and civic leadership . Therefore, the science facilitators can be encouraged to develop some sense of humour.

Self- Development and Reflection

There were twelve items in this sub-construct. The results showed that most of the items reached high and moderate levels (Table 8).

Table 8. *Mean score and interpretation of self-development and reflection construct*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Have Never Visited)	Interpretation
Using their own life experiences in the learning environment	2.86	Moderate	3.07	High
Identify their own learning process	2.83	Moderate	2.93	Moderate
Set their own learning goals	2.79	Moderate	2.92	Moderate
Curious	3.01	High	2.97	Moderate
Creative	3.13	High	3.07	High
Flexible	3.06	High	3.13	High
Reflect on their own professional role	2.99	Moderate	3.00	High
Evaluate their own practices	2.79	Moderate	2.80	Moderate
Self-confident	3.06	High	3.13	High
Committed to their own professional development	2.83	Moderate	3.08	High
Face criticism wisely	2.89	Moderate	3.02	High
Handle stress effectively	2.85	Moderate	2.95	Moderate
Overall mean score	2.92	Moderate	3.00	High

Table 8 shows that the third item, ‘Set their own learning goals’ and ‘Evaluate their own practice ‘ had the lowest mean score according to both group of teachers. This means that the science facilitators had ‘self development and reflection’ at moderate level. Grenier (2005), through his qualitative research, 'How Museum Docents Develop Expertise' found that formal training, continuation of their studies, informal education, and experience indirectly helped in the creation of a museum facilitator expert. Therefore, self -development competencies is a competence which is very important for the facilitators of science so as to produce effective learning (Roberts, & Antioch 2004; Roberts et al., 2006).

Learning Assistance Domain

Learning assistance domain included two sub-constructs, i.e. (i) interpersonal behaviour and communication with students, and (ii) collaboration with external environment. Overall, the mean score of the domain of learning assistance was at a moderate level. The mean values obtained from these two categories of teachers were similar; 2.56 (table 2). Meanwhile, the analysis based on the sub-constructs also showed different levels of competencies.

Interpersonal Behaviour and Communication with Students

There were five items in this sub-construct and most of the items were at high level (table 9).

Table 9. *Mean score and interpretation of interpersonal behaviour and communication with students construct*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Motivate students	3.01	High	3.05	High
Inspire	3.04	High	2.97	Moderate
Use appropriate body languages	3.04	High	3.00	High
Clear in communicating	3.01	High	3.13	High
Managing groups dynamically	2.97	Moderate	3.00	High
Overall mean score	3.01	High	3.03	High

Table 9 showed that there were two items with moderate level, 'inspire' and 'managing groups dynamically'. The science teachers felt that the science facilitators were less inspiring and could not manage groups dynamically. Therefore, the facilitators should make teaching science exciting and they should acquire the ability to inspire and motivate students. Moreover, science facilitators should also have good group management skills. There are various theories, such as theories by Ebersöhn et al., (2007), which can help improve group management skills among the facilitators to create a conducive learning environment for students.

Collaboration with External Environment

There were three items in this sub-construct, most of the items were at a moderate level (Table 10).

Table 10. *Mean score and interpretation of collaboration with external environment construct*

Item	Mean Score (Had Visited)	Interpretation	Mean Score (Had Never Visited)	Interpretation
Look at the subjects that are taught in the context of a wider community	2.74	Moderate	2.93	Moderate
Identify the role of science centres to the subject taught	2.89	Moderate	2.93	Moderate
Work with various stakeholders, such as schools	2.87	Moderate	3.03	High
Overall mean score	2.83	Moderate	2.97	Moderate

Table 10 shows that the item related to 'look at the subjects that are taught in the context of a wider community' had the lowest mean score. This finding suggests that the facilitators did not take into consideration of a wider community during the teaching and learning process. As a competent facilitator, cooperation with the external environment should be enhanced and emphasized. The facilitator should encourage the involvement of students in their learning process to improve their learning outcomes by providing a safe learning environment and encouraging learning process (Chin, 2010; Hunter, & Thorpe 2005; Kolb et al., 2008; Thomas, 2010). Grenier (2005) also found a museum facilitator should have good interpersonal skills and communication skills with visitors. They also should have knowledge about all the materials in the science. Thorpe (2013) has also stressed that communication competency with a group is one of the most important competencies for a science facilitator.

Different Perceptions of Teachers

In order to identify if there are differences between the perceptions of teachers who had visited the science centres and teachers who had never visited the science centre towards the competencies of science facilitators, the multivariate analysis of variance (MANOVA) was carried out. MANOVA test was used to determine the differences in mean and the results are shown in Table 11.

Table 11. *MANOVA test analysis*

Effect	Wilks' Lamda (λ) Value	F Value	D.K Between Group	D.K In Group	Sig. Level
Science teachers visits	0.990	0.668	3	197	0.572

Table 11 shows the comparison of mean scores between the two types of teachers group with Wilks' Value (λ) = 0.990, F (3, 197) = 0668, and p = 0.572, where p> 0.05. This indicates that there was no significant difference in the perceptions of the level of competencies among the science facilitators between the two groups of teachers for all of the three domains. Even if there were teachers who had never visited the Science Centre, their perceptions on the competencies level of the science facilitators had still been at a moderate level. This means that visiting the science centres is not the main factor in influencing the teachers' perception. This also suggests that the experience felt by teachers who had visited the science centres was not encouraging.

According to study conducted by Corbos, and Popescu (2014), they found that 81 % of visitors who had visited the museum with more satisfaction had the desire to re-visit the place. Therefore, in the case of this study, perhaps the offerings by the science centres is not effective or interesting, in particular the role of the science facilitators in providing effective learning experiences. This is because if the experience is seen to be fruitful then teachers are encouraged to bring students to visit science centres and teachers can collaborate with the facilitators who work there to ensure that learning takes place during the tour because science centre is a major source of acknowledgement in science (Falk & Dierking, 2010). Hence, teachers and students with the experience of visiting the science centres would form the intention to revisit and thus the non-formal science education would help to enhance students' interest and learning in science.

CONCLUSION and IMPLICATIONS

Science teachers' perceptions on the level of competencies among the science facilitators were found to be at a moderate level. This shows that science facilitators have not reached a satisfactory level and this gives an overview of the effectiveness of learning science in a non-formal environment. Even if there are teachers who had never visited, they shared the same perception of teachers who had visited science centres. Both groups of teachers agreed that the competencies of the facilitators were indeed very important to produce an effective non-formal learning science environment for students. All the three domains were at a moderate level, while the domain of knowledge of pedagogy had the lowest mean score. Therefore the PCK domain has to be enhanced through a variety of trainings or professional development programmes. The competencies investigated in this study can be used as a guide line for the science centres to gauge the competency level of their science facilitators. Future work on the science facilitators' competencies could be investigated from the perspective of the students themselves and their parents. It will serve a more holistic view of their competencies and better training program can be developed. This is important so that science centres as non-formal science education organization can play a more effective role in order enhancing the interest among students towards science, and thus, to build a scientific literacy community.

