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Misconceptions of Primary and High School Students Related to the Biological Concept of Human Reproduction, Cell Life Cycle and Molecular Basis of Heredity

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ABSTRACT

The aim of this research was to determine the misconceptions of students related to the concept of human reproduction. The research was conducted in the period from 2008 to 2012 in 41 primary and 36 high schools in Croatia, with a total sample of 1931 students. The analysis of the students' answers shows the scope and permanency of misconceptions and problems in the process of understanding the concepts related to human reproduction. The misconceptions associated with mitosis and meiosis, as well as human reproduction itself are particularly emphasised. The results show that students do not understand the purpose of mitosis and meiosis, what sex cells are and what their purpose is. A major problem for all students of both genders is the concept of ovulation and the menstrual cycle in general. The results indicate that the approach to teaching certain concepts should be changed, and that teaching content should be more appropriately distributed and better adapted to the students' developmental levels and interests. Future research should be focused on a more detailed analysis of the identified misconceptions in all grades

Keywords: human reproduction, meiosis, menstrual cycle, misconceptions, ovulation.

INTRODUCTION

Students' misconceptions in science classes imply a lack of understanding of fundamental scientific concepts and facts (Mestre, 2001). Science misconceptions are very resistant to change, especially when the traditional lecturing method is used (Eisen and Stavy, 1992; Bahar, 2003; Cimer, 2007; Hakim et al., 2016). It has been observed that misconceptions acquired more recently could be eliminated easily, while those acquired at very early ages remain entrenched and impervious to change (Griffiths and Moon, 2000; Pace Marshall, 2006). Preconceptions could also pose strong barriers to understanding science, as they might also act as misconceptions (i.e., they might interfere with scientific concepts) and could be difficult to foresee and therefore to control (Fetherstonhaugh and Treagust, 1992; Evans and Winsløw, 2007). To be able to change this kind of situation, it is necessary to

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identify students' misconceptions prior to teaching and to identify those misconceptions that hinder learning (DiSessa, 2002; Chi, 2005).

The study of misconceptions was begun almost thirty years ago by Rosalind Driver (Driver, 1988; Driver and Easley, 1978) in a series of studies on students' understanding of key concepts in many scientific disciplines. Smith and Anderson (1984) pointed out that in teacher education programs, the attention of prospective teachers should be focused on the effects misconceptions might have on learning, and on developing ideas for introducing conceptual changes in the learning process. Hence, besides the necessary theoretical knowledge, teachers also need to develop profound observation skills to effectively meet the students' needs and interests (Smith and Anderson, 1984; Kurt et. al., 2013). Teachers should also be able to recognize common student misconceptions, develop skills to diagnose the misconceptions and adopt specific strategies for overcoming them, as well as to adapt curriculum materials to already identified student preconceptions. However, it is very difficult to explain the cognitive structures that emerge in an individual's minds after the process of learning (Kurt et. al., 2013).

The most often tested concepts in biology education research are associated with photosynthesis, genetics, evolution, and circulatory system. Within these conceptual frameworks, many misconceptions have been identified. A vast amount of published literature deals with misconceptions related to reproduction - one of the basic biological concept of living organisms - and its genetic-parental background and outcomes (e.g., Lewis et al., 2000; Emre and Bahsi, 2006; Akyurek and Afacan, 2012; Aydin and Balim, 2013). The most studied misconceptions about reproduction are related to cell division and many studies discuss the problems and misconceptions related to mitosis and meiosis (Robinson and Lewis, 2000; Tekkaya et al., 2000; Atilboz, 2004; Brown, 2010; Dikmen 2010). Furthermore, Oztas et al. (2003) point out that both teachers and students consider the concept of cell division difficult and problematic, while simultaneously being aware that it is crucial for understanding a number of other biological concepts, including reproduction as a whole.

The finding that pre-service biology teachers have an incomplete insight into the students' understanding of the concept of reproduction is highly important and needs to be addressed. Some studies suggest that there is a problem with the conceptual understanding of reproduction across all academic levels. Thus, teachers could transmit their cognitive insufficiencies to their students, which could further result in incorrect learning (Kurt et. al., 2013); at the same time, adolescents bring into the classroom a number of preconceptions and misconceptions related to the topic of human reproduction, which often rely on poor basics of human reproductive physiology (e.g. Donati et al. 2000; Sydsjö et al. 2006).

Aim

The intention of this research was to: 1) identify the misconceptions of primary and high school students (14-19-year-olds) related to the concept of human reproduction and 2) determine their permanency. The study methodology involved participants completing tests/questionnaires on human reproduction topics that match the participants' age/grade. The permanency of the misconceptions was assessed through the employment of retention questions, which could point to critical points in the teaching and acquisition of certain concepts. Based on the research objectives, the following assumptions have been derived: 1) if specific problems with understanding the concepts of human reproduction occur in all groups of students with respect to the overall students' performance expressed by the percentage of test results, we can probably speak of the existence of misconceptions and 2) if the same misconceptions occur among students of different age groups, we can talk about their permanency and insufficient acquisition, or about a wrongly taught concept.

METHODOLOGY

The research was conducted as part of the project Student Competences in Teaching Science and Biology (MSES, 119-0091361-1223) in the period from 2008 to 2012. Schools from different settings, from small rural to larger town schools all over Croatia were included in the project, with the participation of 1035 students (41 primary and 36 high schools). Two on-line systems for checking the acquisition of basic biological concepts among students were used: Ampyx (www.ampyx.org) and MoD Moodle modification (http://mod.srce.hr/), with the questions compiled by teachers. For the purpose of this paper, only questions related to the concept of reproduction were taken from the database and analysed. Students from the eighth-grade in Primary and the first, second, third and fourth grades in High school (Table 1) were tested at the beginning and end of the school year. They answered 18 questions matching the teaching material of the currently attended grade and 6 questions from the previous grade. Hence, some of the questions (retention questions) were answered by students of two grades (two generations).

Table 1. *Sample of student age groups by grade and age*

PRIMARY SCHOOL	8th grade	HIGH SCHOOL	1st grade	2nd grade	3rd grade	4th grade
Student's age	14-15	Student's age	15-16	16-17	17-18	18-19

Using the $\chi 2$ test for analysing a total of 108 questions in all tested grades, those with poorer results were selected. A histogram of the correlation of students' overall performance and the answers to individual questions is used to analyse the relationship and meaning of the selected answers in detail, where the correct answer is positioned first in the diagram. Assuming that the frequency of choosing the correct answer by classes of overall student performance shows no statistically significant differences between individual classes of students, we expected that deviations in some results would indicate the existence of eventual misconceptions. If any of the distractors appeared equally in all classes of students, we assumed that a misconception exists. Ten classes were defined on the basis of decile values (Table 2) and the percentage of the students' test results for each grade. The lowest percentage was established as class I and students with the highest percentage of success were classified in class X (Figure 1).

Table 2. *Classification of students into success classes in decili by the overall performance for individual age groups*

Grades decili	8th PS	1st HS	2nd HS	3rd HS	4th HS
	Test results performance (%)				
10	29.17	29.17	26.92	26.92	22.86
20	33.33	33.33	32.00	31.43	25.71
30	37.50	37.50	36.00	36.00	31.43
40	41.67	41.67	40.00	40.00	31.43
50	45.83	45.83	43.74	43.74	34.29
60	50.00	50.00	46.15	46.15	37.14
70	54.17	53.85	48.15	49.08	40.00
80	58.33	58.33	52.00	52.17	51.43
90	66.67	66.67	59.26	59.26	57.14

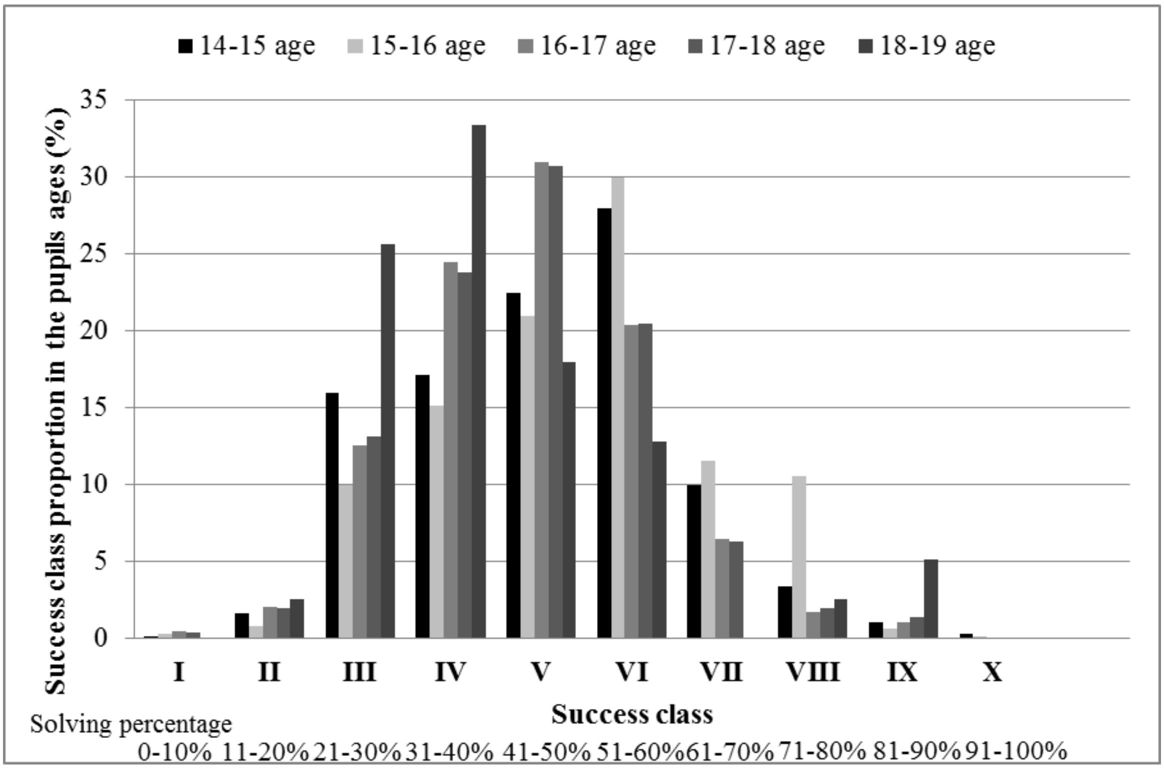

Figure 1. *Success classes based on solving percentage according to grades*

The 38 analysed questions related to the concept of reproduction from different fields are differently represented in this research; 7 matching questions were selected for the purpose of identification of misconceptions on the concept of human reproduction.

FINDINGS

The selected questions related to human reproduction are shown below according to the concepts they test (Table 3). The frequency analysis of the answers by overall performance showed statistically significant differences (χ^2 test, $P < 0.05$) between individual student results in 4 questions (V8T23, R8D12, V1D35, V1P27). In 3 cases (V8T22, R3D33, V4D34), the χ^2 test did not show significant differences in students' success, and the results indicated the existence of possible misconceptions (Table 3). Regarding the mean number of correct answers, there were no statistically significant differences between the differing age groups (χ^2 test, $0.09 < P < 0.90$) and genders (χ^2 test, $0.17 < P < 0.82$) (Table 3).

Table 3. *Selected questions for which students of different grades achieved weaker results and differences in the mean values for student age groups and gender according to the χ2 test*

	Question													
	V8T23		**R8D12**		**V8T22**		**V1D35**		**V1P27**		**R34D33**		**V4D34**	
N	285		393		259		214		217		161		101	
M	0.067		0.239		0.131		0.229		0.673		0.385		0.463	
SD	0.250		0.427		0.338		0.421		0.470		0.488		0.508	
χ^2	**41.095**		**17.531**		**8.142**		**34.389**		**28.970**		**5.965**		**8.261**	
p	*0.00*		*0.01*		*0.32*		*0.00*		*0.00*		*0.54*		*0.14*	
Gender	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**
N	142	143	176	217	125	134	83	131	88	129	67	94	44	57
M	0.06	0.07	0.26	0.22	0.12	0.14	0.28	0.20	0.66	0.68	0.40	0.37	0.61	0.38
SD	0.245	0.256	0.441	0.416	0.326	0.350	0.450	0.400	0.477	0.467	0.494	0.486	0.502	0.500

χ^2	**0.049**		**0.862**		**0.269**		**1.780**		**0.127**		**0.155**		**1.889**	
p	*0.82*		*0.35*		*0.60*		*0.18*		*0.72*		*0.69*		*0.17*	
Grade	**8. P**	**1. H**	**8. P**	**1. H**	**8. P**	**1. H**	**1. H**	**2. H**	**1. H**	**2. H**	**3. H**	**4. H**	**3. H**	**4. H**
N	149	136	88	169	103	156	59	155	50	167	45	116	67	34
M	0.05	0.09	0.26	0.19	0.17	0.10	0.19	0.25	0.68	0.67	0.36	0.40	0.36	0.50
SD	0.212	0.285	0.442	0.393	0.382	0.304	0.393	0.432	0.471	0.471	0.484	0.491	0.483	0.508
χ^2	**1,945**		**4.236**		**2.835**		**0.835**		**0.015**		**0.230**		**0.472**	
p	*0.16*		*0.12*		*0.09*		*0.36*		*0.90*		*0.63*		*0,49*	

N – number of students, M- average acquisition values, SD - standard deviation, P - primary school, H - high school, f – female, m - male

A low performance of only 4.70% was achieved by eighth-graders for question **V8T23,** and it was marked as a difficult question */Meiosis is a division that produces sex cells in sexual glands. Sex cells are formed from the initial cell with double the number of chromosomes. At the end of meiosis, four sperm cells and one egg cell are produced. How many DNA molecules will all the chromosomes in human cells have (2n = 46) before the initial cell division in the ovary (testicle*)?/ Equally weak results were also recorded for the first-grade high school students (8.82%), despite the positive selective enrollment in high schools and the repetition of curriculum topics. The analysis of the chosen answers shows that the number of correct answers is extremely low and occurs in the best and worst classes of students. The highest percentage of correct students' answers (1.8%) was recorded in class II. In general, all classes had a very high percentage of students who didn't answer the question - the exception was the class of highly successful students (Figure 1).

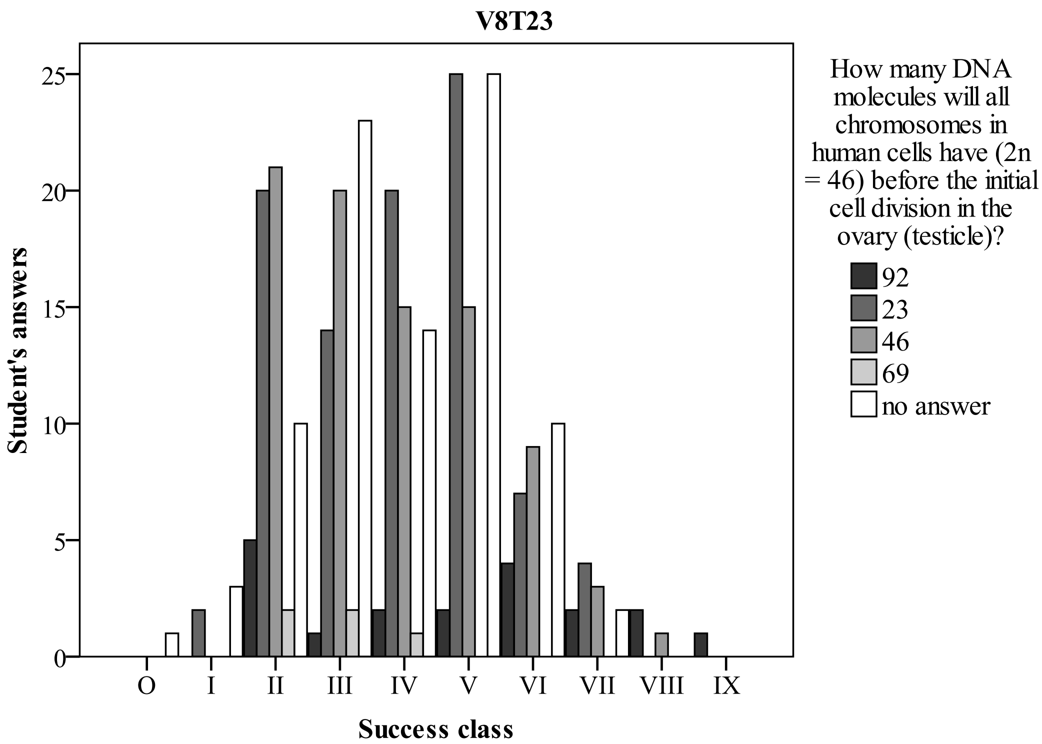

Figure 2. *Students' answers among differing success classes for question V8T23*

Question **R81D12** */Mark the correct statements about meiosis: a) Meiosis is a necessary precondition for the development of all living beings. b) Meiosis is essential for the growth and development of organisms. c) Meiosis allows sexual reproduction. d) Meiosis occurs in the sexual glands./* was correctly answered by 23.92% of students. Analysis of the chosen answers showed that the right answer did not prevail in any class of eighth-graders, but in all cases the significantly represented distractors were – *Meiosis is a necessary precondition for the development of all living beings* (36% of students) and *Meiosis is essential for growth and development of organisms* (16% of students). It is surprising that the first-grade high school students achieved better results by only 9.9% (Figure 2), although the current first-grade high school curriculum prescribes learning about DNA and the cell life cycle.