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The Impact of Beliefs and Challenges Faced, on the Reported Practice of Private School Science Teachers in Abu Dhabi

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ABSTRACT

Private international schools in Abu Dhabi, UAE, are diverse in curriculum, methods and ethos. They all recruit internationally (and often Western) trained teachers. It could be assumed that these teachers bring with them beliefs about current ‘best practices’ from their native countries and that these methodologies are implemented into Abu Dhabi’s schools. This study used a mixed-methods survey design to investigate the reported beliefs and practices in science education, an area that primary teachers are often hesitant to approach, to identify how much impact beliefs have on reported practice, often despite impeding barriers and challenges. It was found that in many areas the reported beliefs and practices of Abu Dhabi’s private school teachers correlate. Where practice does not correlate with beliefs, language barriers and a lack of time, space and resources were identified as the leading reasons. Targeted professional development, support from school management and greater parental involvement are identified as strategies for reducing discrepancies between beliefs and practices.

Keywords: Science Education; Belief Systems; Challenges Primary Teaching; UAE.

INTRODUCTION

The Emirate of Abu Dhabi is one of seven emirates that constitute the United Arab Emirates (UAE). It is the capital of the UAE and is the largest by population of the seven emirates. In mid-2012, the population of Abu Dhabi Emirate was estimated to be 2,334,563 people, of which almost 80% were non-nationals (Statistics Centre – Abu Dhabi, 2013). The UAE has encouraged the establishment of private schools and has seen a surge in such institutes particularly over the last two decades, in part due to the dependence on foreign labour (McKinnon, Barza & Moussa-Inaty, 2013). Approximately 265 public schools provide a free education for the emirate’s national students, while non-national students are educated in a diverse variety of private international schools (approximately 185 schools). National students have the option of attending the fee-paying schools and currently make up about 25% of the private school student population (Abu Dhabi Education Council, 2014).

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All schools in the emirate are under the authority of the Abu Dhabi Education Council (ADEC). Private schools must abide by the Council's governing rules and guidelines and are subject to regular evaluation by ADEC. However, they may operate using any approved curriculum they choose, including those from Britain, Canada, Australia, India, Pakistan and the United States of America.

The teaching faculty in Abu Dhabi's private schools are predominately non-nationals with teaching qualifications earned from their native country's education systems, meaning in theory, these teachers should bring with them 'best practices' from supposedly developed countries which have well-established education systems.

Science Education in Abu Dhabi Private Schools

As private schools use a variety of curricula and language of instruction, and serve a variety of communities, each system may place a different emphasis on science indicating that science education in the emirate may vary greatly. The Abu Dhabi Education Council's New School Model Teacher Guide emphasises inquiry based learning, in which students are "*…encouraged to explore their learning actively through creativity and problem solving, [and are] engaged in purposeful practice as they move towards independence*" (ADEC New School Model Teacher Guide, 2013, p. 8). Private schools are not bound by these definitions, however they have been used as a common basis to form the theoretical framework from which we derived our research tool.

Theoretical Framework – The Impact of Teachers' Beliefs and the Challenges They Face

Since private schooling in Abu Dhabi is so heterogeneous, it is difficult to isolate a common model of what constitutes best practice in primary science education in the emirate. Ornstein (1985) suggests that "*…it is difficult to define or agree upon generalizations of successful teaching*" (p. 176), but asserts that teachers can make a positive difference on student performance.

Academic research has shown that teachers' beliefs exist as a system, and that core beliefs are resistant to change (Fives & Buehl, 2012, as cited in Kılınç, et. al., 2014). Furthermore, Ornstein (1986) believes that one of the biggest issues with defining best teaching practice is that people are handicapped by their own biases and beliefs about what constitutes good teaching. This is particularly important in the area of primary science education as many researchers have documented the hesitancy of teachers to teach science (*e.g.* Appleton, 2008; Tytler, 2007; Mulholland & Wallace, 1996), with the reluctance often attributed to the perceived importance (or lack of) that teachers assign to science, their own science anxiety and low self-efficacy with respect to teaching science (*e.g.* Walan & Rundgren, 2014; Fleer, 2009; Harlen, 1997). Bandura (1997) endorses the viewpoint that teachers' beliefs are a very strong predictor of actual behaviour, and Lederman (2007) found teachers' practices to be directly related to their perceptions and beliefs about science. This idea of a high correlation between beliefs and practice, that teachers' instructional decisions are closely related to beliefs about how students learn best, is commonly held in literature both recent and less contemporary, (*e.g.* Seung, Park & Narayan, 2011; Keys & Kang, 2000; Richardson, 1996; Haney, Czerniak & Lumpe, 1996). Recent research has also found that, for the majority of students, engagement with and interest in science, has been largely formed by the time they reach 14 years of age (*e.g.* Lindahl, 2007; The Royal Society, 2006). Fitzgerald, Dawson and Hackling (2013) found that effective primary school science teachers "*…create a learning environment that stimulates and supports student interest*" (p. 982). Therefore, the role of primary school science teachers is critical.

Mahmoud (2009) suggests that the relationships between beliefs and practices are very complex, due to the fact that beliefs are dependent upon the context in which they exist. Ernest (1988) also suggests that the contextual factors such as curriculum, the schooling systems and others' expectations also impact the practice of teaching, elements which may sometimes be outside of teachers' control.

Concerns about a lack of time and space to deliver science; the need for, and the (lack of) ability to use, technical equipment; and the complex nature of science-based content for primary-aged students have been cited by teachers as challenges to teaching science (Appleton, 2002). Teachers of a science curriculum during the reform of the education system in Kuwait identified a set of internal barriers such as the time allocated to teach science, teaching resources, workload, students' behaviour, the level of the content and poor professional development (Al Shammeri, 2013). Similar challenges were perceived by primary science teachers in Turkish schools (Sengul, Cetin & Gur, 2008). The findings of a study conducted by Al Ghamdi and Al Salouli (2012) pinpoint inadequate physical space, lack of resources and professional development, and not enough instructional time as perceived barriers that impede teaching science in public and private schools in Al Dammam in the Kingdom of Saudi Arabia. The language of instruction in primary schools has long been debated with scholars believing that use of students' first language is better in the first years of schooling (Sua & Raman, 2007). Conteh (2003) argues that language is an important component required to develop teacher-student relationships which are necessary in the process of learning. The student population of Abu Dhabi's private schools is often very multi-cultural and consequently it is not possible for each students' first language to be the language of instruction for science. This creates challenges for teachers and may act as a barrier to learning. Todd (1983) presents an educational definition of mother tongue language where he defines it as a tool through which students learn faster than through an unfamiliar language. Undesirable outcomes of learning through a second weaker language were highlighted by different scholars. Minority students in the USA and the United Kingdom have low attainment and face difficulties in understanding concepts due to their low levels of English language (Jeffcoate, 1984; Baker, 1993; Thomas & Collier, 2002). Sua and Raman (2007) conclude that students who do not have enough language skills cannot work to their full potential and their academic achievement will be impacted.

Therefore, the purpose of this study is to determine the beliefs of Abu Dhabi private school teachers' regarding how students best learn science and whether or not this aligns with their reported practice. The study also seeks to uncover the barriers and challenges faced by these teachers' in order to shed light on why practices and beliefs may not correspond.

The conceptual framework that was developed from the relevant literature in terms of levels of confidence, challenges faced and the perceptions and beliefs of primary school teachers informed our research questions and the development of the data collection tool.

The research questions are as follows:

1. How do the private school teachers' beliefs about science learning correlate with their reported practice?
2. What are the main challenges faced by teachers when teaching science in Abu Dhabi private international schools?

METHODOLOGY

a) Data Collection Tool and Participants

This study followed a case study research design that utilised an online survey questionnaire. This survey was emailed to 13 private primary schools in the Emirate of Abu Dhabi where English is the medium of instruction. In the email forwarded to the participants, the researchers explained the purpose of the study and emphasized that participation is anonymous and voluntary. 66 teachers responded to the survey.

The survey consisted of a variety of items under 3 main themes; barriers and challenges faced, teachers' beliefs about how children learn, and (reported) actual teaching practice. Example items included: 'The physical space in which I teach science is adequate' (barriers and challenges faced); 'Students learn science more effectively when they work in groups and share ideas' (teachers' beliefs about how children learn); and, 'I actively involve students in hands–on activities and investigations' (teaching practice). Participants responded using a 4-point Likert scale (strongly agree, agree, disagree, strongly disagree) and were given the opportunity to write general or explanatory comments at the end of each section, if they wished - 17 comments were recorded.. Teachers were asked to self-report on their practices in the classroom for later correlation with their beliefs on how students best learn science. Teachers were also asked about the barriers and challenges they face when teaching science. It was expected that the answers to these questions would help identify possible reasons for a lack of correlation of beliefs and practice (if applicable), or enlighten us on the obstacles teachers were overcoming in order to teach according to their beliefs. The survey also asked teachers to rank the importance of the English, maths and science subjects to indicate teachers' beliefs about the relative importance of science.

b) Data analysis

The survey questionnaire consisted of four-point Likert scale items and qualitative items that were developed from and linked to the reviewed literature. The questionnaire was piloted with five teachers to get feedback and make necessary changes; however, their responses were not included in the collected data and they were asked not take the survey again. To assure that using the same instrument in different situations will give the same results, reliability test was performed (Field, 2013). The reliability test was run on the 8 items that are exploring teachers' beliefs about how students best learn Science, the 14 items that are exploring the practice of Abu Dhabi's private school teachers and the 7 items that are investigating the barriers and Challenges to teaching Science. Each of the items had an acceptable value of Cronbach's alpha which is greater than 0.7 (Sekaran, 2003).

The results of the survey were tabulated to show percentages of answers along the Likert scale and to highlight discrepancies between teachers' beliefs about how students' best learn science, and how they actually teach science. Significant discrepancies were analysed against responses to 'barriers and challenges faced' items to identify possible causes. Where participants recorded additional optional comments, these were used to further describe the beliefs, practices and barriers faced, and were coded as such under the three themes.

FINDINGS and DISCUSSION

The private school teachers in this study overwhelmingly agreed with the 'best practice' statements in the survey (see Table 1). Over 90% of all participants responded positively to each of the items and 98% of participants agreed or strongly agreed that students learn science best when they work in groups and share ideas, discover scientific facts by exploring and observing by themselves rather than when they read it, and when they are given time to think before answering questions in class and time to reflect on their learning. This certainly aligns with the inquiry emphasis endorsed by the Abu Dhabi Education Council. The only teacher who disagreed with all statements, added this comment:

> *All these statements depend on a particular student's learning style. Some work better in groups and pairs, others learn more through self-exploration. This is why it is important to differentiate learning settings.*

Similar to Fleer (2009) who found that experienced early-childhood educators doubted the value and place of science learning, over 70% of participants ranked science third (least important) when comparing the English, mathematics and science subjects, and only 3% ranked it as most important. This in itself does not denote that teachers believe science to be unimportant, simply that it is not as important as English and mathematics. This belief may affect the time and effort dedicated to teaching science.

Table 1: *Abu Dhabi's private school teachers' beliefs about how students best learn Science*

Answer Options	Strongly Disagree %	Disagree %	Agree %	Strongly Agree %
Students learn science more effectively when they work in groups and share ideas.	0	1.5	51	47.5
Students understand science best when they discuss concepts with their partners.	0	6	52.5	42.5
Students' interest in learning science increases when they pose their own questions and discover the answers by themselves.	0	6	38.5	55.5
Students remember a scientific fact when they discover it by exploring and observing by themselves rather than when they read it.	0	1.5	27.5	71
Students remember a scientific fact when they discover it by exploring and observing by themselves rather than when they hear about it from their teacher.	1.5	1.5	44.5	52.5
Students broaden their scientific inquiry skills by communicating, sharing and reviewing each other's results.	0	6	36	58
Students understand scientific concepts better when they are given time to think before answering questions in class and time to reflect on their learning.	0	1.5	32.5	66
Students develop a deeper understanding of scientific concepts when they regularly record their findings in a science journal.	0	11	48.5	40.5

Table 2: *Self-reported practice of Abu Dhabi's private school teachers*

Answer Options	Never/ Rarely %	Sometimes %	Often %	Always %
I allow my students to explore and discover science concepts on their own with minimal teacher input.	6	45.5	36.5	12
I involve students in class debates and discussions.	1.5	13.5	33.5	51.5
I actively involve students in hands–on activities and investigations.	0	24	45.5	30.5
I provide opportunities for students to work in pairs or very small groups	0	4.5	38	57.5
I incorporate scientific inquiry skills in my science classes.	1.5	18	39.5	41
I encourage collaborative learning among my students	0	7.5	41	51.5
I use ICT tools in my science class.	12	33.5	35	19.5
I arrange library lessons and field trips connected to the science topics	23.5	40.5	26.5	9.5
I relate science concepts studied in class to our daily life and to the real world.	1.5	8	49	41.5
I create differentiated resources to support student learning in science	1.5	27.5	40	31
I create differentiated activities and experiments to support student learning in science	3	33	37.5	26.5
I use different science assessment tools, not only projects and exams.	4.5	29	36.5	30
I demonstrate practical work to my students first before they begin the work.	3	22.5	41	33.5
I help my students to make connections between science, maths and English.	0	15	39.5	45.5

The reported practices of these teachers revealed that teachers are employing the strategies they believe help students to learn science at least sometimes in most cases (see Table 2). This corresponds with other research (e.g. Seung, Park and Narayan, 2011; Lederman, 2007: Keys and Kang, 2000; Bandura, 1997; Richardson, 1996; Haney, Czerniak and Lumpe, 1996) that suggests teachers' practices are closely related to their beliefs about how students learn best. Some anomalies were noticed however. For example 6% of teachers surveyed never allowed their students to explore and discover science concepts on their own and 45.5% only sometimes provided opportunities for students to do this. This is comparable with the research of Brickhouse and Bodner (1992) whose research subject believed science learning should be exploratory in nature however the majority of his teaching was formal and structured. Teachers were also less likely to arrange library lessons and field trips connected to the science topics, and comments supplied by teachers explained that these things were often outside their control:

> *Fieldtrips are planned out by coordinators and administration with excessive concerns placed on cost, rather than on the life-experiences for students.*

Table 3: *Barriers and Challenges to teaching Science in Abu Dhabi Private Schools*

Answer Options	Strongly Disagree	Disagree	Agree	Strongly Agree
I find English language a barrier that affects students' understanding of scientific concepts	3	24	42.5	30.5
I have sufficient resources to teach science practically	23.5	34.5	31	11
The physical space in which I teach science is adequate	16.5	36.5	41	6
I find it hard to manage students' behaviour while teaching science in an active way	30.5	48.5	15	6
I receive professional development on the planning and teaching of science	33.5	35	24	7.5
Parents support adequately by working with their children at home to link with their learning of science at school	21.5	40	34	4.5
Due to time constraints I find it hard to cover the science curriculum adequately	9	29	36.5	25.5

A number of barriers and challenges in the teaching of science were identified by the surveyed private schools teachers (see Table 3). Using English language as a medium of instruction was identified as one of the challenges that the teachers are facing. 73% of the surveyed science teachers agreed or strongly agreed that students' grasp of scientific concepts is influenced by using the medium of English to teach Science. Those findings correspond with Alvarez's (1991) findings that showed that the majority of students in schools in Philippines need to be taught scientific concepts through their native language and that only the high ability students can cope with the second language. Howei (2001) echoes this by stating that students face problems in understanding and responding to various types of science questions including open-ended questions when they are taught through a second language. One teacher commented:

> *Some Arabic science lessons are needed to support the English.*

This is illustrative of other similar comments. This might be helpful as a number of research studies that took place in different contexts have shown that students' achievement is improved when the mother tongue language is incorporated in a bilingual instructional strategy (Cummins, 2007). Despite this, almost 85% of participants reported that they often or always involve students in science debates and discussions.

Time constraints are also perceived by 62% of the surveyed teachers as a challenge that impedes teaching science. This resonates with Al Ghamdi and Al Salouli's (2012) study which shows that teachers in private and public primary schools in the Kingdom of Saudi Arabia perceive time as an internal barrier in teaching science. It seems that the active teaching approach that the teachers are adopting has brought about this challenge. 80% of our participants stated that they teach inquiry skills in their science classes and 76% incorporate hands-on activities and actively involves students in investigations. Using a student-centred teaching approach like the inquiry-based approach that involves investigations and hands-on experiments is time consuming (Alexander, 2000). One of the teachers commented:

> *Administration/Ministry of Education/Abu Dhabi Education Council should understand that science is a core subject and allow more time in the timetable for it.*

47% of the participants reported that they do not have enough physical space that enables them to teach science and 42% of them assert that they do not have enough materials and resources. This could be the reason behind nearly a quarter of teachers surveyed only sometimes including hands-on activities and investigations in their classes, despite the vast majority agreeing that this was best for students. The teachers explained:

> *It would be great if private schools had science labs set up to help promote and encourage students about science education. Also it would mean more space to carry out investigations as I see science as investigations, experiments.*
> *We need more scientific resources or even a junior lab for every student to be able to work using his/her own hands and not wait for others.*
> *We need better facilities!*

The lack of, or insufficient professional development was perceived as an obstacle by almost a third of the surveyed teachers. When they were asked to make suggestions on how to optimize science teaching they expressed their sentiments as follows:

> *We need more teacher training and planning guidance.*
> *Providing the opportunity for teachers to attend professional development courses relating to the teaching of Science and the implementation of the new science curriculum.*

The challenges identified above are in accordance with the findings of Al Shammeri's (2013) and Sengul, Cetin and Gur's (2008) studies.

Inadequate parental involvement emerged as a challenge, a challenge that was not alluded to in the studies mentioned above. Over 38% of the participants expressed their concern about the support that parents give to their children in learning science and they said that parents are not working with the school and teachers to support their kids' learning. This contradicts Agbatogun (2009) who argues that parents whose children attend private schools are more engaged with their kids' schooling due to the fact they pay tuition fees. Different research studies have shown that students' achievement is positively affected when parents are actively involved in the learning process of their kids (Henderson & Berla, 1997; Houtenwille & Conway, 2008). Other studies also researched the effects of parental involvement on the achievement of students in science and the findings have shown that the relationship between the two variables is a positive one (Olatoye & Ogunkola, 2008; Olatoye & Olajumoke, 2009).

CONCLUSION and RECOMMENDATIONS

This study was conducted to identify the beliefs of primary science teachers in private schools in Abu Dhabi and the challenges that they perceive in teaching science. The teachers surveyed reported beliefs that align with current 'best practice' and with the Abu Dhabi

Education Council's viewpoint on science education and, wherever they had control, were endeavoring to include these strategies in their teaching. This was not true for exploratory type learning, however. Almost all teachers surveyed agreed or strongly agreed this was how students learned best, yet just less than half of the teachers provided these types of activities for students often or always. This finding contradicts both previous educational psychological theories and recent research that held the viewpoint that teachers' beliefs are a very strong predictor of actual behavior (Bandura, 1997), and found teachers' practices to be directly related to their perceptions and beliefs about science (Lederman, 2007).

Our findings pinpointed a number of perceived obstacles that the teachers were facing that affect the way they teach science which may go some way to explaining the aforementioned inconsistency. Identifying these professed challenges has important implications for school principals and heads of departments who might need to revise some of their policies and strategies to address the teachers' concerns. The majority of teachers reported that using English language impeded them from teaching effectively. However, in private schools in Abu Dhabi, there is a diverse student population and English is the only common language through which science curriculum could be delivered, changing the language of instruction is not an option. It might be useful to review studies on teaching science using a second language in multicultural classrooms in other contexts to explore solutions that were suggested and conduct an action research project to check their applicability and practicality. Moreover, schools should evaluate and assess their scheduling issues especially the time allocated for teaching science as this was perceived as a barrier. Another issue that emerged is the physical space and materials and this shows the importance of collaboration between corporate departments in schools and teachers as it is the teacher who knows exactly what resources and facilities are needed for proper delivery of the curriculum. In addition, teachers expressed their concern about the inadequacy of professional development activities that they are provided with. It is recommended that school administrators and heads of departments should consider providing teachers with both in-house and external professional development opportunities. Parental involvement was also highlighted as a challenge that the teachers perceive and this issue should be explored carefully by school administrators to open more parent-school communication channels. Schools should organize workshops to guide the parents on how to be involved with their children's curricular activities.

Teachers in this study ranked science least important (out of English, mathematics and science) which may affect the time devoted to science in class. Therefore, any time spent on science needs to be quality, 'best practice' teaching and learning. In order to develop the scientists of tomorrow, students must be interested in and engaged with science, and primary education has a huge impact on this. Therefore, administrators and policy-makers must support teachers in the best practice of science education.