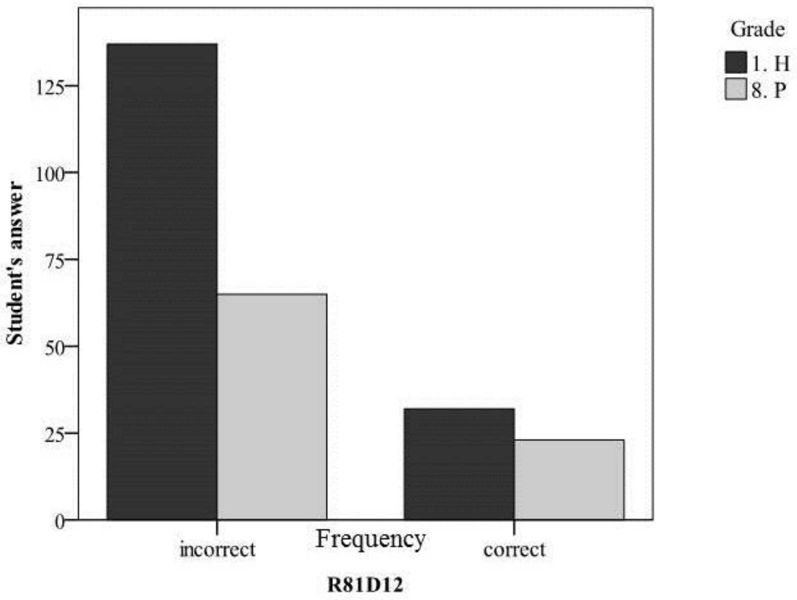

Figure 3. *Students' answers between the primary- (P) and high- (H) school grades for question R81D12*

Several questions about the *concept of human reproduction* from the curricula of different grades point to problems with understanding the concept of the menstrual cycle. Thus, the average result obtained for the more difficult question **V8T22** from the eighth-grade curriculum is 15.03% /*A woman whose menstrual cycle lasts 21 days had sex without using contraception on the 12th day of the cycle. Assess the chances that fertilization occurred: a) very small because it has been five days since the ovulation b) high, because sexual intercourse took place only a day after ovulation, c) not particularly great, because the sexual intercourse did not occur on the day of ovulation, but on the next day, d) small, because ovulation occurs only on the 14th day of the cycle*/. It has been noticed that older age groups achieved weaker results for this question (8.P = 52.9%, 1.H = 47.1%), although not statistically significant (Table 3). The analysis of the chosen answers showed that two distractors prevailed: *b) great, because sexual intercourse took place only a day after ovulation*, and *d) small, because ovulation occurs only on the 14th day of the cycle* (Figure 3).

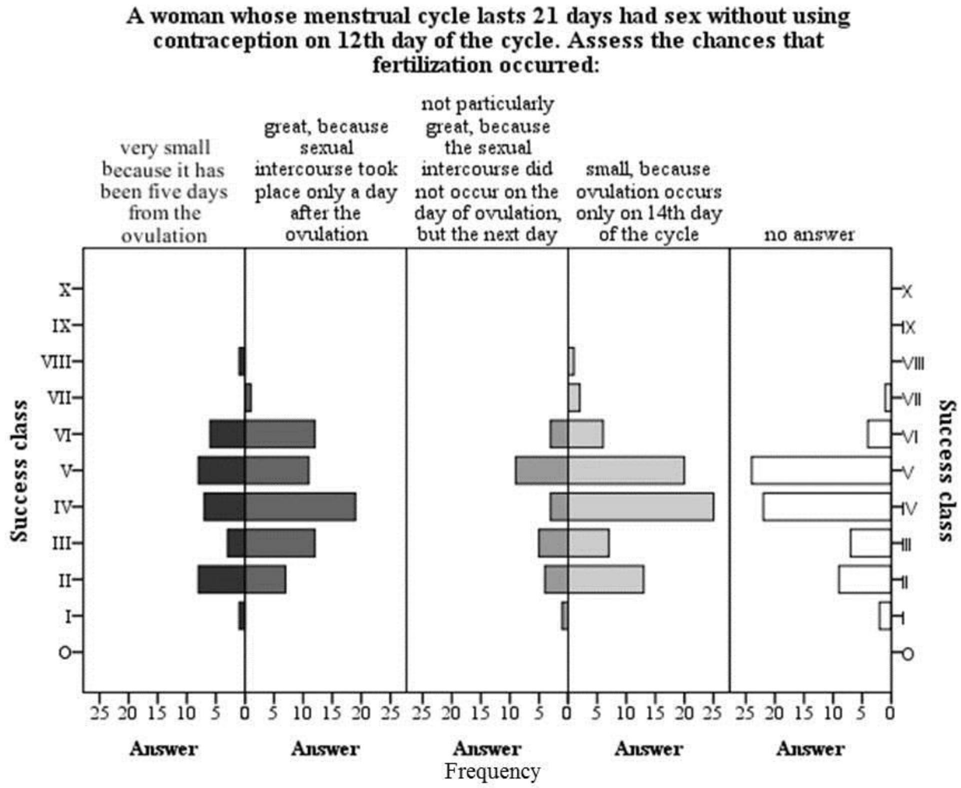

Figure 4. *Relationship between the answered questions and the success classes for question V8T22*

It turned out that students think ovulation always occurs on 14th day of the cycle or that it always occurs in the middle of the cycle regardless of its duration. From the frequency of the selected answers, and the statistically insignificant differences between the students' answers (Table 3), it can be concluded that these are very common misconceptions, but further research is needed due to the large number of students (26.1%) who did not answer the question at all. The analysis of the results revealed an equal distribution of answers in respondents of both genders (Figure 4), and the χ^2 test indicated that there was no statistically significant difference between the answers of male and female students (only 1.5% girls answered better). This result indicates the existence of identical problems and misconceptions as were observed for ovulation among students of both genders.

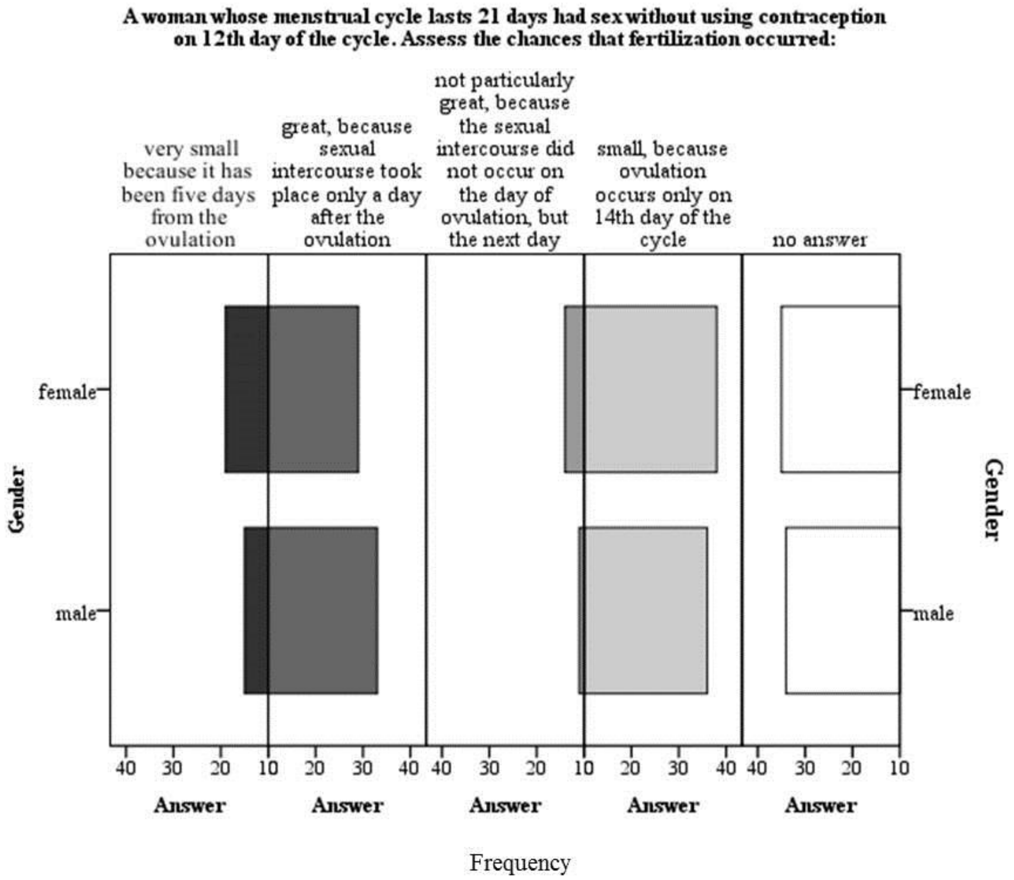

Figure 5. *Answers of female and male students to question V8T22*

Question **V1T35** */Which process does the figure show: a) oogenesis leading to the production of 1 egg cell, b) spermatogenesis leading to the production of 1 sperm, c) spermatogenesis leading to the production of 4 sperm cells, d) oogenesis leading to the production of 4 egg cells/* was correctly answered by only 22.17% of students. The analysis of the chosen answers showed that only students belonging to class X generally choose the correct answer, while all the others chose one of the distractors (Figure 5). Most students chose the distractor *oogenesis, four egg cells are produced* (40%) and the distractor *spermatogenesis, four seminal cells are produced* (32%). This result shows that students acquired a very poor basic knowledge of sex cell generation, although this topic is taught in the first high school grade.

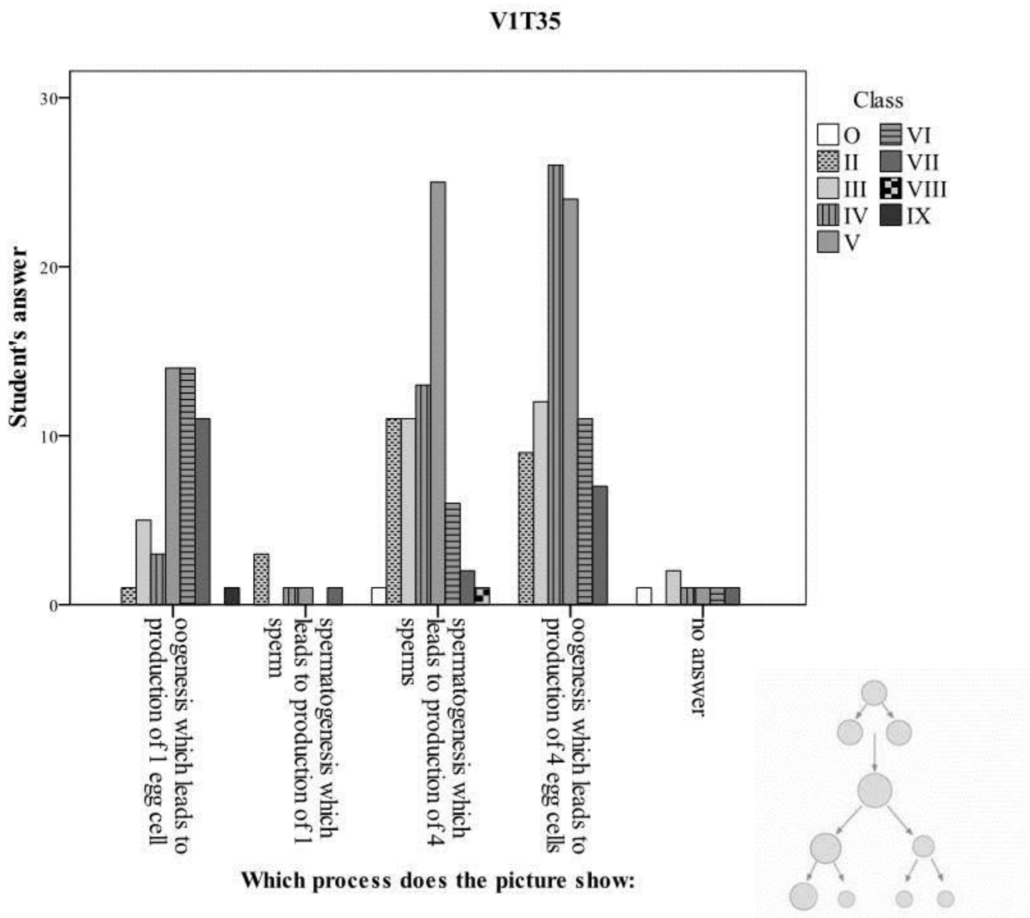

Figure 6. *Students' answers among the success classes for question V8T23*

The question **V1P27** for the first high school grade was selected */Without meiosis there would not be any: a) sex cells, b) reproduction, c) cloning, d) sexual dimorphism/* which was correctly answered by 67.3% of students. The equable result (1.H = 68%, 2.H = 67.1%) was achieved by students in both tested grades (Table 3). The analysis of the answers (Figure 6) showed a large number of correct answers (67.3%), but they decreased in proportion from the best class students (88.3%) to the weaker students (33.3%).

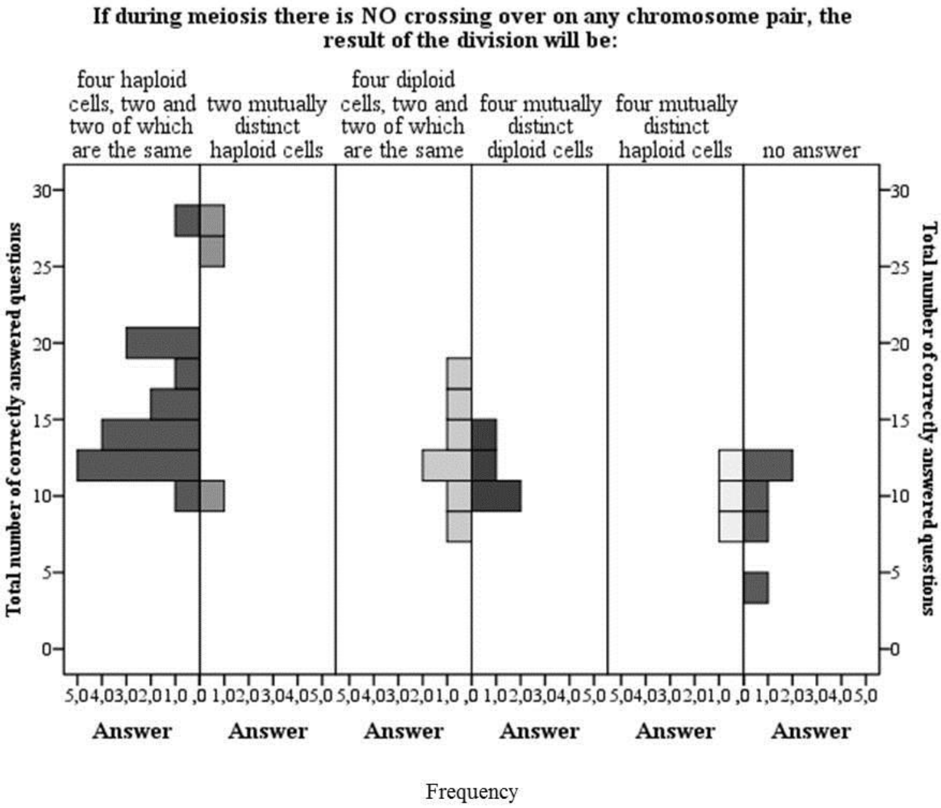

Figure 7. *Relationship between the answered questions and the success classes for question V1P27*

For question **R34D33** /*A young woman, whose menstrual cycle is regular and lasts for 33 days, got her regular period on 5 April. When is she most likely to be ovulating?/,* an average of 37.3% of third and fourth-grade high school students correctly specified the date of ovulation. The frequency analysis of the selected answers showed the largest number of correct answers in the success classes V and VI, and an equal number of wrong answers in classes I and VIII (Figure 7). The distractor *-22 April* was chosen by students of all classes, a total of 33%, and the distractor *-19 April* was most frequently chosen by students from class I, a total of 27%. This result confirms the existence of misconceptions about how to determine the date of ovulation, as already established in the previous question for eighth-grade students.

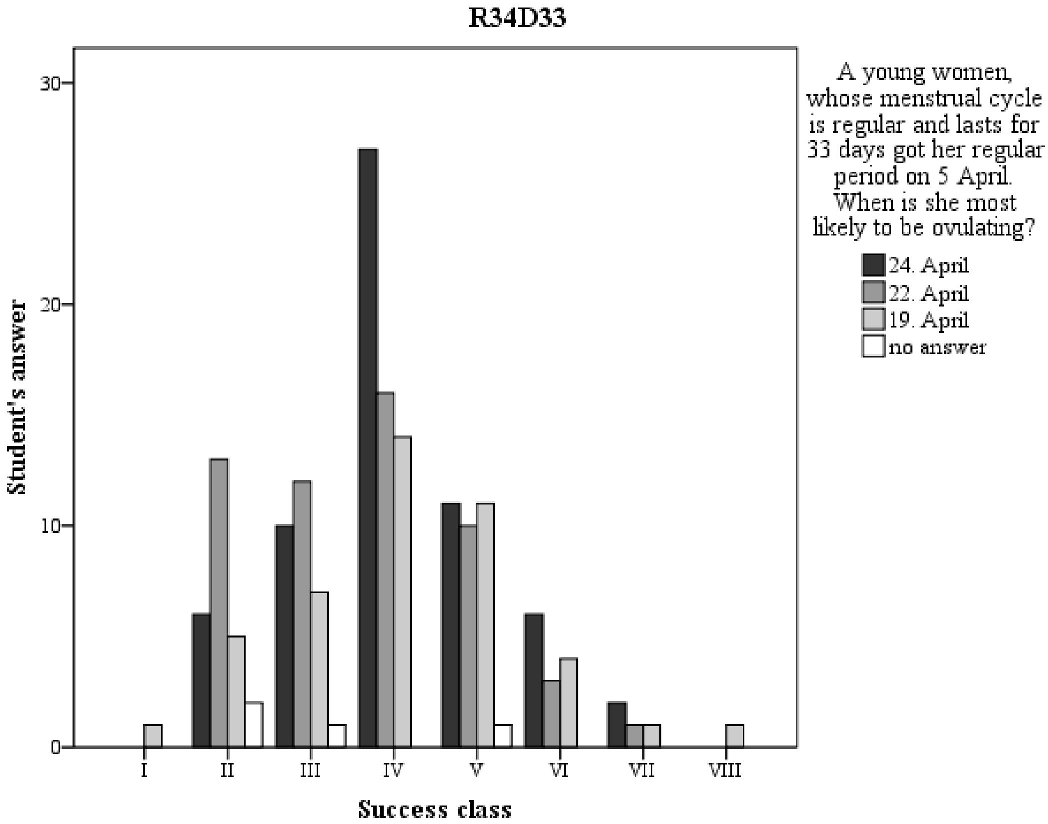

Figure 8. *Relationship between the answered questions and success classes for question R34D33*

A large number of students think that ovulation always occurs on the 14th day of the cycle or that it always occurs in the middle of the cycle, regardless of its duration. Similar to the previous question, the difference in the selection of answers by gender barely exists (Table 3). The overall performance is modest (39%), showing a slight upward trend in the older age group (Figure 8). The question is undoubtedly of vital importance and applicable in life, and therefore it is worrying that 26-28% of high school seniors think that ovulation occurs on 14th day from the beginning of the cycle. From the frequency of the selected answers, and the statistically insignificant differences between individual classes of students (Table 3), it can be concluded that these are very commonly expressed misconceptions in the population of students with less than 40% of total answer success. It means that more than a quarter of respondents have a misconception that could cause an unwanted pregnancy. Other respondents were divided almost equally between the correct answer and the distractor, which gives the middle date (*April 22*). Due to the structure of the question, it is not completely clear whether those who chose *22 April* just guessed, hoping that the correct answer was somewhere in the middle, or made a mistake in calculation. A mistake in the calculation was possible, given that the test was taken in a computer lab without a pen and paper, so many students counted by heart. This is an example of a well-conceived question that really tests the application of knowledge, but only limited conclusions can be drawn from its results: we know that a quarter of respondents have no expected knowledge and more than a third of respondents do. For a one third of the respondents, we can only say that they did not answer correctly and it is not known whether this is a result of ignorance or a calculation error.