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Lessons Learned and Strategies Used While Teaching Core-Curriculum Science Courses To English Language Learners At A Middle Eastern University.

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ABSTRACT

This article describes a reflection on teaching strategies used and lessons learned by two western, expatriate university professors teaching core-curriculum science courses at a middle eastern university, where the native language is Arabic and the language of instruction is English. Descriptions of effective strategies used and the benefits and limitations of each are provided. No rigorous quantitative data were collected on the efficacy of the interventions. However, the authors did note a marked increase in student engagement and active learning, critical thinking, student self-confidence, science self-efficacy and student performance over five semesters. As more of the pedagogical techniques were employed instructors noticed an improvement in instructor evaluation scores and an increase in positive student comments.

Keywords: Science Teaching Strategies; Arabic ELLs; Science Education; Mind Maps; Science Drawings.

INTRODUCTION

In Fall 2012 I was employed to teach core-curriculum science courses at a local university in the United Arab Emirates (UAE). In FALL 2013 my colleague joined the faculty in the same department. We had both previously taught at the same university and between us had over 30 years of science teaching experience.

In our home country the official language is English, although there is a dialect (called Patois), which is spoken by the majority of the population. Patois has a vocabulary that is largely English but differs enough in the phonology, morphology and syntax to be unintelligible to non-local English listeners (Craig, 1983). It is not uncommon to find students incorporating Patois in the Standard English used for academic writing and both my colleague and I were accustomed to making accommodations for this. However, in our new environment we were teaching native Arabic students.

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The Arabic language has a different phonology, grammar and writing system from English. For the first time we realized how much the expression and assessment of scientific knowledge depended on language literacy (Shea, Shanahan, Gomez-Zwiep, & Straits, 2012; Bradley & Bradley, 2004).

Students at our current university in the UAE are primarily local with a minority of students from other Arabic countries. The university has two campuses. The primary language of instruction is English and faculty members are drawn from over fifty different nationalities. In the Science section of the University College (this college is responsible for core curriculum courses) faculty in Abu Dhabi alone are from six different nationalities. This places students in the position of international students as described by Arkoudis (2006) and cited by Jewels and Albon (2012), though they are studying at a Federal Institution. Teaching English Language Learners (ELLs) is always challenging and this is also true for Western English-speaking faculty teaching in non-English speaking environments (Jewels & Albon, 2012). The situation becomes increasingly complicated when faculty are required to teach science to a majority of non-science majors. There is the added dimension of stimulating interest, increasing student engagement and encouraging students towards intrinsic motivation.

The major objectives of core-curriculum science courses are to encourage critical thinking, develop cognitive maturity and increase student awareness of global scientific issues, especially those related to the environment. Having previously been advanced level (A' Level) examiners, in a system similar to that of the British, we thought using conventional assessments and known teaching strategies such as anthropomorphism, story-telling and problem papers, would stimulate and encourage critical thinking among students. It soon became apparent this was not the case. The results of my first quiz, which I thought was quite simple, were disastrous. Students failed to pick up nuances of the language, cues in the questions and were totally thrown by stimuli. They therefore had no access to context clues geared to thought stimulation and information retrieval. Assessment results and general observations revealed low comprehension, lack of retention and transferability, rote learning, fatigue and frustration and reduced critical thinking. These observations became our inspiration to find pedagogical strategies to increase student comprehension and performance, while increasing student self-efficacy and critical thinking. We began to ask ourselves questions such as:

1. How are the different epistemic conventions of disciplines creating complications for our ELLs? Is this the reason for the observed lack of transferability of knowledge and skills taught in other courses?
2. How do differences in cultural values and expressions between students and instructors impact student comprehension?
3. In what ways do the situatedness of language and meanings impact student learning? For example students regularly used the phrase "too much" to mean "a lot".
4. What are the factors responsible for rote learning and ritual reproduction of material noticed in exams? Are these the result of prior educational experiences, lack of comprehension due to deficiencies in language competence or a combination of both?
5. To what extent do our current methods of assessment test literacy rather than critical thinking and knowledge comprehension?

6. What teaching and learning strategies best communicate and assess scientific knowledge in UAE classrooms?

In an effort to answer questions 4, 5 and 6, and minimize the effects of some of the factors outlined above we tried various pedagogical strategies, some of which have their roots in language teaching. The strategies outlined in this report were specifically tried based on the physical, social and cultural environment, the course objectives and English language competence of our students. With each semester, as we learned more about local culture and teaching Arabic ELLs, we acknowledged and accommodated the exigencies of teaching science in this environment.

METHODOLOGY

The study employed an action research methodology. Action research deals primarily with the understanding of practice, the improvement of the context of the practice and an improvement of the practice itself (Carr & Kemmis, 2004). The study took place over five semesters (32 classes of more than 800 male and female students) and involved two professors observing, trying methods, reflecting and sharing on their classroom practices; teaching science to non-science majors in an Arabic English language learning environment. The process was cyclical and involved the following steps:

1. Identification of the issues
2. Designing strategies as a plan of action
3. Gathering data through teacher observations, solicited and unsolicited feedback from students
4. Organizing the data by seeking patterns
5. Analyzing the data
6. Reflecting, sharing and discussing the results with each other
7. Drawing conclusions
8. Implementing feedback into designing new strategies

FINDINGS and DISCUSSION

The results and discussion are centred around each of five teaching strategies reported. The strategies include: student-generated concept sketches, mind mapping, group work, traditional literacy techniques and gamification and online student response systems. Each strategy is explained using definitions and examples of student work, where applicable. Comments are made on the usefulness of each technique to our classes, teaching core-curriculum science.

Each of the strategies used were grounded in a learning theory. Both sketches and mind maps are useful for main idea selection, organisation of material and meaning making. These characteristics help students with scaffolding, as new knowledge is anchored to prior knowledge. This has its roots in cognitive constructivist theories as purported by psychologists such as Piaget, Bruner (1960, as cited in Palinscar, 2005) and Ausubel, Novak & Hanesian (1978, as cited in Ausubel,1980). These theories emphasize the construction of knowledge through organization and social interaction, all of which are facilitated by these two methods. We were able to adapt our teaching, as we had readily available external representations of the cognitive models of students. This helped us in turn to influence the mental schema of students through corrective actions.

Group work, gamification and student response systems helped students to improve their existing mental schema through social constructivist opportunities. These techniques facilitate active and social avenues for learning, as students have more interactions with their peers. According to Woo and Reeves (2007), peer interactions promote conversation, discussion and negotiation of meaning. These activities augment the learning outcomes of our course, focussed on ELLs learning science.

The literacy strategies discussed in the paper are sentence frames, word lists, code-switching and modelling of activities. Some may argue that these techniques do not encourage deep learning. However, we believe these methods, mainly founded on behaviourism have their place inside our unique classrooms. There have been arguments to support the use of modelling, demonstration and reinforcement of activities close to the target response, in teaching factual content (Palinscar, 2007). We have found these methods very useful in teaching content matter to students who do not have the language abilities to communicate in writing what they are thinking, and who get lost in advance organisers meant to illuminate concepts.