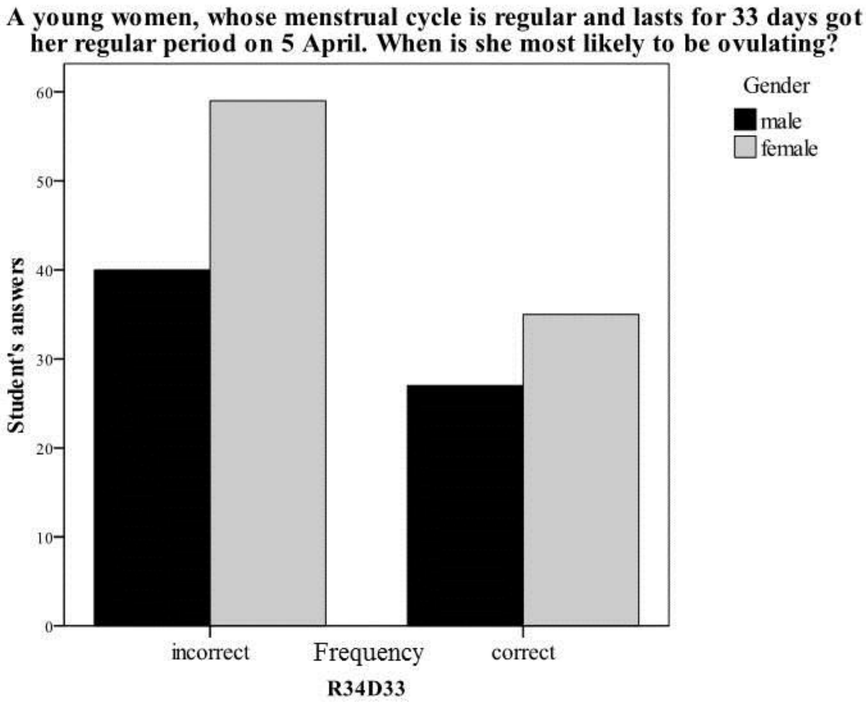

Figure 9. *Answers of third and fourth high school grade students to question R34D33*

The frequency of the selected answers in question V4D34 /*If during meiosis there is NO crossing over on any chromosome pair, the result of the division will be: a) four haploid cells, two and two of which are the same; b) two mutually distinct haploid cells; c) four diploid cells, two and two of which are the same; d) four mutually distinct diploid cells; e) four mutually distinct haploid cells/* showed that students chose correct and incorrect answers equally. Correct answers were recorded in all the success classes (Figure 9), while the highest percentage of incorrect answers (41.2%) was recorded in the first four success classes. While there were no significant differences between the students' answers (Table 3), it could be concluded that there are very commonly expressed misconceptions regarding haploid and diploid concepts during meiosis because 17.9% of students answered *four diploid cells, two and two of which are the same* (Figure 9) and 12.8% of students did not answer the question.

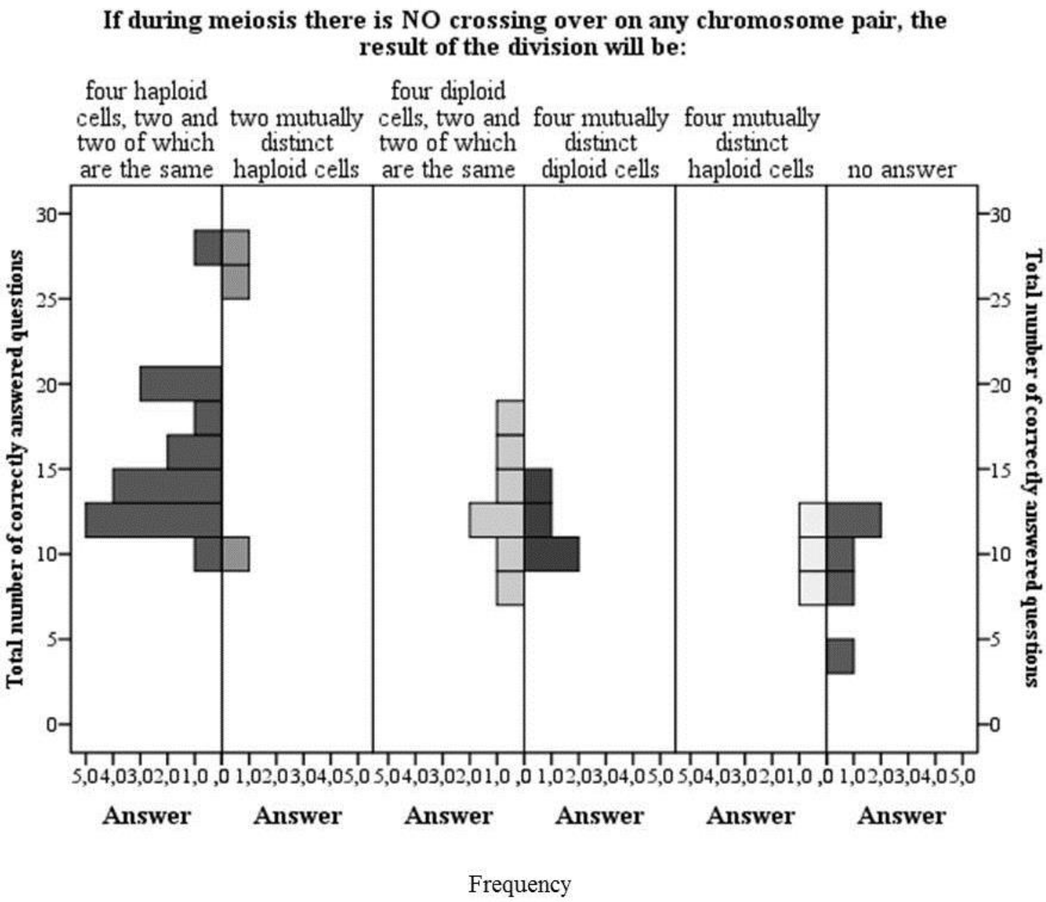

Figure 10. *Relationship between the total number of correctly answered questions and students' answer to question V4D34*

DISCUSSION

The present study supports the notion that primary and high school students have problems with the concept of cell division, especially understanding meiosis. As 36% of all students hold the opinion that meiosis *is essential for the creation of all living beings*, i.e. – *is essential for the growth and development of organisms*, it becomes clear that there is a problem in the conceptual understanding of crucial cell division events, although mitosis and meiosis are included in the curriculum for 14-year-old students. It turns out that some students have not acquired the concept of asexual reproduction, which does not imply meiosis, and other students obviously do not distinguish between mitosis and meiosis and their roles. Regarding the high prevalence of these distractors in all classes of students, we can talk about misunderstandings. It seems that the presentation of cell division in too much detail, as well as traditional teaching approaches, result in an overall misunderstanding of cell division processes.

Brown (2010) evidenced that the main learning problem among students of different ages in different countries is the lack of understanding of the meiosis aspects and their relationship to Mendelian genetics. Other biology education researchers have also described a number of problems with the understanding of meiotic division, especially processes related to chromosome number reduction (Robinson and Lewis, 2000; Tekkaya, 2002; Dikmenli 2010; Akyurek & Afacan, 2012; Aydin & Balim, 2013) and/or the role of nucleic acid (Flores et al., 2003). It has also been found that these misconceptions are remarkably resistant to change (Chi, 2005; Atilboz, 2004), though the research by Tekkaya (2002) showed (using the example of mitosis as well) that the best results in conceptual understanding and overcoming cell division misconceptions are achieved by a constructivist approach within teaching.

One of the basic concepts of living organisms is reproduction. The existing literature has identified various conceptions and misconceptions about: chromosomes, genes, meiotic and mitotic division, mutation, modification, DNA (Robinson & Lewis, 2000; Topçu & Şahin-Pekmez, 2009; Akyurek & Afacan, 2012; Aydin & Balim, 2013), genetic material and the connections between chromosomes, relationships between the behaviours of chromosomes during cell division (Lewis et al., 2000; Emre & Bahsi, 2006), diploid-haploid cells, the number of cells that emerge as a result of meiotic and mitotic division (Atilboz, 2004), distinctions among alleles, homologous chromosomes, replicated chromosomes, chromosome number and DNA (Tekkaya et al., 2000; Topçu & Şahin-Pekmez, 2009).

The analysis of the answers regarding the number of DNA molecules prior to initial cellular division in the ovary/testicles shows that the majority of 14- and 15-year old students have not successfully grasped the concept of the relationship between the DNA molecule and chromosomes. Some authors have demonstrated the existence of a misconception regarding the number of chromosomes in sex vs. body cells and a lack of understanding of the fact that different types of cells in the human body contain the same genes (Lewis et al., 2000; Robinson & Lewis, 2000; Topçu & Şahin-Pekmez, 2009; Aydin & Balim, 2013). A question related to this concept was used in Croatian national tests for 14-year-old students. The results showed that only 32.6% of the students gave the correct answers, and according to the choice of distractors, 26% of the students even showed a complete failure in understanding the concept (Radanović et al., 2011).

The analysis of the answers chosen by 18-year-old students (*If during meiosis crossing over **does not** happen on any chromosome pair, the result of the division will be…*) confirms that there is a significant proportion of students who fully or partially do not understand the process and result of *meiosis*. Many other authors evidence the same mitosis and meiosis conceptual understanding problems (Flores et al., 2003; Tamir and Zohar, 1993, Anderson et al., 2002; Hadjichambis et al., 2015). As the understanding of mitosis and meiosis is the foundation for understanding the processes and forms of reproduction, especially the genetics taught in the fourth high school grade, more attention should be paid to teaching these topics in the future. For more quality changes, further interventions in curricular planning, and the preparation and training of teachers would be needed. More attention should be given to problems concerning the basic mitosis and meiosis features and concepts, as the students might mix up the terms, especially after a time lag in learning. They are not sufficiently familiar with the root words used for the description of these cell divisions so they might have trouble permanently linking certain terms to the relevant meaning. If the terms are not continuously used and applied, they are subject to forgetting. Therefore, in teaching and student assessment, more attention should be paid to the descriptive determination of each division - especially when checking the retention of knowledge. Regarding the confusing mitosis and meiosis terminology issues, Akyurek and Afacan (2012) have found that eighth-grade students have developed alternative conceptions regarding the concepts of “chromosome”, “gene”, “meiotic division”, “mitotic division” and “DNA”. Robinson and Lewis (2000) carried out a similar study with 16-year-old students and found that they had an imperfect knowledge of “genes”, “chromosomes” and “cells”. We suggest that at the primary and secondary school level, memorising names should not be the real learning objective. Furthermore, if the curricular orientation inclines towards higher levels of cognitive skills and if the application of knowledge is highlighted, then curriculum success should not be measured on the basis of distinguishing names.

With regard to the concept of *Forms of reproduction,* the analysis of the answers to the question *Without meiosis there would not be* ... shows that almost a quarter of 15- and 16-

year-old students in all success classes show a complete misunderstanding of the role of meiosis in humans. This result could be compared to a very similar question for 14-year-old students, in which the misconception of meiosis as a *division that is necessary for the development of all living beings* was found. Besides the lack of conceptual understanding of meiosis, such answers also indicate the lack of differentiation between sexual and asexual reproduction in 14-16-year-olds. It seems that the perception of meiosis is still too demanding for 14-year-old students. The comparison of the results of all questions related to the concept of meiosis points to a very bad and worrying outcome of the overall teaching process. The situation is slightly better with 18-year-olds, although more than 40% of these students still have not acquired this concept. Other studies have evidenced similar results and the same misconceptions as the present study (Dikmenli 2010; Akyurek & Afacan, 2012; Aydin & Balim, 2013). It has been proven that these misconceptions are often resistant to elimination through conventional teaching strategies (Bahar, 2003). However, they could be corrected through the usage of inquiry-based learning techniques, as evidenced in the study of Hadjichambis et al. (2015), who conducted comprehensive research on over 6000 students. It is evident that problems with the concept of meiosis have been noted on a global level. Also, more comprehensive studies should be done along with teaching efforts to effectively resolve the problems with the students' acquisition of human reproduction topics and concepts.

Further in our analyses, it turned out that almost 80% of 15-year-old students have not acquired the concept of creating gametes and do not distinguish between *oogenesis* and *spermatogenesis.* The question taken from the curriculum taught to 14-year-old students reveals a very poor understanding of the concept of *ovulation* and the *menstrual cycle*. According to the analysis of the chosen distractors, the existence of two misconceptions can be noted. One is that *ovulation always occurs in the middle of the cycle*, and the other is that *ovulation always occurs on the fourteenth day of the cycle*. Thereby, the most frequent student misconceptions were used to create distractors (following the teachers' experience). Additional analysis of the selected answers by gender shows no significant differences in the choice of answers, indicating that established misconceptions exist equally in respondents of both genders. The same was observed for 17- and 18-year old students, and it further coincided with the research done by Yip (1998) that included 17-year-old students. Yip (1998) found that less than half of the candidates correctly identified the likely period of conception. A large number of students (40.5 %) thought that conception would most likely occur when the uterine lining was at its thickest. The poor performance on this issue indicated that many students do not understand the significance of the menstrual cycle in the reproductive process, although this is required in the Certificate level syllabus. The lack of understanding may be due to a variety of reasons, such as the tendency of students to learn by rote, or the use of ineffective teaching strategies (Yip, 1998). It is also interesting to compare these results with research on the knowledge of reproductive physiology and anatomy among adolescents in Sweden. Sydsjö et al. (2006) demonstrated that the level of knowledge tended to be higher in older age groups, and among the female population who responded correctly in 63.4% of cases vs. 21.4% of males. In our case, the proportion of answers shows no difference between males and females. However, a more thorough knowledge was expected for girls, as they often show significantly greater interest in the functionality of contraception than their male peer colleagues (Garašić, 2012). Although we expected some difference in the answers between boys and girls, it was not observed at all, so our results could be generalised and interpreted irrespective of gender. This could be emphasized as an important finding of our study. The analysed series of overall questions reveals that a large number of tested students aged 14-18 have problems with understanding content related to *human reproduction*, which is especially worrying because this knowledge is important for their daily life. It demonstrates that the facts and concepts considered basic knowledge among professionals in a subject are not broadly familiar and clear to the public in general. Our findings correlate with Hadjichambis et al. (2015), who stated that despite the importance of understanding how the human reproductive system works, adolescents worldwide exhibit weak conceptual understanding, which leads to serious risks, such as unwanted pregnancies.

CONCLUSION and IMPLICATIONS

The analysis of the students' answers to questions regarding the concept of *human reproduction* shows a large number of problems and misconceptions, and their retention among students of all ages. The results show that students do not understand the purpose of sex cells, mitosis and meiosis. Another major problem is observed in the misunderstanding of the ovulation and menstrual cycle shown by primary and high school students of both genders. Future research should be focused on the identified misconceptions, which should be analysed in more detail for all age groups and compared with the representation of related concepts in the curriculum. It would also be beneficial to identify an effective style of teaching for such complex concepts. Also, the increased use of active learning should be implemented, as it was suggested that this offers a significant contribution to conceptual understanding that might correct already acquired misconceptions. It is also important to examine the linguistic values of the terms for students and to determine how much students really understand the words and language structures that teachers use to explain the concepts.

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Correlating Beliefs and Classroom Practices of Public School Science Teachers in Abu Dhabi, U.A.E.

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ABSTRACT

The education system in Abu Dhabi, the capital city of the United Arab Emirates, has undergone radical changes over the past seven years. A major emphasis of these reforms has been to increase the degree to which students can self-motivate, inquire and carry out work independently. Nowhere is this more critical than in the subject of science, which has been historically taught in the U.A.E. as a didactic subject. The vision of Abu Dhabi's Educational Council (ADEC) is for science to be taught very differently with a focus on inquiry based learning, exploratory approaches and a facilitation of student autonomy to do this. Research on the relationship between teachers' belief systems and their classroom practices often (though not always) shows a positive correlation between the two. We explored whether this relationship was true for science teachers working within the challenging reforming education system in Abu Dhabi. We employed a survey questionnaire which asked teachers to rate belief statements about science learning and about their reported classroom practice. 248 teachers responded, the vast majority of whom reported beliefs in science which are well aligned with accepted 'best practice' including the need for students to learn independently and using inquiry based approaches to learning. However, only a weak statistical correlation was found to exist between their beliefs and science classroom practices, due to constraints such as a lack of resources and lack of trained science lab assistants which they report as rendering them unable to practice their ideals about science teaching and learning. This research is significant for the scientific education community, particularly as it adds to the body of research describing teacher behavior amidst educational reforms.

Keywords: Beliefs, Emirati, Science teachers, Teaching practices

INTRODUCTION

Educational Reform in the United Arab Emirates

In response to calls to modernize the education system in the U.A.E, the emirate of Abu Dhabi began testing out a variety of policies and practices in its governments schools. In 2006, many schools were assigned to educational advisory consultancy companies whose remit was to provide subject and pedagogical advice, and coaching and mentoring of local staff in order to raise the quality of the teaching to international standards. This was no easy task by all accounts at the time; various authors reported teacher-centred learning

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environments with little or no opportunities for students to apply what they had learned in a hands-on fashion (e.g. Dickson, Kadbey and McMinn, 2015). Whilst there were varying degrees of success in these projects, it was felt by some that a lack of a coherent strategy and inconsistency among companies, along with a lack of consultation by the advisory companies of the schools in some cases, hampered progress (e.g. Crabtree, 2010, Thorne, 2010). By 2009/2010 the consultancy companies mostly ended their tenures, and although in-service advising still took place, it was in a much less frequent and intensive form with advisors mostly coming from Abu Dhabi Educational Council (ADEC) itself. 2010 also heralded the first waves of major recruitment of primary school teachers from overseas, who would, in theory, bring years of experience and training from developed countries with established educational systems and implement these international practices into classrooms in Abu Dhabi.

The educational reform in Abu Dhabi has involved major financial and human resource investment, yet there has been little research to date of the effectiveness of science classroom practice in the midst of the reforms. This paper will explore the relationship between what these teachers actually believe about ideal ways in which students learn science, and how they themselves practice science teaching in the classroom. We then attempt to explore whether or not the practices of the teachers live up to the vision which ADEC has well-articulated in its New School Model documentation, i.e.: "the nature of learning opportunities is meaningful and encourages active involvement. This is evident when the teacher establishes: a meaningful context for learning, a balance of focused teaching, demonstration, discussion and practice, [and] children are encouraged to explore their learning actively through creativity and problem solving" (ADEC New School Model Cycle 1 Teacher Guide, 2013, p. 8).

Science Teaching within ADEC's New School Model

In science, the New School Model (NSM) emphasises inquiry based learning. Learning through inquiry holds a variety of different understandings for different teachers. For example, some consider the concept to be about the teacher posing challenging questions for students to answer, others think of it as a 'question-centred' conception where students develop their own questions, whilst others yet think of it as being experience-centred, with sensory experience playing a large role in the inquiry (Ireland, Watters, Brownlee & Lupton, 2012). ADEC defines inquiry based learning in the classroom broadly as when students are "working together, constructing meaning through collaboration with others, engaging in critical thinking and problem solving, reaching conclusions with regard to the 'rich' question from their research, presenting their conclusions and using the knowledge and understanding they have gained, developing their understanding of the process skills of acquiring knowledge" (ADEC New School Model Teacher Guide, 2013, p. 21). Key to these descriptions is the fundamental philosophy wherein the classroom teacher acts as a facilitator and supports students to reach their own conclusions, allowing students to become more self-directed, responsible and increasingly independent thinkers. These concepts, and ADEC's definition of inquiry in science as above, form the theoretical framework from which we derived our research tool, described subsequently.

The Links between Teachers' Beliefs and Practices, and Factors affecting Practice: Literature Review

We will now give some consideration to why an understanding of teachers' beliefs is so critical when examining the efficacy of classroom practice. This is examined through the lens of ADEC's New School Model, and in view of the context which is the developing education system being rolled out at full speed, coupled with the variety of experiences of the expatriate teachers joining the classrooms in Abu Dhabi. We must consider if, in theory, beliefs actually affect ones' practice in order to fully explore whether classroom practice is aligned with the New School Model's ideals, or is ever likely to be.

It has been repeatedly shown in research that a teacher's perceptions and beliefs have a very strong bearing on their practice and style as a teacher (Bryan & Atwater, 2002, Savasci-Acikalin, 2009, De Souza & Marcos, 1997). There appears to be a direct link between pre-service teachers' attitudes towards science and science teaching and learning, and the hands-on science inquiry activities which they experience at school (e.g. Bleicher, 2006; Dickson and Kadbey, 2014; Mazur, 2009,). Teachers' practices are often directly related to their perceptions and beliefs of science (Fitzgerald, Dawson, & Hackling, 2008; Howit, 2007) and Bandura (1997) upheld the perspective that teachers' beliefs are a very strong predictor of actual behavior and highly influential to this. Beliefs can be strong predictors of behavior and may be more influential than knowledge in understanding an individual. 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. Haney, Czerniak & Lumpe, 1996; Keys & Kang, 2000; Seung, Park & Narayan, 2011,). The low confidence levels of pre-service science teachers has also been shown repeatedly by researchers (e.g. Kucuk and Cepni, 2015) and the critical importance of self-efficacy (Karaduman and Emrahodlu, 2011).

Mahmoud offers a different viewpoint to this, professing that due to the variability of teachers' beliefs and the 'simplification' which may occur when categorizing beliefs in what he surmised to be a limited fashion, it is "necessary to take into account the contextual factors which have shaped and formed certain beliefs" (2009, p.32) before declaring a clear correlation between beliefs and practices. Contexts within which teachers work is significant, according to Ernest (1988), who cites factors such as others' expectations, curriculum and schooling systems, which may sometimes be out of teachers' control, as impactful. Mahmoud (2009) sums this up by suggesting that the relationship between beliefs and practices are very complex, due to the fact that beliefs could be at times both contradictory and (again) context dependent. He argues that teachers' beliefs and practices simply cannot be properly examined in isolation of the context.

The rationale of our study was to investigate, for expatriate teachers working within the reforming context of government schools in Abu Dhabi, the relationship between beliefs and practices. We were guided by the following research questions:

1. What beliefs about best science teaching practice to the school teachers hold?
2. How do they describe their actual practice in Abu Dhabi classrooms?
3. How well do these described practices correlate with their beliefs, and with the vision of ADEC's New School Model?

In doing so, we hoped to illustrate science practice in classrooms within the context of reform, but also to add to the growing body of international studies which examines the effect of teachers' perceptions on their science teaching practice.

METHODOLOGY

A mixed methods research approach was adopted, whereby a survey questionnaire with questions utilising a four point Likert scale was used to gather quantitative data, whilst qualitative responses could be added via a prompt for additional information for that item. The questionnaire was devised through a process of linkage to the framework briefly outlined in the previous literature and this was used as a basis for the questions, which would (it was hoped) probe the teachers' beliefs about science teaching and learning in order to then provide a context for their described practices. An important limitation of asking teachers to report their practices is of course in the nature of any self-reported data and we do take this into consideration while discussing the results. Nonetheless, such data can give important indications of trends which can later be triangulated by classroom observation or other means of data gathering. The final version of questions was piloted on ten teachers who had previously taught in government schools but who were not eligible to take part in the survey. Adjustments were made on the basis of their feedback and their questioning during the survey taking (indicating a problematic question), thereby cross-checking the questionnaire's content validity. The authors carefully studied each question for its value and alignment to the overall framework provided by the literature, along with its relevancy to our research questions, discarding, modifying and adding questions as we went along. We leaned carefully on the ADEC definitions and descriptions regarding an inquiry approach to learning to provide our framework for the questions. These relate in particular to collaborative learning opportunities, allowing students to think, create questions and explore ideas without teacher interjection.

The survey comprised of four sections, one relating to some basic demographic information such as number of years of teaching experience and grade taught, along with nationality of the teacher carrying out the survey (specifically, Emirati versus non-Emirati). The latter is important because we were focusing on the beliefs of expatriates and so wished to eliminate the Emirati teachers' responses from this particular study. Some of this data has more significant for other research questions which are explored in other papers, but it provided an interesting background for discussion of practice in any case. Secondly, teachers were asked about their practices in the classroom to see how closely aligned their reported practices were to ADEC's vision for science education, as well as internationally standardised 'best practices'. They rated their responses using a four point Likert Scale of how often they would be likely to do these things, opting to omit a neutral option so as to push candidates towards making a choice (Newby, 2007). Finally, they were asked to respond to a series of statements on "how children learn science best" which were accompanied by another four point Likert scale; this time (strongly disagree/ disagree/ agree/ strongly agree).

The survey was sent out to 60 public schools in Abu Dhabi via the school principals, which they were asked to forward to the relevant teachers. ADEC primary schools have generalist teachers for Maths, Science and English taught through the medium of English; it was these teachers whom we targeted. All of the respondents were female due to the policy within Cycle 1 schools of feminization of primary school teaching staff. The teachers had a wide range of years of teaching experience, with half of the sample having more than ten years' experience. Due to the anonymity of the survey responses, we did not know which schools (or how many) had partaken in the survey, only the number of respondents. Using a very rough estimate of there being around 8-10 English medium teachers per primary school, this would mean that the survey response rate fell within the region of between 40-60% overall, by most accounts a very reasonable response rate for an online survey (Nulty, 2008).

FINDINGS and DISCUSSION

RQ 1: What beliefs about best science teaching practice to the school teachers hold?

The teachers were asked to rate their agreement with a number of belief statements. These statements lean heavily towards a student-centred, inquiry-based approach to learning and are all illustrative of the kind of classroom environment aligned to international based practice for science education, as well as with the NSM. For each of the statements it can be seen that the majority of teachers agreed or strongly agreed with each of the statements; between 92% and 98% across the statements were in these categories (Table 1). These high mean responses indicate a leaning towards the education philosophies stated earlier and suggest uniformity across teachers. They also suggest uniformity across teachers in government schools and a cross section of nationalities and training backgrounds. High mean percentages of responses would appear to bode well for the implementation and success of ADEC's goals, in theory at least. Let us now look at how all of these concepts come together and fit with actual classroom practice, as reported by the teachers.

Table 1. *Teachers' Beliefs about how students learn science best*

Items	Strongly disagree %	Disagree %	Agree %	Strongly agree %	*n*
1. Students learn science more effectively when they work in groups and share ideas.	0	2	56	42	246
2. Students understand science best when they discuss concepts with their partners.	0	7	56	37	245
3. Students' interest in learning science increases when they pose their own questions and discover the answers by themselves.	0.4	7	53.6	39	245
4. 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	7	46	46	245
5. Students broaden their scientific inquiry skills by communicating, sharing and reviewing each other's results.	1	6	54	39	245
6. Students understand scientific concepts better when they are given time to think before answering questions in class and time to reflect on their learning.	1	3	49	47	245

RQ 2: How do they describe their actual practice in Abu Dhabi classrooms?

Learning science through inquiry is one of the most fundamental and universally recognized strategies which has to be employed in the classroom in order to produce students who are able to question and think critically. For the NSM, this is of fundamental importance. Teachers' reported practices, again aligned to best practices, were overall responded to less positively than their belief statements may have predicted (Table 2). Many statements had a relatively high proportion of teachers agreeing that they often or always carried out those practices, and many practices were answered only 'sometimes', and some even 'never' as high as 55% of respondents for one statement. The practice statements closely align to the practical implementation of the belief statements, yet some teachers report that they never, or rarely, practice certain strategies, for example allowing students to explore science concepts independently (21%). Only a tiny percentage of teachers 'always' allow for this (2 %).

Table 2. *Teachers' Reported Classroom Practices*

Statement of Practice in the Classroom	Never/ Rarely %	Sometimes %	Often %	Always %	Response Count (n)
1. I allow my students to explore and discover science concepts on their own with minimal teacher input.	21	61	15	2	245
2. I involve students in class debates and	18	30	37	16	244

	discussions.					
3.	I actively involve students in hands–on activities and investigations.	2	38	46	15	246
4.	I provide opportunities for students to work in pairs or very small groups	3	22	44	30	245
5.	I incorporate scientific inquiry skills in my science classes.	5	38	44	13	245
6.	I encourage collaborative learning among my students	2	19	47	31	245
7.	I arrange library lessons and field trips connected to the science topics	55	37	6	1	243
8.	I relate science concepts studied in class to our daily life and to the real world.	1	20	47	31	244
9.	I create differentiated resources to support student learning in science	13	42	35	9	244
10.	I create differentiated activities and experiments to support student learning in science	14	44	34	7	243
11.	I use different science assessment tools, not only projects and exams.	11	31	45	13	244
12.	I demonstrate practical work to my students first before they begin the work.	16	20	46	33	245
13.	I help my students to make connections between Science, Maths and English.	2	23	47	28	244

RQ 3: How well do these described practices correlate with teachers' beliefs, and with the vision of ADEC's New School Model?

We examined the teachers' responses and brought together statements of belief and practice which have a direct pedagogical link, in order to explore a possible correlation. Literature predominantly reports that beliefs often inform practices, and will form a critical part of a teacher's eventual profile. We wished to test whether this was true in the case of teachers in Abu Dhabi too, that is, whether their beliefs which they brought with them from lands afar, translate into related practice in the classroom.

Some of the statements for which the responses were highly negative (i.e. many never/rarely choices) can be explained by exploring the qualitative statements. For example, 55% said they never, or rarely organized to take their students onto school trips. From the qualitative comments, we came to understand that general classroom teachers have no authority to do this in the government schools and the role appears to be undertaken by the teachers of Arabic medium teachers, e.g. "Field trips are arranged by the Arabic teachers. The EMTs (English Medium Teachers) are never allowed to arrange Science trips." and "At my school, we are not allowed to arrange our own field trips, only to suggest. We get only one a year. All my science related suggestions were turned down." Changing this policy could help with the lack of empowerment these statements suggest is felt by the teachers. It could also help provide teachers with opportunities for teaching students about the nature of science in a deep and meaningful context. Kucuk and Cepni (2015) found that students' understanding of science (and therefore, likely, their confidence) could be improved by using direct-reflective methods rather than indirect methods.

Taking a belief statement such as 'students learn science more effectively when they work in groups and share ideas' which teachers overwhelmingly agreed or strongly agreed with (98% of the sample). A teacher who holds such a belief (which the sample overwhelmingly did) would, it might be hypothesized, be expected to strongly practice collaborative work in the classroom. However lower scorings on the practice statements 'I provide opportunities for students to work in pairs or very small groups' and 'I encourage collaborative learning among my students' indicate a less optimistic picture of classroom practice. Indeed, descriptive statistics would appear to marginally support this, with 98% of teachers either agreeing or strongly agreeing with the belief statement, and 77% sometimes or always providing opportunities for students to work in pairs or groups. It is not, however, as strong a relationship as one may have imagined. The discrepancy of 22% and over, of teachers believing that collaborative practice makes more effective science learning, yet not actually putting this into practice, is noteworthy. To take this a little further, we then used the Excel statistics toolbox to run Pearson's correlation coefficient testing for these items and found that the correlations between the belief and practice statements were not statistically significant (Table 3).

Table 3. *Correlation of Beliefs with Classroom Practices*

Belief Statement	**Practice Statement**	**Correlation Coefficient** *(Pearson's CC; r >0.5 considered significant correlation)*[1]
1. Students learn science more effectively when they work in groups and share ideas.	4. I provide opportunities for students to work in pairs or small groups	0.29
1. Students learn science more effectively when they work in groups and share ideas.	6. I encourage collaborative learning among my students	0.32

Responses to other belief statements such as 'students' interest in learning science increases when they pose their own questions and discover the answers by themselves' and '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' also scored very high (92% for both) agreement or strong agreement with these statements. Again, this might lead us to expect reported statements of active classroom practice according to some of the research mentioned earlier. Both of these belief statements are illustrative of a teaching philosophy which embraces the concept of inquiry based learning and allowing for student autonomy in order to explore and independently answer, all of which would fit into the objectives of science education in Abu Dhabi's educational reform objectives. These questions are formed on the basis of inquiry based approaches, and upon the premise that exploratory learning opportunities are optimal for students. The statements of classroom practice which best align with these beliefs are selected and re-represented in Table 4. Here, we see a far less positive response; very few teachers reportedly 'always' practice these exploratory, hands-on and inquiry approaches. Poor correlations of positive beliefs with practical approaches to inquiry are particularly poignant, given the emphasis from ADEC on the teaching of inquiry skills. ADEC's Science Curriculum Teacher Guidebook (2013) specifically articulates the ideas which should be covered, and the need to focus on such skills.

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[1] Newby (2010)

Table 4. *Correlation of Beliefs with Classroom Practices*

Belief Statement	Correlations (r) of Beliefs with Practice (*>0.5 considered significant correlation)*		
	1. I allow my students to explore and discover science concepts on their own with minimal teacher input.	3. I actively involve students in hands–on activities and investigations.	5. I incorporate scientific inquiry skills in my science classes.
3. Students' interest in learning science increases when they pose their own questions and discover the answers by themselves.	0.23	0.12	0.2
4. 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.	0.11	0.19	0.13

We have seen earlier how the number of teachers who said they often or always used particular practices considered to be exploratory/inquiry based are relatively low, such as allowing students to explore and discover science concepts on their own with minimal teacher input (18%), actively involving students in hands-on activities and investigations (60%), incorporation of inquiry skills in the science class (57%) which would appear to be at odds with the high responses to the belief statements which embody these ideas. The statistical correlations between these two entities are displayed in Table 4. Here, it can be seen that no correlation is greater than, or even close to, 0.5, the threshold for statistically significant correlation (Newby, 2010).

Having seen that the relationship between teachers' beliefs and practice is not statistically correlated for our data, we now delve into the additional qualitative comments which teachers added to the survey to attempt to understand why this would be. One teacher showed an understanding of the need to allow students to explore independently sometimes: "I don't always demonstrate as I want my students to find things out by using their enquiry skills". This, however, was something of an anomaly in the data. Many commented that the levels of students' behavior in government schools severely hampered their ability to make their lessons more hands-on and practical, in particular working collaboratively in groups. Some expressed nervousness about the students' handling of equipment due to the behavioral issues too.

The teachers' statements appear to corroborate the idea that their beliefs are indeed aligned with the NSM model's vision, and indeed international best practice in science. However, practices seem to deviate widely from these ideals for a number of reasons. Firstly, the teachers repeatedly mention the language barriers they face in the classroom and how this prevents them from fully embracing inquiry learning. Many commented that they need an Arabic teacher to co-teach science, that much more support was needed with bilingual resources such as signage, and many even said that science should be completely taught in Arabic, expressed in quite emotive terms. For example:

> "teaching [science] in English is doing a huge disservice to the students and I fear that an entire generation of potential scientists will be lost due to the language barriers that are formed."