Student-Generated Concept Sketches

A student-generated concept sketch is an annotated drawing that illustrates the basic concept being taught (Johnson & Reynolds, 2005). One of the first things noticed in our classrooms is that many students, especially females are comfortable and well able to express themselves through drawing/sketching. According to students the social and religious culture does not promote public displays of creative expression such as dancing and singing, so especially females, express themselves through art. We made use of this aspect of the culture by asking students to provide annotated representational drawings after interacting with prompting materials on content such as global warming, photochemical smog and ozone layer depletion. Figure 1 provides an example of a student-generated concept sketch.

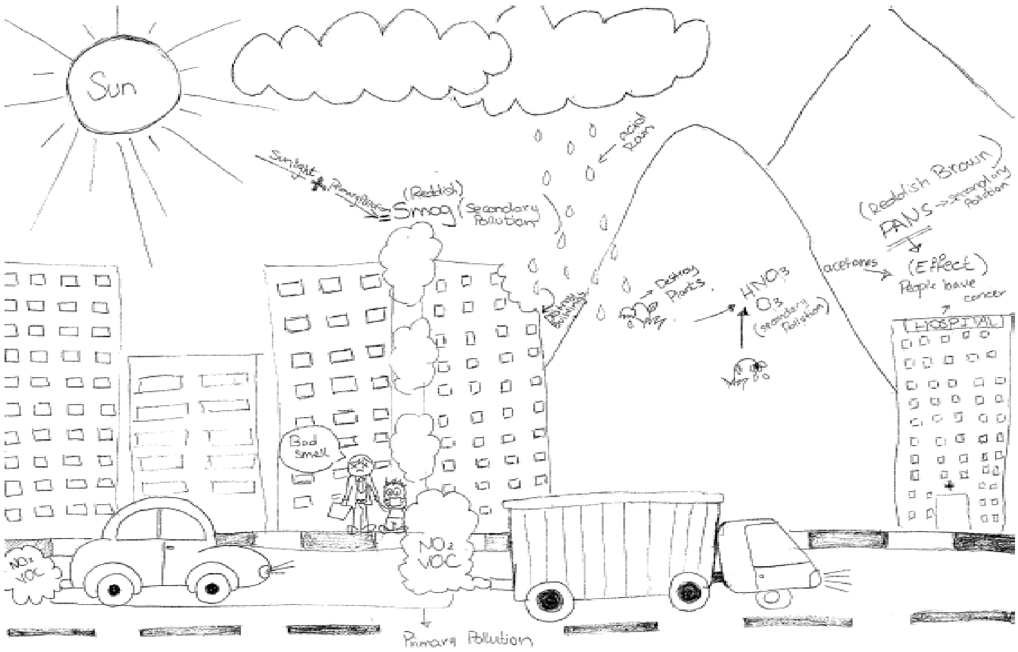

Figure 1: *Student Sketch on Photochemical Smog*

From the sketches it became immediately obvious the conceptions/misconceptions students had. For example, it was clear whether students could differentiate between the behaviour of tropospheric and stratospheric ozone, and carbon dioxide and chlorofluorocarbons as pollutants with different environmental effects. We were then able to correct misconceptions by giving students immediate oral or written feedback on their sketches. This made for excellent formative assessment and was easy for both students and instructors. In a study looking at feedback from Middle Eastern students studying in English, Jewels and Albon (2012) reported that students saw instructor feedback as essential to their achievement.

Students were also allowed to use sketches to represent their answers in summative assessments. Students expressed happiness that their answers were not lost in translation. According to Jewels and Albon, it is easy for faculty who teach ELLs to forget that they do not teach English they teach in English and so they frequently misinterpret students inability to express themselves in the language (linguistic intelligence) as students' misunderstanding of content (logical/mathematical intelligence) (Jewels & Albon, 2012; Prophet & Badede, 2009). These professors penalize students heavily for incorrect language use. Students who have been on the receiving end of this kind of misdirected grading tend to focus on expression rather than deep erudition, and frequently resort to plagiarism and rote learning to raise their scores. Although no rigorous scientific study was done on the effectiveness of the concept sketching technique in our classrooms the following benefits were noted:

- Increased contact between students and instructors
- Easy identification of student misconceptions
- Increased student engagement through active participation
- Increased student confidence in seizing opportunities to express their opinions
- Increased student self-efficacy towards previously difficult concepts
- Development of reciprocity and cooperation among students
- Prompt and painless feedback provided by instructors
- Extensive language use is not required, which frees the working memory of students for increased critical thinking
- Increased organization of knowledge by students

According to Chickering & Gamson (1987) and Kerns et al. (2005) the benefits listed above exemplify good teaching. Limitations of the method included not all students liking to draw and some science topics not readily lending themselves to representational sketches.

Mind Maps

Mind maps are visual tools used to organize information. Usually there is a single concept, around which ideas, images and words are added. Major ideas are directly connected to the central concept and supporting ideas branch out from major ideas. The major benefits of mind maps include the ease with which they are drawn, the freedom of creative expression (students may add colours and graphics as desired) and the ability to document associations between concepts (Davies, 2010; Eppler, 2006).

We thought mind maps would be particularly useful in our classes because of the artistic and creative abilities of our students and the limited language use required. Mind maps help to scaffold difficult academic vocabulary (Bradley & Bradley, 2004) and force students to organize information by making associations between concepts, which results in increased student engagement. ELLs regularly tune out in class unless something grabs their attention. The diversity among faculty means students are exposed to a multiplicity of English Language accents within a day. This is very difficult especially when we consider that even native English speakers have a hard time understanding each others' accents. Using mind maps during lessons helps to retain student focus. Mind maps help communicate ideas and relationships without the need to process too much semantic information. This is especially useful to ELLs, as it reduces the cognitive load of the learner. Figure 2 provides an example of a student-generated mind map illustrating air pollution effects.

Figure 2: *Student mind map showing Ozone Layer Depletion and Photochemical Smog*

Teaching, revising and encouraging students to take notes using mind maps have been very useful in teaching the science modules. There are several lessons within each unit. Teaching using a mind map to recap past lessons and introduce new ones enables students to see each lesson in perspective with the rest of the unit. Student-generated mind maps also help students to associate concepts within a lesson. The authors found mind maps especially useful where concepts were not easily represented using annotated sketches. It was also useful to add variety to the class as different topics were introduced. The main benefits to using mind maps in our classes were:

- Easy creation - using online tools, apps or pencil and paper
- Students gained practice in the organization of information
- Student misconceptions were easily identified
- Mind maps were generated by students using smartphones, tablets and laptops
- Students practiced writing key words and phrases
- Extensive language use was not required for expression but there was an avenue for scaffolding technical vocabulary
- The visual nature and flexibility in individual creative expression appealed to students