One teacher even described resorting to having the students demonstrate their findings in Arabic, which she did not herself understand, but which she observed the other students responding very positively to. Most felt that the low levels of English language skill among the students rendered many of the ideals mentioned in the questionnaire, particularly with discussion of concepts and ideas, unattainable in English.

This sample of teachers certainly seem well aware of what needs to be done and what constitutes 'ideal' practice in the science classroom. Some voiced frustration that they cannot do this in practice due to the perceived constraints they are working under, e.g.:

> "My answers are based on what should be happening, but because of language barriers, Grade 1 has no idea most of the time what is being taught. They can't form questions, collaborate/discuss most of the topics."

A perceived lack of adequate resources was mentioned very frequently (some even said their schools had absolutely no resources for science experiments and activities), and needing to supplement or purchase resources personally was another frustration commonly voiced. An articulate example of this is:

> "Science is a very important subject. "Science kits" that contain teaching experiment materials would be MOST effective for me. Time and resources are not on our side. I have spent a lot of money to find materials. I can't afford it!"

One teacher added that "The fact that schools are not provided with science kits and materials is failing our students."

In addition to the lack of science equipment and resources, an absence of trained science lab support personnel came up frequently in the responses, emerging as another theme for why their beliefs are unable to translate into actual classroom and providing further explanation for the poor correlations we observe. Although most schools do have a named person responsible for organizing science labs and setting up experiments, in reality it would seem from the responses that these may not be properly trained, nor even available to support most of the time as they are allocated to other tasks within the schools. This corroborates a theme explored by Guo (2007) who found that struggles in obtaining science equipment in order to perform experiments was highly stressful and a major factor in a poor science teaching practice. Atav and Altunoglu (2010) also found that pre-service teachers perceive themselves as only partially competent in both the effective use of laboratory instruments, and the teaching of techniques in the lab.

The positive correlation between beliefs and practice which other researchers (e.g. Bandura, 1997) have found has not been observed in this study. Instead, these results align more closely with the work of authors such as Mahmoud (2009). The vast majority of the studies which were earlier quoted took place in environments where students are in their first language environment, which makes it difficult to draw comparisons. Mahmoud, in a wide-scale literature review on the subject of science teachers' beliefs and practices, found that "inquiry-oriented and constructivist teaching appeared to conflict with more traditional beliefs about the nature of science and some aspects of science teaching and learning " (p. 40). From the statements we posed, this did not appear to be the case since all questions pertaining to inquiry-oriented, or what could be conceived as 'constructivist' were answered very positively. Mahmoud considers that the relationship between beliefs and practices to be complex, due to the fact that beliefs could be, at times, contradictory, and again, context dependent. He argues that teachers' beliefs and practices simply cannot be properly examined independently from context. This would appear to be the case for our data too. Teachers in this study were clearly articulating an awareness that their beliefs don't match up to their practices, that they know what they 'should' be doing but that due to their contextual constraints, are unable to. For example, one teacher wrote that *"this* [referring to the practice statements] *would all be done in the "perfect" setting."* and:

> "Each of these points are true when the students are confident to express themselves in a way that will be nurtured by the teacher, but if English is

> especially difficult for them, they often lack the confidence to follow instructions or express their results".

One also made the point that the concepts were good in theory and she agreed with all the statements on how students learn best, but that "we have to teach children how to collaborate, how to work independently, how to enquire and how to ask questions... before they can use these skills IN learning." Many teachers commented on their students' dependency on rote learning and the challenges they faced in pushing them to think more independently, which may be another factor in putting beliefs into practice. The necessity of dynamic teaching practice in science is well understood and researched, for example, Bas (2012) notes that students who learned a particular science concept through the vehicle of Multiple Intelligence theory tended to exhibit higher motivation levels and self-directed learning.

CONCLUSION

In conclusion, we have found that the teachers in this study overall held lofty ideals regarding best practice in science, and that their beliefs were in close alignment to accepted 'best practice' in science education internationally. However, according to the self-reported practices of teachers which are described here, these beliefs were not fully able to be converted into practice due to a number of factors. Chief among these are a reported lack of classroom assistance and lab technician support to help in the preparation and setting up/ clearing away of activities and experiments, lack of equipment and resources (e.g. "*If there were resources students would be able to do all of this. It is not the teachers' position to purchase items. The school should have these resources for the teachers and students for them to teach the outcome properly")* and time constraints. The teachers felt unable to teach in the hands-on, student-centered fashion they would like to in some cases because of unresolved student behavioral issues along with language barriers which hamper students' ability to understand tasks and concepts.

Feyzioglu (2012), in a discussion about teachers' beliefs, suggested that when beliefs are not aligned with what is considered to be best practice (usually based upon constructivist principals), teachers were normally clinging on to traditional beliefs. They suggested that professional development sessions in collaboration with presenting research findings, be employed to change teachers' beliefs. Our findings do not support this, and suggest that it is not necessarily always true that beliefs are indicators of practice, even self-reported practice. However, what can be done when in fact the opposite is true, when teachers appear to hold all the beliefs in theory which well match the ideals of the educational system within which they are working (ADEC, in this case) but when their environmental constraints apparently do not allow them to put these beliefs into practice? The issue of the language issues is more problematic to solve, because a dual language approach to learning is key to ADEC's long term goals. The teachers in this study are not against this in theory, but are saying that science is not a subject which should be included in this policy, since in their view not only is this damaging students' understanding of science concepts, but it is also hampering their pedagogy and ability to teach science as they wish. This is an issue which would need to be addressed at governmental policy level.

We suggest that professional development programs and in-service training of these teachers (the majority of whom are highly experienced classroom teachers) are unlikely to be effective if their aim is to overturn beliefs. Instead, since the teachers' beliefs indicate they would likely (under ideal circumstances) be able to be effective and ideal science practitioners, we suggest that more emphasis, resources and funding are channeled towards the provision of trained and qualified lab assistants who would provide practical support, and towards providing science equipment and resources which would prevent the need for teachers to purchase their own. The findings that teachers' beliefs about science education practice are not reflected in their reported practice has significance not only at a local level, but is also applicable to science education fields internationally, particularly within other educational reform settings. The possible reasons given for this mismatch between beliefs and practice are also applicable to settings outside of the Middle East, and add to a body of literature which echo the need for teachers to be support by both resources, funding, trained personnel to be able to teach science in the most effective way.

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Scale Development on Educational Value of The History of Science

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ABSTRACT

This study was aimed at developing a scale for revealing the views of teachers concerning the educational value of the history of science. To this end, the draft scale form, which was composed of 37 items, was administered to primary school teachers, science and technology, mathematics and social science teachers, working in elementary and middle schools in various Turkish cities. While the exploratory factor analysis was conducted with 350 teachers, the confirmatory factor analysis was carried out with 161 teachers. A three-factor model, entitled "Understanding and Being Interested in Science", Understanding the Scientific Process" and "Outlook on Science and Scientists", explaining 56.94% of the total variance, was obtained through the exploratory factor analysis. The first-order and the second-order confirmatory factor analyses demonstrated that the three-factor model of the scale had a theoretical and statistical fitness.

Key Words: History of science, Opinions of teachers, Scale development

INTRODUCTION

George Sarton begins his work, *Ancient Science and Modern Civilization*, with the following words: "*When I was a child, the table of multiplication was called The Table of Pythagoras, but the teacher did not tell us who Pythagoras was; perhaps she did not know it herself.*" He continues with the criticism of not mentioning the social environment in which great scientists grew up and not uttering a word about their personalities or their prodigies whilst introducing them. These expressions hold two important evaluations: the way the history of science is handled in lessons and relevant teacher competencies.

The way the history of science is handled in lessons is quite problematic. The history of science aims at specifying which phases have been experienced throughout the scientific journey, describing the emergence and development of scientific theories, the contribution of other cultures during this period, how scientists endeavor, a revelation of the methods,

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instruments and tools they employ and knowing and promoting scientific activity from all aspects (Topdemir & Unat, 2008). However, schools, curricula and books are only interested in scientific products so they often ignore the experiences, efforts and explanations that have taken place during this process (Laçin-Şimşek, 2009; Laçin-Şimşek, 2011b; Monk & Osborne, 1997; Narguizian, 2002; Wang, 1998). The history of science is merely used for identifying those who have made the discoveries and inventions.

Teacher competencies are another aspect of the problem. In order to use the history of science in education effectively, it should be appreciated and valued by teachers (Laçin-Şimşek, 2011a). Also, they should have adequate knowledge regarding this issue. Although previous studies have reported that including the history of science in lessons helps students to understand the nature of science, it has been stated that schools are not really interested in the history of science (Lin & Cheng, 2002); teachers are not really eager to teach about the issue (Brush, 1974); the process-based nature of science is rather ignored (Wang & Marsh, 1998); and teachers are not aware of the importance of the history of science (Wang & Marsh, 2002). In a study conducted with pre-service teachers and elementary and middle education science teachers, it was reported that the teachers were not competent enough to reflect the history of science in their lessons, even though they were aware of its importance (Wang & Cox-Petersen, 2002). Since teachers have deficient knowledge and understanding about the history of science, they do not include issues related to it in their classes (Abd-El-Khalick & Lederman, 2000; Monk & Osborne, 1997).

Similar results have been reported in Turkey as well; some studies conducted with pre-service social sciences (Laçin-Şimşek & Şimşek, 2010) and science teachers (Laçin-Şimşek, 2011) detected that pre-service teachers had inadequate knowledge of the history of science. In the study, which inquired about the opinions of science and technology teachers regarding the history of science and introducing this aspect to their classes (Laçin-Şimşek, 2011), it was found that teachers had an inadequate understanding regarding the history of science. It was concluded that teachers who participated in that study generally focused on the conceptual aspect of science and, therefore, gave coverage to the history of science in their classes only within the framework of an attempt to offer scientific knowledge to students. Moreover, it was determined that they mostly skipped the aspects of how science works, how scientists conduct research, under what conditions studies are carried out, and how social, cultural and financial characteristics influence these studies.

There are only a limited number of studies in Turkey on the history of science and its use in classes. Therefore, this study aims at developing a scale to determine teachers' opinions on the use of the history of science in classes and its contribution to students. In relation to the benefits of using the history of science in courses, the literature provides the following aspects: the contribution of the history of science to conceptual comprehension, the contribution of the history of science to comprehending the process, and the contribution of the history of science to comprehending the context (Laçin-Şimşek, 2011; Wang & Marsh, 1998; Wang & Marsh, 2002).

What conceptual comprehension refers to here is what scientific thinking and concepts mean. In order to achieve this, the history of science is used to enrich the presentation of scientific knowledge and highlight the changeable nature of the science. Concepts are explained by using the examples from the history of science. Comprehending the process refers to the research process. Examples are drawn from how to conduct research, how data is collected and evaluated and how the experiments are designed and conducted. Thus, the aim is to make students understand how a scientific study is conducted. Contextual comprehension draws the attention to the sociological, social, cultural and personal characteristics. It is about the lives of scientists, the cultures they lived in, how these influenced their viewpoints and studies, and the personal characteristics of scientists.

The absence of such a scale in Turkey made its development necessary. Elementary education was re-organized in 2004, which introduced the history of science to science, the social sciences and mathematics courses as a separate acquisition. However, it is not thoroughly known what teachers now think about the use of the history of science in classes. Therefore, it is necessary to reveal what they think about the use of the history of science in class and the value they attach to this practice, thus, there was a need for such a scale. There is only one scale in the international literature about the use of the history of science in classes (Wang & Marsh, 1998). There are two sections in this scale. The first section has 13 items, with teacher perceptions regarding the use of the history of science in classes. The other section also has 13 items, which deals with to what extent they can reflect it in their classes. The purpose of this study is to develop a scale to reveal teacher opinions about the educational value of the history of science.

METHODOLOGY

a) Study Group

The study was conducted with primary school, science, social studies and mathematics teachers working in primary or middle schools located in different provinces of Turkey. Study groups were determined through purposeful and convenience sampling. Purposeful sampling was employed because the branch teachers, who had acquisitions related to the history of science in their courses, were included in the study. Convenience sampling was employed as the data was collected with the help of the teachers, graduated by the researchers. The study was conducted in two different study groups. While the data obtained from the first study group was exposed to exploratory factor analysis, the data collected from the second study group was exposed to confirmatory factor analysis.

Confirmatory factor analyses were carried out with 350 teachers in total. Of these, 192 were primary school teachers (54.9%); 61 were science and technology teachers (17.4%); 49 were mathematics teachers (14.0%) and 48 were social sciences teachers (13.7%). The ratio of males in this group was 55%; while the ratio of females was 45%. In terms of area of work: 118 of these teachers worked in a central district; 158 worked in other districts and 69 worked in towns and villages. There were participants from both primary and middle schools. Their ages ranged from 22 to 60 (m=32.9; Sd=7.85). Confirmatory factor analyses were carried out with 161 teachers in total. Of these, 90 were primary school teachers (55.9%); 34 were science and technology teachers (21.1%); 24 were social science teachers (14.9%) and 13 were mathematics teachers (8.1%). The ratio of males in this group was 54%; while the ratio of females was 46%. Of these, 65 teachers worked in a central district; 60 worked in other districts and 36 worked in towns and villages. There were participants from both primary and middle schools. Their ages ranged from 22 to 60 (m=33.2; Sd=7.68).

b) Data Collection Tool

In order to develop a measurement tool to reveal teacher opinions regarding the educational value of the history of science, a literature review was conducted and the theoretical information was reviewed. As Wang & Marsh (1998) had developed a scale on this subject, their study was examined. Afterwards, the study conducted on teachers by Laçin-Şimşek (2011), regarding the evaluation of the use of the history of science, was examined. In that study, the data was collected through open-ended questions. The expressions provided in that study as direct quotations were reviewed. Items were created out of these expressions after receiving permission from the author. After analyzing all the data, an item pool,which had 38 items, was formed by the researchers.

Five academics were consulted to evaluate the validity of the form composed of these expressions, in terms of clarity, content validity and face validity. The academics were selected because they had written publications on the history of science, the nature of science and scale development. In accordance with the opinions and criticisms of the academics,, the scale items were rearranged; some were corrected and some were removed from the scale. In the end, a pilot scale consisting 37 items, was created. The validity and reliability of these items was investigated. There were seven negative and 30 positive items in the scale. A 5-point Likert-type rating was employed to express the agreement levels with the items. The rating was as follows: "*I strongly agree (5), I agree (4), I partially agree (3), I disagree (2), I strongly disagree (1)*".Moreover, an instruction was put in the beginning of the scale about the purpose of the scale, as well as the types of responses expected for the items.

c) Data Analysis

Initially, a confirmatory factor analysis was carried out to test the construct validity of the data obtained from the pilot study. During the confirmatory factor analysis, in determining the number of the factors in the scale, the contribution of each factor to the covariance had to be not less than 5% (Seçer, 2013);eigen values had to be 1 at least (Büyüköztürk, 2006) and the fractures in scree plot had to be taken into consideration (Çokluk, Şekercioğlu & Büyüköztürk, 2010). Furthermore, factor loadings had to be at least 0.32 (Tabachnick & Fidel, 2001), being part of only one factor and a difference of a minimum 0.10 between the load values of the items, which are part of two factors (Büyüköztürk, 2006) were taken as the basic principles. Internal consistency and split-half test reliability analyses were conducted for the reliability of the scale. Also, for the item analysis, the corrected item-total score correlation was calculated and the significance of the differences between the item averages of the top 27% ,and the bottom 27% ,was acquired through the *t* test.

The item-factor structure, which was obtained through confirmatory factor analysis, was tested for model fit via confirmatory factor analysis. To evaluate the fit of the model in confirmatory factor analysis, the criteria were >.90 for GFI, AGFI, NFI, CFI, IFI, and TLI and <.08 for RMR and RMSEA (Jöreskog & Sörbom, 1993; Tabachnick & Fidel, 2001; Şimşek, 2007, Bayram, 2010). Moreover, a value of $\chi 2/sd$ between 0 and 2 refers to a perfect fit (Tabachnick & Fidel, 2001).

SPSS 15 and AMOS 7.0 were used for all the validity and reliability analyses.

FINDINGS

Testing the Validity and Reliability of the Scale

The first phase of ensuring the scale's construct validity involved exploring the internal consistency and the item-total correlation of 37 items. Seven negative items with a low item-total correlation (e.g., "The history of science in the class is *only* good for telling about the lives of scientists."; "Quoting from the history of science in classes is good for drawing the attention of students only for a second.") and 1 positive item with a low item-total correlation, which means eight items in total (the 9th, 10th, 16th, 20th, 22nd, 24th, 32nd and 37th items), were excluded from the scale. The rest of the items were tested for construct validity. In order to determine whether the scale was appropriate for factor analysis or not, Kaiser-Meyer Olkin (KMO) and Barlett's test of sphericity were conducted. At the end of the analysis, the KMO value was found to be 0.95 and Bartlett's test of sphericity was found to be ($\chi^2_{(406)}$=5367.31; p<0.01) significant. A KMO value higher than 0.90 indicates that factors can be extracted from the data (Şencan, 2005; Büyüköztürk, 2006). At the end of the analyses, the resulting values met the aforementioned basic assumptions at a pretty good level. Therefore, the factor analysis could be conducted. Principal component analysis was used as a factoring method and the direct oblimin method, which is one of the oblique rotation methods, was used as a rotation method to reveal the factor structure of the scale.

At the end of the analysis, it was seen that 29 items in the scale had an eigenvalue over 1, with a four-component structure. Taking into account the contribution of these components to total variance, scree plot, and the number of the factors identified during the development phase of the tool, a 3-factor structure was accepted.

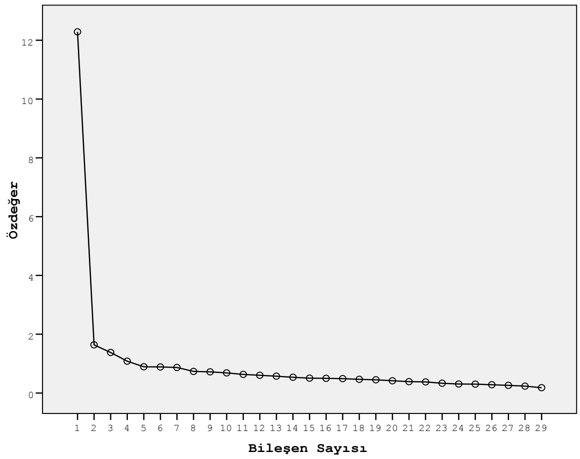

Figure 1. *Scree Plot*

According to the scree plot in Figure 1, there is a fast curve downwards (i.e., fracture) until the third factor, but after that it is fixed. Therefore, the 3-factor structure was approved.

At the end of the repetitive analyses, which were carried out for the 3-factor structure, six items (the 6th, 7th, 8th, 18th, 19th, and 25th) were excluded due to overlap, and another item (11th item) was excluded because it had a lower factor load value in comparison to the other factor load values. Seven items were excluded in total. The analysis conducted afterwards revealed that the contribution of the first factor to total variance was 45.03%; that of the second factor was 6.29%; and that of the third factor was 5.61%. The total contribution of these three factors was 56.94%. In multiple factor designs, it was expected for the factor covariance to be over 41% (Kline, 1994). Accordingly, it is possible to say that the percentage of the total variance explained by three factors is quite good and adequate.

At the end of the analysis, a scale consisting of 22 items was obtained. Table 1 shows the factor design of the scale, as well as its factor load values, factor covariances, item-total correlations and internal consistency coefficients. In addition, it indicates the comparison results of the bottom and top groups for each item.

Table 1. *Findings Regarding the Scale Items and Factors at the End of the Factor Analysis*

Item	FactorCovariance	Load Values After Rotation			Item-Total Correlation	Reliability			Bottom Group (27%)		Top Group (27%)		
		1st Factor	2nd Factor	3rd Factor		Internal Consistency	Split Half Test		$\bar{X}$	S	$\bar{X}$	S	T
i28	.65	.88			.69	.93	.91	95	3.08	.68	4.62	.57	16.91*
i29	.62	.86			.69			95	3.06	.83	4.53	.54	14.36*

i34	.56	.74			.68			95	3.07	.71	4.56	.60	15.55*
i13	.65	.73			.70			95	3.03	.83	4.42	.63	13.00*
i27	.58	.71			.69			95	3.21	.77	4.74	.47	16.53*
i14	.60	.70			.71			95	3.02	.79	4.65	.52	16.81*
i31	.55	.68			.68			95	3.08	.82	4.54	.54	14.39*
i33	.56	.67			.70			95	3.08	.74	4.68	.49	17.61*
i26	.54	.65			.66			95	3.33	.88	4.79	.41	14.68*
i36	.51	.63			.66			95	3.12	.71	4.52	.58	14.84*
i12	.56	.63			.66			95	3.02	.84	4.43	.63	13.12*
i35	.45	.63			.60			95	2.99	.90	4.50	.73	12.70*
i30	.55	.55			.69			95	3.30	.74	4.68	.51	15.03*
i3	.65		.79		.57			95	3.63	.69	4.66	.52	11.71*
i4	.60		.74		.52			95	3.21	.88	4.40	.75	10.02*
i1	.59		.72		.57	.83	.81	95	3.14	.87	4.53	.67	12.36*
i5	.56		.67		.58			95	3.66	.80	4.66	.54	10.13*
i2	.64		.63		.68			95	3.40	.75	4.63	.53	13.10*
i17	.55			.70	.46			95	3.58	.78	4.60	.66	9.74*
i23	.60			.68	.54	.73	.70	95	3.33	.74	4.52	.76	11.00*
i21	.55			.64	.53			95	3.26	.83	4.50	.74	10.80*
i15	.45			.43	.58			95	3.25	.93	4.73	.61	12.89*
Total						.94	.89	95	70.84	7.19	100.87	5.54	32.25

*p<.001

Considering Table 2, it is seen that the first factor covers thirteen items which are the 12th, 13th, 14th, 26th, 27th, 28th, 29th, 30th, 31st, 33rd, 34th, 35th and 36th items. The load values of these items range from 0.55 to 0.88. The second factor of the scale has the load values ranging from 0.63 to 0.79. It covers five items in total, which are the 1st, 2nd, 3rd, 4th and 5th items. The third factor covers items whose load values range from 0.43 to 0.70. It covers four items in total which are the 15th, 17th, 21st and 23rd items. In terms of sizes, the factor load values follow a course from "good" to "perfect" (Tabachnick & Fidel, 2001). Taking the content of the items falling under each factor and their suitableness for the construct together, the factors were named, based on the theoretical background, as follows: the first factor was "*understanding the science and having an interest in it*" (*conceptual comprehension*); the second factor was "*understanding the scientific process*" (*scientific process comprehension*); and the third factor was "*viewpoints regarding science and scientists*" (*contextual comprehension*). Twenty-two items associated with the educational value of the history of science scale had factor covariance values over 0.20, which indicates high contribution to the variance (Çokluk, Şekercioğlu & Büyüköztürk, 2010).

In relation to the discrimination capacity and homogeneity of the scale, the item-total correlations were calculated and a *t* test was conducted to identify the significance between the item-total scores of the bottom 27% and the top 27% groups. It was seen that the item-total correlations of the scale ranged from 0.46 to 0.71, and t values for the difference between the scores of the top 27% and the bottom 27% groups (sd=188) ranged from 9.74 to 17.61. Having item-total correlations over 0.30, and the significance of the difference between the total scores of the top and the bottom groups, indicated that each item disciminates the characteristic it measures; items measure similar behaviour and the internal consistency of the scale is high (Büyüköztürk, 2006). In relation to the reliability of the scale, the internal consistency (alpha) coefficient was found to be 0.93, while the split half reliability coefficient was found to be 0.89. The internal consistency of the first factor of the scale was found to be 0.93, while its split half reliability coefficient was found to be 0.91. The internal consistency of the second factor was found to be 0.83, while its split half reliability coefficient was found to be 0.81. The internal consistency coefficient of the third factor was found to be 0.73, while its split half reliability coefficient was found to be 0.70. All these findings are indicative of the fact that the scale is reliable at a satisfactory level.

Confirmation of the Scale Construct

In order to see whether the factor structure of the scale, which was developed as its validity and reliability was tested through confirmatory factor analysis would be confirmed or not, the first order and the second order confirmatory factor analyses were conducted. Confirmatory factor analysis (CFA) is an analysis to evaluate model-data fit by testing the hypotheses formulated for the relationship between variables (Daniel, 1989).

The confirmatory factor analysis concentrated on the model-fit indices of the three-factor scale. The results of the order CFA are given in Figure 2.

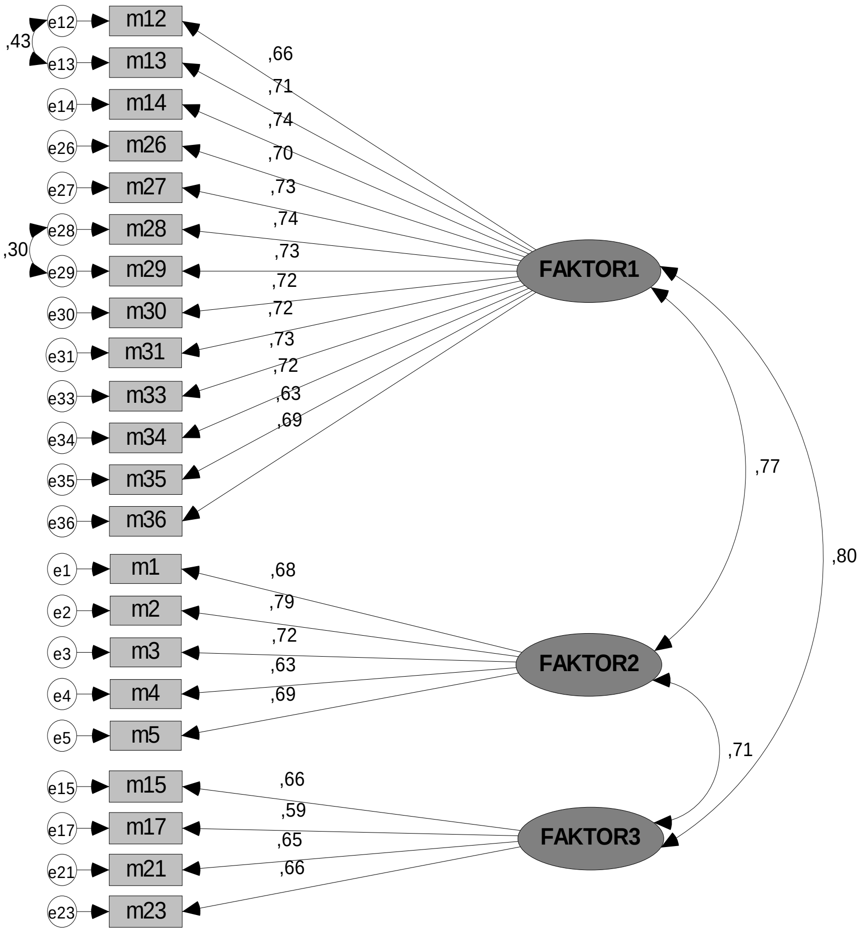

Figure 2.*The First Order CFA Results Regarding the Educational Value of the History of Science Scale*

At the end of the CFA, it was seen that the Educational Value of History of Science Scale (EVHSS), which consisted of 22 items and three factors, had significant model fit indices ($\chi2$=389.4; sd=204; p=.00; $\chi2$/sd=1.91). Since $\chi2$ is not a statistic that can be used by itself, $\chi2$ was proportioned to the degree of freedom, and $\chi2$/sdrate was seen to be 1.91. This value refers to the perfect fit. Fit index values were found to be RMSEA=.05; RMR=.03; GFI=.91; AGFI=.89; NFI=.91; CFI=.95; and TLI=.95. Considering the RMSEA=.05 and

RMR=.03 values of the scale, it is possible to say that the RMSEA value corresponds to good fit while the RMR value refers to perfect fit. Considering the GFI and AGFI values, GFI corresponds to good fit, whereas AGFI corresponds to poor fit. Considering the NFI, CFI and TLI values, NFI corresponds to good fit, while CFI and TLI correspond to perfect fit. Associations were made between i12 and i13 and between i28 and i29, which were included in the first factor, in order to yield better fit values, since they contributed to a decrease in the $\chi 2$ value in the relevant model in the first order CFA analysis. It is possible to say that relationships emerged between the error variances of these items because they were under the same factor and measured the same aspects.

Many studies emphasize the necessity of conducting the second order CFA for multiple dimension scales (Çokluk, Şekercioğlu & Büyüköztürk, 2010; Meydan & Şeşen, 2011).The second order CFA results regarding this three-dimension model are given in Figure 3.

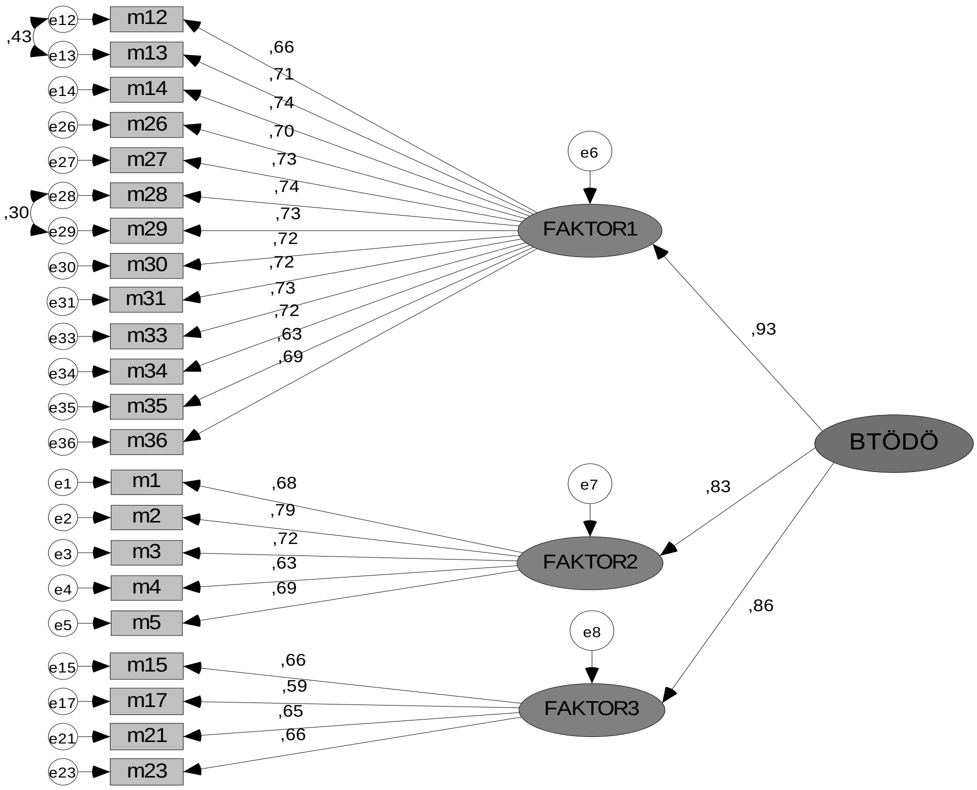

Figure 3.*The Second Order CFA Results Regarding the Educational Value of the History of Science Scale*

According to the results of the second order CFA, conducted in relation to the three-factor structure of EVHSS, the model fit indices were significant ($\chi 2$=389.4; sd=204; p=.00; $\chi 2$/sd=1.91). The fit index values were found to be RMSEA=.05; RMR=.03; GFI=.91; AGFI=.89; NFI=.91; CFI=.95;and TLI=.95. Since modification was made in the first order CFA, the same modification was kept the same in the second order. It is seen that all the values produced in the second order CFA were the same. This indicates that the second order relationships do not have any influence on parameter values in the model (Şimşek, 2007). As a high order latent (hidden) variable of the second order CFA, EVHSS explains FACTOR 1, FACTOR 2 and FACTOR 3 variables. The variable having the highest association with EVHSS is FACTOR 1 with a value of 0.93; whereas the variable having the lowest association with EVHSS is FACTOR 2 with a value of 0.83. As seen in Figures 1 and 2, factor loads ranged from 0.63 to 0.72 for the first factor; from 0.63 to 0.72 for the second factor and from 0.59 to 0.66 for the third factor.

DISCUSSION

This study was conducted to develop a scale in order to reveal teacher opinions regarding the educational value of the history of science course. Initially, confirmatory factor analysis was conducted and a three-factor structure explaining 56.94% of EVHSS' total variance was obtained. Explaining over 41% of the variance is deemed adequate in multiple factor scales (Kline, 1994). Therefore, it is possible to claim that the scale had construct validity at a good level and it measures what needs to be measured at a reasonably good level. Factors of "The Educational Value of the History of Science Scale" were named based on the theoretical background. The first factor was "understanding science and being interested in science"; the second factor was "understanding the scientific process" and the third factor was "viewpoints regarding science and scientist". As for the distribution of 22 items among the factors, the 12th, 13th, 14th, 26th, 27th, 28th, 29th, 30th, 31st, 33rd, 34th, 35th and 36th items are under the first factor; the 1st, 2nd, 3rd, 4th, and 5th items are under the second factor and the 15th, 17th, 21st and 23rd items are under the third factor. All the items have high factor load values under their own factors, whereas these values decrease in other factors. That indicates the independence of the factors.

Internal consistency and split half tests were employed as reliability methods in order to identify the reliability of the scale. At the end of the analyses, the internal consistency for the entire scale was found to be 0.93, while its split half reliability coefficient was found to be 0.89. Considering the sub-dimensions, the internal consistency coefficient of 'understanding science' and 'having an interest in science' was found to be 0.93, and its split half reliability coefficient was found to be 0.91. The internal consistency coefficient for 'understanding scientific process' was found to be 0.83, and its split half reliability coefficient was found to be 0.81. The internal consistency coefficient of viewpoints regarding science and scientists was found to be 0.73, and its split half reliability coefficient was found to be 0.70. Considering the fact that the reliability coefficient estimated for psychological measurement tools should be over 0.70 (Büyüköztürk, 2006), it can be said that the above-mentioned results are indicative of a consistent and stable reliability for both the entire scale and its sub-dimensions. Moreover, a *t* test was conducted on the total scores of the top 27% and the bottom 27% groups. The results indicated significant differences between all items. At the end of the item analysis, it was seen that the item-total score correlation of the scale was at a desirable level (0.30 and over). In this sense, considering all the obtained results, it is possible to say that the items in "The Educational Value of the History of Science Scale" discriminate all the characteristics they measure and measure similar behaviour and that the scale has a high internal consistency (Büyüköztürk, 2006).

The reliability of the scale was tested through confirmatory factor analysis. The final version of the scale consisted of 22 items and a three-factor structure. Finally, the scale was subjected to confirmatory factor analysis and model fit testing. At the end of the first and second order confirmatory factor analyses, the three-factor model of the scale was found to be organizationally and statistically fit. Accordingly, it is possible to assert that the theoretical construct obtained through the confirmatory factor analysis was confirmed via the confirmatory factor analysis.

Even though the literature contains numerous studies focusing on the history of science and the importance of its use in lessons, there is only one scale measuring teachers' views in this matter. This study was carried out by Wang & Mash (1998) who administered the scale to science teachers. It consisted of two sections; the first section was formed to determine teachers' perceptions regarding the importance of the history of science. The second section, on the other hand, was made up of questions investigating how they included the history of science in their lessons (i.e., how they used it in practice). No scale has been administered on this issue in Turkey. Althoug Wang & Marsh's scale was only for science teachers, our study does not have such a limitation. While the items were being formed in the present study, all the branches involving acquisitions about the history of science (teaching in primary schools, science, social studies and mathematics) were all taken into consideration. Furthermore, whereas Wang & Marsh measured what teachers did in practice, the present study does not include items for this purpose.

To conclude, all the findings obtained in the present study indicate that the developed scale is a valid and reliable tool. Therefore, it can be used to reveal teachers' opinions regarding the educational value of the history of science.