Group work

Group work was another technique we found extremely beneficial in the Middle East. According to Jewels and Albon (2012) there may be a need for specific pedagogies for Arab cultures. This idea is not farfetched as due to differences in social and physical environments specific strengths and weaknesses are highlighted among different ethnic groups. Increasingly educators are realizing that a “one size fits all” pedagogical approach is inadequate to fulfil the demands of diversity within the modern classroom. A number of social, cultural and environmental reasons precipitated our push to incorporate a collaborative approach in our classroom practices. These include:

- Student distraction - Some students who are distracted in the large lecture setting but became much more focused in small groups. Class sizes are relatively small (30±5), yet they are still too large for us to interact with each student on an individual basis, during a teaching session. It was therefore decided to work with groups of 2-4 students and this made things very manageable.
- Range of student abilities - Students are on a range of abilities, some with disabilities as well, group work gave them a chance to engage with material and get specialized attention.
- Complimentary student abilities - Students could be grouped to compliment each other’s abilities or grouped according to abilities that would facilitate academic development.
- Lack of student engagement - The element of competition among groups, even without external incentives, increased student engagement.
- Practical applications of theory - Group work facilitated practical applications of theoretical information given in the lecture.
- Culture – The Middle Eastern culture encourages teamwork and the group consensus or needs are favoured over individual success.
- Arabs have familial and social responsibilities, which are obligatory. Students are therefore not always able to find time outside of class to do homework. Group work in class took care of work that in other contexts would be done as homework.

Topping (2005) believes it was from such community collaborations as observed among Arabs that peer assisted learning (PAL) had its origins. The benefits of PAL, such as reciprocity among students, improved study habits, persistence on task and increased exam performance, have been extensively documented. Lee (2010) explained that in a peer assisted environment, where students are well motivated, the positive effect on their study achievements is clearly seen. A peer assisted learning environment results in improvements in both student performance and retention in a particular course (Tien, Roth, & Kammeier, 2002). We found similar results from our group work activities and there was an obvious increase in student science self-efficacy.

Working in small groups helped to create a relaxing environment for our students. It has been found that appropriately planned peer assisted learning activities, creates an informal learning environment where potentially intimidating factors are eliminated, such as very structured lessons from “fearsome” instructors (Huijser, Kimmins, & Evans, 2008). We believe that creating a comfortable, “safe” environment is paramount to learning, taking into consideration the stark differences in cultures and languages that exist between faculty and students. Research has shown that humans are emotional learners and deep erudition is accomplished when we are relaxed in a non-threatening learning environment. This is keenly emphasized in this environment as students regularly comment on the “kindness” of the instructor in student evaluations. This value is well appreciated by female pupils who withdraw when feeling threatened.

Sharif (2012) stated in his findings, that at the tertiary level ELL students benefitted most from working with peers. The students found such environments more comfortable and hence were able to practice using and understanding the foreign language, which better enabled them to understand subject content. Again, our findings concurred; we found that students, who may have been timid to ask for clarification in halting English, had no reservations with each other. They therefore got the opportunity to practice the English language, in a less intimidating, and what they may see, as a less embarrassing, setting. The planned group assignments further helped with students' understanding when those who understood a concept explained the material in the mother tongue to the one(s) that may have found it challenging.

Additional documented benefits from a peer assisted learning environment, which were also observed from our interventions, were increase levels of time allotted to specific task and practice (Jewels & Albon, 2012), coupled with a greater sense of accountability by the students involved (Topping, 2009). We have noticed increased student engagement, participation and understanding, increased self-confidence and more sustained student performance. Another noted benefit stemming from the group work in class is the formation and cementing of friendships outside of class, which has reduced the friction of group homework activities, especially those geared towards summative assessment. Student feedback has been positive and quite a few students have expressed their pleasant surprise that science classes are interesting and engaging.

Group work as a pedagogical strategy works especially well among male Emiratis. It is an aspect of the Middle Eastern culture that one does not refuse to assist another who has asked your help. Setting group work using worksheets has resulted in huge success in classes as students work to help each other in real camaraderie.

Literacy strategies

Teaching at a university where the language of instruction is English and the native tongue of students is Arabic brings home forcefully the need for instructional strategies in science and language to complement each other. As faculty in the General Studies section of the university we encounter students at the beginning of their university careers. Matriculation for entry requires a minimum International English Language Testing System (IELTS) score of 5.0. This means students are still developing their English language competence, which makes every teacher a language teacher. As science teachers in previously English speaking environments we did not realize the close overlap between the two disciplines. As McCullagh and Jarman (2009) state, it is a challenge to shift one's science pedagogical culture from viewing language as a marginal activity to one that places it at the core. However, as we quickly found out this was one of the great demands of our job. A thorough search of the literature showed that the majority of the work done in combining science and literacy is done at the primary and secondary levels. Yet, with many Gulf Cooperation Council (GCC) and other non-native English speaking countries opting to educate students in English at the tertiary level this is an issue of increasing importance (Ministry of Higher Education and Scientific Research, 2014; Prophet & Badede, 2009).

A comparison of Science with reading and writing skills shows a startling overlap (Sessoms, 2012). Many of the skills developed in literacy are also used in science. Facilitating language literacy competencies in the science classroom therefore results in huge benefits for the learner. Table 1 illustrates a comparison between science, reading and writing skills (Sessoms, 2012).

Table 1. *Comparison of science skills with reading and writing skills*

Science Skills	Reading Skills	Writing Skills
Observing	Note details	Descriptions and observations
Hypotheses	Predicting	
Inferences	Inferring	Problems and solutions
Comparing and contrasting, noting similarities and differences	Comparing and contrasting	Comparing and contrasting
Communicating	Communicating	Descriptions
Classifying	Sequencing	Organizing main ideas
Collecting and organizing data	Summarizing	Summaries
Interpretation of data and graphs	Recognizing main ideas	Analysis, persuade and convince
Linking cause and effect (independent and dependent variables)	Recognizing cause and effect	Cause and Effect
Drawing conclusions	Drawing conclusions	Summaries

The science skills in the table are all developed in the core curriculum science courses we teach. Recognizing this we began to seek language teaching pedagogies that could be applied to our classes. Borrowing from literacy, we have gained positive results using the following strategies inside the classroom.

Sentence Frames

Students sometimes find it difficult to find words to express ideas or show the relationship between ideas. The latter was one challenge faced by students when writing scientific hypotheses. The definition for a hypothesis is a testable statement. Challenges faced by students included knowing the difference between a question, an idea and a testable statement.

Sentence frames involve students filling in gaps in a pre-prepared sentence frame to produce a structure they find difficult to formulate on their own (Carr, Sexton, & Laguno, 2007). Signal words are used to cue students on how to frame their statement and clue in the instructor to what the student wishes to say. The "**IF** (independent variable), **THEN** (dependent variable)" format was used to help students to relate their independent and dependent variables in a hypothesis. For example, **IF** the temperature increases **THEN** the solubility of sugar in water increases. This strategy was particularly successful when students were taught how to identify the cause and effect, independent and dependent variables, and later use the If/then format to complete hypotheses.