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APPENDIX-I. THE SCALE FOR TEACHER OPINIONS REGARDING THE EDUCATIONAL VALUE OF THE HISTORY OF SCIENCE

	I strongly agree	I agree	I partially agree	I disagree	I strongly disagree
1. Students understand how discoveries and inventions are made through the history of science.					
2. Lecturing with the help of the history of science makes students comprehend how scientific concepts were formed.					
3. The history of science makes students understand where scientific knowledge and tools come from.					
4.Thanks to the history of science, students realize how scientific studies are conducted.					
5.The history of science makes students aware of the contribution of inventions and discoveries to the advancement of human kind.					
12. Students become more interested in classes when the history of science is included.					
13. Examples from the history of science make it easier to understand the subjects.					
14. Examples from the history of science increase students' eagerness to conduct research.					
15. Examples from the history of science help students know scientists.					
17. Examples from the history of science helps students to know who made the discoveries.					
21. Examples from the history of science help students understand that scientific information changes with time.					
23. Examples from the history of science help students understand that science is a matter of process.					
26. Examples from the history of science help students to understand the importance of imagination for the development of science.					
27. The history of science makes students think that if they want, they can be scientists as well.					
28. Learning about the lives of scientists encourages students to conduct research.					
29. Examples from the history of science help students to develop research skills.					
30. Lecturing with the help of the history of science makes students understand that science is created as a result of human activities.					
31. Examples from the history of science help students to see the relationship/interaction of science with society and culture.					
33. Giving examples from the history of science in classes help students to acquire different perspectives.					
34. Examples from the history of science help students to see the motivation underlying the scientific studies.					
35. Examples from the history of science help students to see how scientific studies have an influence on the welfare of human kind.					
36. Examples from the history of science help students to adopt inquiry skills.					

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Construction of a Chemical Literacy Test for Engineering Students

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ABSTRACT

The objective of this study was to construct an assessment instrument to assess chemical literacy among undergraduate engineering students at a university in Thailand. The subjects were 400 undergraduate engineering students who were enrolled in a basic chemistry course in 2012 from the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces. The instruments consisted of 1) a table of test specifications, and 2) assessment forms to check congruence of agreement between experts. The assessment tool was entitled "Chemical Literacy Test (CLT)". The CLT had two assessment formats: 1) Multiple-choice CLT, and 2) Written CLT. The results showed that the K-R 20 of the multiple-choice test was 0.720. The Cronbach's alpha reliabilities of the Written CLT for knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning, and moral awareness and a sense of responsibility were 0.66, 0.61, 0.82, and 0.77, respectively. The result showed that the CLT was a quality assessment tool for assessing chemical literacy of engineering students studying chemistry.

Keywords: Chemical Literacy; Chemical Literacy Test; Construction, Engineering; Undergraduate Students.

INTRODUCTION

A changing world has resulted in the need for human society to be involved in the production of scientific knowledge and understanding of technology. The influence of science and technology on modern society has been so extensive that the print and electronic media often announce the latest advancements in science and technology in the fields of genetic engineering (e.g., human genome project, gene transplant, and cloning) and artificial intelligence as well as about space stations (Yrez & Cakir, 2006). Moreover, the impact of science on a nation and her citizens could be seen from the production of basic human needs for social, political, educational, technological and economic advancement (Oludipe & Awokoy, 2010). Thus, understanding scientific information and the relationship between

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science, technology, and society are extremely useful. We need to prepare people to have enough knowledge and ability when encountering changes with competence to solve real-world problems. This calls for the need to have scientific literacy (Bond, 1989). Scientific literacy is a target in major reforms in the teaching of science today and is conceptualized as the main goal of science education (American Association for the Advancement of Science (AAAS), 1993; DeBore, 2000; Institute of the Promotion Science and Technology (IPST), 2003; National Research Council (NRC), 1996). Scientific understanding is a goal for a scientifically literate society. Scientific understanding deals with the ability to use the conceptual knowledge of science and the ability to differentiate between scientific data and data from other disciplines (Barlia, 2016). Scientific literacy, which is the gateway to achieve scientific and technological advancement and economic survival, is achievable through science education (Oludipe & Awokoy, 2010). Scientific literacy is for everyone because it enlightens and enables each individual to make informed choices and to make rational decisions where issues of science and technology are concerned. Therefore, all of us need to develop scientific literacy with the ability to understand how science works, to make informed decisions, to apply knowledge rationally, creatively and ethically and to use our science related skills to improve ourselves and to develop the country.

In addition, science involves life-long learning because scientific knowledge is about the natural world which has changed over time, so everyone must learn to apply science learning in our everyday lives and careers. Science enables us to develop our process skills in logical, creative, analytical, and critical thinking. It also enables us to obtain essential investigative skills for seeking knowledge and allows the ability for systematic problem-solving, and for verifiable decision-making based on diverse data and evidences. When students learn science that arouses excitement, enthusiasm, and challenges problem situations facing them, they corporately think and act together in order to understand and to see a connection between science and other issues in life so that they will be able to describe, explain, predict, and forecast things rationally (IPST, 2003).

At present, scientific literacy is an important issue affecting human decisions. It is evident at the international level in various perspectives of science education. Coll and Taylor (2009) conducted a survey of the perspectives of scientific literacy at the international level and found that scientific literacy played an important role in science education worldwide. The view of scientific literacy has spread in education at all levels from children to the general population. Scientific literacy can be developed from children to adults and scientific literacy is an indication that individuals have participated in the life-long sciences (Liu, 2009). Science scholars have suggested that the definition of scientific literacy should consist of components of knowledge of science, understanding and application of science, higher-order cognitive skills, the ability to use scientific knowledge to solve problems, understanding the nature of science, ethics that guide the work of scientists, and its relation to culture, society, and technology. Scientifically literate individuals will also be able to use science concepts, processes, and terms accurately and appropriately (Chin, 2005; Duschl, Schweingruber, & Shouse, 2007; Holbrook & Rannikmae, 2009; Norris & Philip, 2003; NRC, 1996; Preczewski, Mittler, & Tillotson, 2009; Rutherford & Ahlgren, 1990).

Chemistry is one of the most important branches of science. It enables learners to understand what happens around them (Sirhan, 2007). Chemistry topics generally involve studying about matter and understanding the properties of matter that are important in many disciplines such as health sciences, geography, physics, environmental science and economics (Brown, LeMay, & Bursten, 2000). Moreover, in recent years it has been shown that the use of chemicals can play a role in our daily life as a consumer both directly and indirectly. It can also affect human decision making in areas such as health, information on dietary intake (starch, carbohydrates, fats, vitamins) and food choices that affect the metabolism of the human diet. The use of chemicals can affect social decisions, for example, about choosing a place for locating an incinerator. The public must have knowledge and understanding about pollution control, chemical absorption processes, and catalytic converters, including economic decisions about climate change caused by the use of biotechnology in industry, and decisions about genetic engineering, such as genetically modified chemicals and their risk to humans and the environment (Gilbert, de Jong, Treagust, & van Driel, 2002). Therefore, we would not deny that that it is unavoidable that we will have to use chemicals in our lives. Gräber et al. (2001) have said that the direction of teaching chemistry in classrooms should consider real-life issues in the actual practice of science, applications in technological contexts, and social relations of environmental issues related to matter that will enable students to understand life and the world of science. In future, research about teaching chemistry effectively is needed to improve skills and chemical literacy, at both the secondary and tertiary levels (Moje, 1992). Therefore, it is necessary to prepare the population to be knowledgeable about chemicals in everyday life. It makes learning chemistry to not just learning content available only in textbooks or the requirements of the curriculum. However, for the learning to be effective, learners must be able to put that knowledge into practice in everyday life, get involved in activities concerning chemical issues, and make informed decisions about their own experiences rationally.

To achieve the goal of teaching chemistry to encourage the development of students' chemical literacy effectively, assessment instruments of chemical literacy have been very important in helping instructors to assess students' chemical literacy and evaluating the effectiveness of their practice in the classroom in promoting chemical literacy. Currently it is difficult to find a suitable instrument for evaluating chemical literacy. The researchers, as instructors of basic chemistry, were interested in constructing an assessment instrument for assessing students' chemical literacy. The instrument should be useful to lecturers and researchers at any institution for assessing the chemical literacy of learners.

Objective

This study aimed to construct an assessment tool to assess chemical literacy of undergraduate engineering students in Thailand.

Definition

Chemical literacy refers to a person's ability to comprehend and apply the knowledge of chemistry in everyday life in terms of understanding of three major aspects of knowledge, awareness and the application of chemistry in daily life appropriately and effectively. This chemical literacy test was constructed based on five components consisting of the following:

a) Knowledge and understanding of chemistry contents

This involves an understanding of relevant facts, concepts, principles, laws, hypotheses, theories, and models (AAAS, 1998; BouJaoude, 2002; Chin, 2005; Duschl et al., 2007; Gräber et al., 2001; Lee, 2002; Norris & Philips, 2003; NRC, 1996; PISA, 2008).

b) Knowledge and understanding of the relationship between chemistry, technology and society

This involves an understanding of the relationship between chemistry, technology and society and an awareness of the advantages and disadvantages of chemistry, technology and society, including an awareness of various benefits of chemistry for the general public (BouJaoude, 2002; Chin, 2005; Lee, 2002).

c) Application of analytical thinking

This involves the ability to break down complex problems into small, manageable components that allows the problems to be solved quickly and effectively (Duschl et al., 2007; Holbrook and Rannikmae, 2009; Lee, 2002; Norris & Philips, 2003; NRC, 1996; Preczewski et al., 2009).

d) Application of reasoning

This involves the ability to reach rational conclusions based on evidence, as well as to evaluate the logical soundness of other peoples' conclusions (AAAS, 1998; Lee, 2002; Norris & Philips, 2003).

e) Moral awareness and a sense of responsibility

This refers to an awareness of the potential consequences, both practical and moral, of chemistry-related scientific and technological developments on the general public (Gräber et al., 2001; Holbrook & Rannikmae, 2009).

METHODOLOGY

The researchers constructed a chemical literacy test assessing chemical literacy of students studying in engineering according to the components of chemical literacy based on scientific literacy tests developed by Chang and Chiu (2005), Mateapinitkul (2005), PISA (2006), and Shwartz, Ben-Zvi, and Hofstein (2006). Overall, the results were as follows:

a) Construction of Multiple-choice Chemical Literacy Test

The procedure in constructing an assessment instrument assessing knowledge and understanding of chemistry content is illustrated below.

Develop a table of specifications or test blueprints: The table was able to serve as a framework and a guide in writing and selecting of test items for assessing representative concepts of chemistry in 11 topics of fundamental chemistry and seven topics of general chemistry. The eleven topics related to the fundamentals of chemistry are 1) Theory of atoms, 2) Atoms, elements, and the periodic table, 3) Chemical bonds, 4) Mole and volume per mole, 5) Stoichiometry, 6) Gases, 7) Chemical equilibrium, 8) Acids-bases, 9) Electrochemical reactions, 10) Thermodynamics, and 11) Chemical kinetics. The seven topics of general chemistry are 1) Oil, 2) Pollution, 3) Food additives, 4) Cancer, 5) Polymers, 6) Detergents, and 7) Medicine.

Construction of 90 items of the multiple-choice test**:** The items were constructed with an item stem and four options according to a table of specifications with only one correct answer.

Index of congruence**:** To ensure relevance and adequacy of test items related to contents and concepts, three experts were asked to evaluate the congruence of test items and chemical concepts using a checklist as an assessment form.

Pilot testing**:** The revised test items based on the views of the thesis advisor and an expert were administered to a group of 50 students of the North-Eastern University. Appropriateness of words and time of testing were examined. Item analysis was investigated in terms of item discrimination indices, item difficulty indices, and distractor analysis.

Selection of items: Weak items identified in the analysis were discarded or revised and all item options that functioned well with wrong answers were plausible. Sixty items were chosen to comprise a test according to item difficulty indices ($.20 \leq p \leq .80$), item discrimination indices ($r \geq 0.2$), and a table of specifications.

Investigation of test quality: Sixty items were chosen to comprise a Multiple-choice Chemical Literacy test and the test was administered to a group of 400 students studying in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces to examine the internal consistency reliability (K-R 20), item difficulty indices, and discrimination indices.

b) Construction of Written Chemical Literacy Test

***Develop a table of specifications*:** The table used for constructing situation-based questions required students to write down answers and express opinions towards situation-based questions. This essay test consisted of four parts: 1) knowledge and understanding of the relationship between chemistry, technology and society, 2) application of analytical thinking, 3) application of reasoning and 4) moral awareness and a sense of responsibility. Eighteen given situations were constructed based on the guidelines of the scientific literacy test of Eubanks et al. (2006) and PISA (2008). The 18 situations were about electric cars, chemistry of global warming, gasohol, chemistry in daily life, acid rain, the solubility of substances in daily life, acids-bases, temperature, pollution, classification of substances, molecules, pressure, chemical equilibrium, electric cells, marble reacting with acid, factory emissions scenario, owner of soft-drink factory, and role of engineer as a responsible citizenship.

***Construction of 22 items of essay test and scoring rubric*:** The items were constructed according to a table of specifications. The scoring rubric was developed to score answers based as follows:

Two points for a correct answer, which shows understanding of the relevant chemistry content and theories and/or demonstrates good reasoning ability.

One point for a partially correct answer, which shows some understanding of the relevant chemistry content and theories but lacks certain important elements and/or demonstrates limited reasoning ability.

Zero point for a wrong answer, which shows a lack of understanding of the relevant chemistry content and theories and/or demonstrates a lack of reasoning ability.

***Index of congruence*:** To ensure relevance and adequacy of the test items related to the contents and concepts, three experts were asked to evaluate the congruence of test items and chemical literacy concepts using a checklist as an assessment form.

***Pilot testing*:** The revised test items based on the views of the thesis advisor and an expert were administered to a group of 50 students of the North-Eastern University for the purpose of collecting information about the usefulness of the test itself, and for the improvement of the test and testing procedures. Appropriateness of words and time of testing were also examined.

To investigate the quality of the test items: The written test was administered to 400 students studying in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces. Item analysis was investigated in terms of item discrimination power using item-total correlation coefficients, and item difficulty indices were calculated as a proportion of the average score and maximum score for each question. Internal consistency reliability (Cronbach's alpha) was computed for each part of the test. The results of the construction of an assessment instrument to assess the chemical literacy of undergraduate engineering students were summarized and discussed.

FINDINGS

The researchers constructed a chemical literacy test assessing chemical literacy of students studying in engineering according to components of chemical literacy based on scientific literacy tests developed by Chang and Chui (2005), Chin (2005), Mateapinitkul (2005), PISA (2008), and Shwartz et al. (2006) as indicated in Table1. There were two assessment formats. They were: 1) a multiple-choice test and 2) an essay test.

Table1. *Components of Chemical Literacy Test and types of assessment*

	Components of chemical literacy	Types of assessment	Item sources
1.	Knowledge and understanding of chemistry content	Multiple-choice	Chang and Chiu (2005), Mateapinitkul (2005), and PISA (2008)
2.	Knowledge and understanding of the relationship between chemistry, technology and society	Essay	Mateapinitkul (2005) and PISA (2008)
3.	Application of analytical thinking	Essay	Chang and Chiu (2005), PISA (2008), and Shwartz et al. (2006)
4.	Application of reasoning	Essay	Chang and Chiu (2005) and PISA (2008)
5.	Moral awareness and a sense of responsibility	Essay	Chang and Chiu (2005)

RESULTS OF ITEM ANALYSIS AND TEST VALIDATION

Four hundred first year students enrolled in the 1st semester of the academic year 2012 in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces were randomly selected using a stratified sampling technique from a population of 5,841 students to be a sample in pilot testing the items. Items and test statistics were computed using the SPSS statistical package for windows.

a) Item analysis of Multiple-choice Chemical Literacy Test:

In scoring the test items, the students were awarded one point for a correct answer and zero point for a wrong answer. The item difficulty index (*p*-value) is the proportion of the number of students who answered an item correctly to the total number of students, whereas the point biserial correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (KR-20) is used to judge the consistency of results across items on the same test, whether the item measures the same construct or whether the items are homogeneous. Nunnally (1978) has indicated 0.7 to be an acceptable reliability coefficient. Content validity is the degree of correspondence between the test content and the content of the materials to be tested as evident by showing the test blue print and Index of Congruence between three experts. The results of the item analysis are summarized in Table 2.

Table 2. *Item statistics (IOC, p-values, and discrimination indices) for Multiple-choice Chemical Literacy Test (See example of test items in appendix part1)*

Items	IOC	p	r	Item	IOC	p	r
1	1	0.29	0.21	31	0.67	0.36	0.24
2	1	0.56	0.31	32	1	0.36	0.24
3	1	0.24	0.25	33	1	0.41	0.35
4	1	0.21	0.21	34	1	0.55	0.35
5	0.67	0.25	0.28	35	1	0.26	0.21
6	0.67	0.29	0.29	36	0.67	0.35	0.36
7	0.67	0.32	0.24	37	1	0.25	0.26
8	1	0.31	0.22	38	1	0.37	0.28
9	1	0.42	0.30	39	1	0.25	0.27
10	0.67	0.20	0.22	40	1	0.23	0.22
11	0.67	0.22	0.23	41	0.67	0.24	0.21
12	0.67	0.24	0.24	42	1	0.21	0.21
13	1	0.30	0.21	43	1	0.20	0.26
14	0.67	0.35	0.26	44	0.67	0.51	0.52
15	0.67	0.46	0.29	45	01	0.53	0.34
16	1	0.23	0.28	46	0.67	0.24	0.25
17	1	0.48	0.34	47	1	0.20	0.20
18	1	0.44	0.52	48	0.67	0.48	0.56
19	0.67	0.42	0.35	49	0.67	0.41	0.27
20	1	0.25	0.25	50	1	0.61	0.36
21	1	0.46	0.32	51	0.67	0.54	0.68
22	0.67	0.22	0.21	52	1	0.48	0.56
23	1	0.54	0.27	53	1	0.52	0.40
24	1	0.29	0.26	54	1	0.24	0.23
25	1	0.31	0.22	55	0.67	0.31	0.23
26	.67	0.37	0.45	56	1	0.26	0.23
27	1	1.32	0.30	57	1	0.42	0.27
28	0.67	0.23	0.23	58	0.67	0.25	0.24
29	1	0.24	0.23	59	1	0.37	0.50
30	1	0.24	0.29	60	1	0.50	0.61

b) Item analysis of Written Chemical Literacy Test

The students were awarded *two points* for a correct answer—that is, an answer which shows accurate understanding of the relevant chemistry content and/or demonstrates good reasoning ability; *one point* for a partially-correct answer—that is, an answer which shows some understanding of the relevant chemistry content but lacks certain important elements and/or demonstrates limited reasoning ability, and *zero point* for a wrong answer—that is, an answer which shows a lack of understanding of the relevant chemistry content and/or demonstrates a complete lack of reasoning ability.