Completing sentence frames gives students the chance to participate without the added pressure of thinking how to formulate a hypothesis or conjecture correctly as a statement. The task then becomes one of completion rather than generation, which is more attainable. This method has been very successful in science classes with less task-mature ELLs. Students show greater self-confidence in writing hypotheses.

Word Lists

A list of key terms is sometimes provided for students to aid with definitions at the beginning of teaching a concept. The definitions are explained and sometimes linked with kinesthetic actions to facilitate recall. For example the words *convergent*, *divergent* and *transform* are defined while moving the hands together, apart and moving past each other to reinforce understanding while teaching about the movement of tectonic plates. Repetition of the words and their definitions throughout the course also helped to buttress meanings. Root words and prefixes are used to illuminate meanings and form scaffolds for student memory. An example includes the prefix bio – *meaning life* and shows *a connection between life and living things*. This prefix turns up frequently in the environmental science course in words such as: **bio**me, **bio**diversity, **bio**tic, **bio**sphere, and **bio**mass. Relating each of these words with life and living things helps to form a latch for remembering the definitions. This is very necessary for ELLs, especially those with a mother tongue such as Arabic, which not only has different sounds, grammar and writing system, but has few connections to English to provide clues.

Code-Switching

While teaching specific concepts the authors tried to use some words from Arabic to facilitate understanding. When trying to explain the different levels of an independent variable, for example, the word *Kemmiya* (English spelling) was used to emphasize the importance of quantity/amount as the independent variable is changed. Other words used during instruction included: *Icktashif* – discovery and *Adilla* – evidence. Although there seems to be conflicting ideas on the use of code-switching in classes we have found this to be a powerful way of communicating some concepts. As mentioned previously code-switching was also allowed during group activity and seemed to enhance rather than detract from the lesson.

Modelling of activities

Receiving instructions in a foreign language can be daunting for language learners (Prophet & Badede, 2009). Sometimes students do not complete an assignment because they simply do not understand the instructions. Sometimes it is a matter of the language being difficult and sometimes the instructions are too long and complicated and increase learners' fatigue. Recognizing this, we tried to increase students' science self-efficacy by modelling activities. The results were particularly dramatic in an individual project where students had to complete a report on an experiment they had carried out based on a research question they conceived. The report had detailed requirements of research questions, conjecture, hypothesis, possible outcomes, data collection, representation and analysis and conclusions. Students were required to use APA format throughout the report.

The activity was modelled and students were taken through a mock report presentation. Though the reports covered a wide range of topics, using this model as a template, students felt empowered and many were able to write excellent reports on other topics, by following the outlined steps. Modelling of assignments makes instruction explicit and reduces learner anxiety. There were fewer incidences of students omitting whole sections of an assessment either by accident, lack of understanding or language deficiencies.

Gamification and the use of online student response systems.

Karl Kapp, in his book *The Gamification of Learning and Instruction: Game-based methods and strategies for training and education*, defines gamification as "…using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems" (Kapp, 2012).

The easy access and availability of mobile devices and Wi-Fi in the classroom and the expertise in electronic devices displayed among students makes gamification a good choice for Emirati pupils. All students have access to at least one mobile device at all times. In fact, one challenge faced by instructors is to have students use these devices only for educational purposes in class. The use of online student response systems such as Socrative and Kahoot! has been very successful in increasing student engagement and subsequent performance on summative assessments.

Socrative is an online student response system that allows instructors to monitor student progress through use of real time questioning, with instant result aggregation and visualization (Berte & West, 2014). Teachers can gauge the whole class' current level of understanding and provide instant feedback through this platform. Socrative comes with apps for both teachers and students and these may be stored across a variety of mobile devices for easy access. Each teacher is assigned a unique virtual classroom number. Teachers deploy their stored quizzes and students are allowed to enter the classroom and take the test as long as they have access to the number. Each quiz has a unique socrative number that can be shared among socrative teachers. The main features of Socrative used inside our classrooms include:

- Deployment of stored quizzes. During revison classes students are able to take socrative quizzes and get instant feedback. As teachers we are able to monitor student preparation. One feature we have found very useful is the ability to leave the "classroom" open so students gain access at all hours outside of class.
- Space Race. Socrative also has a gaming feature called the *space race*. This feature allows students, or groups of students to race against each other as they take the quiz. Each group is assigned a colour and students are able to monitor their progress relative to other groups based on the movement of the corresponding coloured rockets, if the teacher displays her screen on the board. Groups advance based on the number of correct answers to the quiz. This feature has resulted in increased student engagement during revision.

Kahoot! is a classroom response system which creates an engaging learning space, through game-based digital pedagogy (GetKahoot.com, 2014). It is similar to Socrative as it can be used across all mobile devises and allows teachers to store quizzes. It has additional gaming mechanics such as music, points and timer, but is more limited than Socrative in the length and variety of question types. Kahoot! is great during revision as it has the ability to peak student engagement and the whole class participates. It pulls out even the most introverted students as it increases the competitive edge. Both male and female Emirati students are highly competitive and are experts at video games. Kahoot! usually has students calling for more revision.

CONCLUSION

Research has documented reduced critical thinking, concept development and academic achievement in science among second language learners (Cassels & Johnstone, 1984; Johnstone & Selepeng, 2001; Prophet & Badede, 2009). According to Johnstone and Selepeng (2001), a reduction on average of 25% of the working space available for critical thinking has been observed among language learners. Many countries, including those in the Middle East, continue to offer content instruction in a foreign language, English. The issues are complex, as currently English is the primary language of trade and countries aim to prepare their graduates to be competitive in the marketplace. Despite the obstacles to learning content as ELLs, we have found that using a combination of the pedagogic strategies outlined, dramatic improvements in students' engagement occur. Having the students participate in these mostly active learning activities seemed extremely beneficial in improving their discussions, negotiation of meaning and ultimate motivation in wanting to study science. These benefits relating to group work have been well documented (Sharif 2012, Topping, 2009). Generally, these collaborative and cooperative activities were effective for supporting a range of desirable learning outcomes. These effects include improved academic achievement and other attitudinal outcomes such as enhanced interpersonal skills (Prince, 2004). Drawings and mind maps have also proven to be successful in main idea selection, organization and relating ideas (Davies, 2011, Johnson & Reynolds, 2005, Leopold & Leutner, 2012). Increases in student grades over previous semesters, which did not employ these strategies, were observed. We have also noted increased satisfaction among students, characterised by a decrease in the number of student letters at the end of the semester asking for work for extra credit. Increased positive comments and increasing student evaluation scores have also encouraged us. Students have expressed a liking for the course instructional methods and have articulated their desire to see more of this type of pedagogy in their other courses. Akin to this, other colleagues have consulted with us on the methods of our interventions, as mutual students have requested these in their classes.

We will therefore continue to incorporate these and other active learning strategies into our teaching. We do not see this project as complete, but on going, as we assimilate more of the culture, nature and environment of our students. Having observed the efficacy of these teaching methods we plan to do extensive qualitative and quantitative studies on individual strategies to establish their usefulness to other science instructors at the college level. These results will also inform the choice of reference materials and assessment of student performance used in our courses.

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