Item difficulty index (p-value) of an item is the quotient of the average score of all students and the maximum score, whereas the Pearson Product Moment correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (Cronbach's alpha) was used to judge the consistency of results across items on the same test or items that measure the same construct or items that are homogeneous. The results of the item analysis are indicated in Table 3 and Table 4.

Table 3. *Item statistics (means, p-values, and discrimination indices) of Written Chemical Test (One item =one situation and/or one case, see example of items in appendix part 2)*

Components of Chemical literacy	**Items**	**Frequency (N=400)**			**r**	**Mean score**	***P*-value**
		Score 0	**Score 1**	**Score 2**			
Knowledge and understanding of the relationship between Chemistry, technology and society	1	59	172	169	0.59	1.28	0.64
	2	49	199	152	0.66	1.26	0.63
	3	38	175	187	0.67	1.37	0.69
	4	54	169	177	0.62	1.31	0.66
	5	70	150	180	0.73	1.28	0.64
Average for each component					.65	1.30	0.65
Application of analytical thinking	1	189	187	24	0.55	.58	0.29
	2	221	136	43	0.67	.56	0.28
	3	213	150	37	0.58	.56	0.28
	4	215	126	59	0.65	.62	0.31
	5	158	150	92	0.68	.84	0.42
Average for each component					0.63	.64	0.32
Application of reasoning	1	225	116	59	0.72	.58	0.29
	2	157	173	70	0.74	.78	0.39
	3	198	154	48	0.71	.62	0.31
	4	151	169	80	0.68	.82	0.41
	5	240	89	71	0.58	.58	0.29
	6	276	88	36	0.63	.40	0.20
	7	148	186	66	0.67	.80	0.40
	8	72	101	227	0.51	1.38	0.69
	9	247	92	61	0.52	.54	0.27
Average for each component					0.64	.72	0.36
Moral awareness and a sense of responsibility	1	87	131	182	0.79	1.34	0.62
	2	69	117	214	0.86	1.36	0.68
	3	69	140	191	0.83	1.30	0.65
Average for each component					0.83	1.33	0.67

The Pearson Product Moment correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (Cronbach's alpha) is used to judge the consistency of results across items on the same test or items that measure the same construct or items that are homogeneous. Table 4 shows the summary of the analysis of test quality of the Chemical Literacy Test.

Table 4. *Summary analysis of test quality of Chemical Literacy Test (N=400)*

Assessment formats	Components of chemical literacy	Test quality
60-item Multiple-choice Chemical Literacy Test (Objective test for 80 minutes)	(1) knowledge and understanding of chemistry content	IOC = 0.67-1.00, p = 0.20-0.61, *r* = 0.20-0.68, *KR-20 = 0.72*
22-item Written Chemical Literacy Test (80 minutes for18 situation-based questions)	(2) knowledge and understanding of the relationship between chemistry, technology and society	IOC = 0.67-1.00 p = 0.63-0.69 r = 0.59-0.73 Cronbach's alpha =0.66
	(3) application of analytical thinking	IOC = 0.67-1.00, p = 0.28-0.42 r = 0.55-0.68 Cronbach's alpha = 0.61
	(4) application of reasoning	IOC = 0.67-1.00, p = 0.20-0.69 r = 0.51-0.74 Crobach's alpha = 0.82

	(5) moral awareness and a sense of responsibility	IOC = 0.67-1.0, p = 0.65-0.68 r = 0.79-0.86 Cronbach's alpha=0.77

DISCUSION

As a result of the development of the assessment instrument and investigation of the test quality of paper and pencil testing in assessing and reflecting the chemical literacy of students studying basic chemistry in college, the Chemical Literacy Test was constructed consisting of two assessment formats: Multiple-choice Chemical Literacy and Written Chemical Literacy. The Written Chemical Literacy Test consisted of four parts for assessing: knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning and moral awareness and a sense of responsibility.

a) Multiple-choice Chemical Literacy Test

This test had quality in terms of internal consistency reliability of 0.72 which was acceptably enough to assess the knowledge and understanding of chemistry content of students studying basic chemistry in Thai higher education institutions. This result was consistent with the results derived from studies of Chang and Chiu (2005), Mateapinitkul (2005), and PISA (2008). According to Chang and Chiu (2005) and PISA (2008), scientific literacy was measured as the understanding of scientific concepts, scientific methods, and the nature of science, whereas Mateapinikul (2005) measured students' knowledge and understanding of scientific concepts for students under 15-year-old.

b) Written Chemical Literacy Test

This test used situation-based questions in the context of chemistry in Thailand, assessing chemical literacy in four components. The first component was knowledge and understanding of the relationship between chemistry, technology and society. This aspect of chemical literacy was a part of the knowledge and understanding of the relationship between science, technology and society investigated by Mateapinitkul (2005) and PISA (2008) which used free responses in writing. The second component was application in analytical thinking, and the third component was application in reasoning. These components were situation-based questions that involved higher-order thinking skills that required students to apply analytical thinking in solving problems and answering problematic situations in chemistry in context and to create rational and reasonable conclusions based on evidence, or to evaluate whether or not conclusions made by others were consistent with the evidence. It can be seen that the Written Chemical Literacy Test was able to assess students' thinking skills and to relate scientific data to claims and conclusions (use of scientific evidence, which is similar to scientific literacy developed by Chang and Chiu (2005) and PISA (2008). The fourth component was moral awareness and a sense of responsibility toward the result of development of science and technology in solving problems in everyday life. Moral awareness and a sense of responsibility component was assessed using an assessment tool constructed by the researchers to reflect on the situation that the chemical was a virtue so that students should have a social responsibility as citizens regarding the impacts of social and environmental issues caused by the chemicals. Social responsibility was a new issue of concern in the perspectives of science education, which lacks monitoring and checking of such aspects.

The construction of the Chemical Literacy Test, an assessment instrument assessing chemical literacy and investigation of test quality, was found to be able to assess higher education students' chemical literacy as aforementioned in a similar way to the development of assessment tools by Shwartz et al. (2006). They constructed assessment tools measuring students' ability to: a) recognize chemical concepts, b) define some key-concepts, c) use their understanding of chemical concepts to explain phenomena and d) use their knowledge in chemistry to read a short article, or analyze information provided in commercial ads or internet resources. They developed tests to measure different levels of chemical literacy. Likert–type scales, open-ended questionnaires, and multiple-choice questionnaires were used to assess high-school students' levels of chemical literacy in Israel. Celik (2014) used some parts of the tests developed by Shwartz et al. (2006) to assess the chemical literacy of first-year students in the Department of Secondary Science and Mathematics Education in Turkey. In addition, Witte and Beers (2003) used a test to assess chemical literacy in aspects of knowledge and skills to understand information relevant to issues in everyday life using essay type questions by writing answers in chemistry in context in the examination for 17-year-old students in the Netherlands.

Therefore, the Chemical Literacy Test developed by the researchers was considered as a key part to be used as guidelines to assess the important construct of chemical literacy of students which is a major goal in teaching and learning chemistry in Higher Education of Thailand.

CONCLUSION

This research aims to develop an instrument with quality to assess the chemical literacy of students studying chemistry in Higher Education (University level). According to the aforementioned results, two assessment types of the Chemical Literacy Test were developed. The first type of assessment was the Multiple-choice Chemical Literacy Test to assess knowledge and understanding of chemistry content. The second type of assessment was a Written Chemical Literacy Test to assess four components of chemical literacy in knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning and moral awareness and a sense of responsibility. The Chemical Literacy Test was used to assess the chemical literacy of undergraduate engineering students because this test is acceptable in analysis of test items (Berk, 1984) and test validation in terms of content validity and reliability as indicated in the aforementioned results (Johnson & Christensen, 2008).

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APPENDIX
Example of Chemical Literacy Test (CLT)

Part 1: Multiple Choice Test Items *(Some examples of questions)*

Ex1. Which of the statements below is ***not*** the answer to explain Dalton's atomic model?
a. Atoms are small and indivisible.
b. Atoms of different elements can have the same mass of the neutrons.
c. Atoms of the same element have the same properties.
d. Elements react with each other in a simple ratio.

Ex2. Sulfur hexafluoride (SF_6) gas is colorless, odorless and non-reactive. Calculate the pressure (in atm) of 1.82 moles of gas with a volume of 5.43 liters stored in steel tanks at a temperature of 69.5 ^{0}C?
a. 4.5 atm b. 9.42 atm c. 12.52 atm d. 15.42 atm

Ex3. Which of the following about gasohol 91 is ***not*** correct?
a. It is a mixture of 95% of gasoline and 5% of ethanol.
b. It has an octane number of 91.
c. Reduces global warming.
d. Arises from the use of ethanol instead of using the MTBE.

Ex4. What are synthetic drugs?
a. Morphine and heroin
b. Marijuana and opium
c. Seconal and opium
d. Amphetamine and marijuana

Part 2: Written Test Items *(some examples of situations and cases)*

Part 2.1 Situations

Situation #1: Electric cars

Some people advocate the use of cars that use electricity as an alternative instead of a gasoline car, which seems to be the hope for the future. But currently, it is only possible for some areas. You are going to use the criteria in deciding what car to buy using such power. Therefore, if you are going to make a decision about buying an electric car, what criteria would you use in deciding to buy such car?

Answer

……………………………………………………………………………………………………

Situation # 5: Acid rain

The case of atmospheric pollution is due to "acid rain". Do you think that the conditions of acidity of the rain in the area of your house and Metropolitan areas of Bangkok are different? Explain how and why.

Answer

……………………………………………………………………………………………………

Situation #15:

Mr. Smith puts a small piece of marble with a mass of 2 grams in vinegar. After he puts it into vinegar, he leaves it overnight. He puts another marble into pure water and leaves it overnight as well. The next day, he takes the debris and makes it dry. What are the changes in the mass and shape of the marble after putting it in vinegar? Why does Mr. Smith conduct an experiment with the marble in water?

Answer

……...……..............................

Part 2.2. Case Studies

Case study # 1: The factory in an industrial estate is releasing toxins.

Currently found is an area of an industrial estate with many factories that use chemicals in the manufacturing process. The results of such a process cause the formation of toxins that are released into the atmosphere, with impact on health. Some have severe effects leading to death. In many other people, the toxins accumulate in the body so that the chronic hazard results in the need for medical treatment. As you are likely to be part of the industry in the future, do you think anyone else would have to be involved in solving the problem? What should be the approach to handle the problem?

Please express your opinions and answer the question about this case study

………………………………………………………..

Case study # 3: An engineer

You will be an engineer in the future. Do you think you will take responsibilities as a citizen of Thailand who will be critical to growth and sustainable development?

Please express your opinions and answer the question about this case study

………………………………………………………..

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Grade 10 and 12 Bhutanese Students' Attitudes toward Science in the Thimphu District of Bhutan

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ABSTRACT

Attitudes toward science have received substantive research, mainly because they influence students' science learning, their achievements, and their participation in science. Therefore, this study, conducted using mixed methods sequential explanatory design, examined the effects of gender, grade, ethnicity, and the parents or guardians' involvement on students' attitudes toward science. A total of 383 Grade 10 and 12 students completed a questionnaire measuring attitudes toward science and their parents or guardians' involvement in science. The data was analyzed using *t*-tests, one-way ANOVA, and Pearson's correlations. Based on the quantitative results, 13 students and 15 science teachers were interviewed. The qualitative findings supported the quantitative results. Gender had no significant effect on students' attitudes toward science, while attitudes based on grade were significantly different. The parents or guardians' involvement in science was positively correlated with students' attitudes toward science. The study suggests that students' attitudes toward science at higher grades can be improved by offering science as a subject to interested students, depending on their science performance in previous grades.

Keywords: attitudes toward science; Bhutan science curriculum; mainstream and science stream students; parental involvement.

INTRODUCTION

Background: Science Education in Bhutan

Bhutan, a small landlocked country between the world's two most populous countries—China and India—introduced science education (borrowing the curriculum from India) to its school children with the inception of a modern education system, which was a part of the modernization process that began in 1961. Since its inception, the science curriculum has undergone several revisions at different times, in various ways and in an unplanned manner, mainly with a view to "Bhutanize" it or make it more innovative within a Bhutanese context (Childs, Tenzin, Johnson, & Ramachandran, 2012).

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The government's 10th five-year plan (2008–2012) prioritized the reform of the science curriculum, and in order to have a detailed study well- informed perspectives for major science curriculum reformation and also to recognize and understand the issues and challenges presented by the number of revisions the science curriculum had undergone, a needs assessment for science education from different stakeholders' perspectives was conducted (Childs et al., 2012). The findings of this needs assessment led to a further revision in the curriculum's content and the implementation of a reformed "spiral curriculum" is currently still in process.

Statement of the Problem

In all the countries where progress has been strong in the areas we strive to develop, the strength of the education system has been in math and science.

—Jigme Khesar Namgyal Wangchuck, Fifth King of Bhutan (Royal Education Council, 2012; p. v)

Science knowledge and education are critical for a developing country's developmental process. Bhutan, like other developing countries, places great importance on its science education and has spent a considerable amount of money on science education, as judged by its investments into the various revisions of its science curriculum, as well as its investments into science laboratories, science equipment, and in-service training for science teachers and laboratory assistants. This is because science is recognized as an indispensable feature of a modern society that plays an integral part in people's lives, both now and in the future. Yet, most science is learned in abstract and Bhutanese people, especially students, have found science to be difficult (Rinchen, 2003) in a number of ways. This is unfortunate because the beliefs or opinions of students may indicate an unfavorable attitude toward science, which can influence students' performance in ways that reinforce lower achievement (Güzel, 2004; Kan & Akbaş, 2006; Papanastasiou & Papanastasiou, 2002).

Students' attitudes toward science can serve both as an outcome and as a factor (Akçay, Yager, Iskander, & Turgut, 2010). As an outcome, it is believed to be the result of science learning in school. Science in Bhutanese schools is taught in various ways at different grade levels—as environmental science (EVS) at the pre-primary level through Grade 3, then as an integrated common course for all students from Grades 4 through 8, and finally as three specialized subject disciplines (physics, chemistry, and biology) for Grades 9 through 12. The students' experience of learning science in their science classes thus varies by grade level, with a change in teaching mode from student centered to teacher centered as students move from lower to middle secondary school, which has probably helped to shape students' attitudes toward science (Childs et al., 2012; Movahedzadeh, 2011).

The students' attitudes toward science are a leading factor that can influence their science learning (Perkins, Adams, Pollock, Finkelstein, & Wieman, 2005) because an individual student with a favorable attitude toward science often looks forward to science classes and laboratory experiments. Moreover, there is growing evidence that individual students who possess favorable attitudes toward science perform better academically in science as well as in other subjects, because there is a relationship between learning about science and learning about other subjects (Narmadha & Chamundeswari, 2013). Science teaches students to think critically, not only in science but in other subjects as well (Movahedzadeh, 2011; Yaşar & Anagün, 2009). In addition, attitude seems to explain why some students engage in science and others do not (Aydeniz & Kotowski, 2014). Therefore, "the investigation of students' attitudes towards studying science has been a substantive feature of the work of the science education research community for the past 30-40 years" (Osborne, Simon & Collins, 2003, p.1049), and anyone familiar with the science education literature will be aware that students' attitudes toward science—along with the many factors affecting it, ranging from students' gender to the involvement of parents or guardians at home—are being researched so that proper interventions can be planned.

One of the most important factors affecting students' attitudes toward science is gender (Weinburgh, 2000). According to Brotman and Moore (2008), many studies, with a few exceptions, demonstrate girls' less favorable attitudes toward science in general and their lower levels of participation in science courses than boys. Also, they reported that girls prefer biological science and physical science topics related to their lives and society more than physical sciences, a trend similarly reported by Clewel and Campbell (2002). Another important factor affecting students' attitudes toward science is grade. With each higher grade, there is a decline in positive attitudes toward science (Greenfield, 1997; Neathery, 1997; Weinburgh, 2000) or the attitudes of older students are less favorable than the attitudes of younger students (Greenfield, 1997). One of the underlying reasons for the decline in attitudes is in how science is taught at upper grade levels (Weinburgh, 2000). According to Aydeniz and Kaya (2012), the learning among students in science classrooms at upper grade levels is limited to most teachers preparing students for tests, rather than promoting a conceptual understanding through active learning strategies. However, Shah, Mahmood, and Harrison (2013) found that students' attitudes toward science learning become more favorable as grade increases.

The research on the effect of ethnicity on students' attitudes toward science is limited in comparison to research on attitudes toward science as influenced by gender and grade. However, ethnicity is often thought to potentially influence students' attitudes toward science, their career interests, and their science achievements (Catsambis, 1995; Fnu, 2011; Neathery, 1997). However, Neathery (1997) found no correlation between ethnicity and attitude toward science. Similarly, Hafza (2012) also found that ethnicity alone did not influence students' attitudes toward physics but saw a significant interaction between gender and ethnicity. An individual's ethnicity sensitized him/her to negative gender stereotypes but gender failed to qualify the effect of ethnicity (Gonzales, Blanton, & Williams, 2002).

The research findings on the influence of parental involvement on students' attitudes toward science vary according to the many different forms of parental involvement. Parents' involvement has great potential for affecting their children's attitudes, both positively and negatively (Alrehaly, 2011), their self-concept and self-esteem, and their behavior (Rinchen, 2003), and may lead to measurable gains in student achievement (Desforges & Abouchaar, 2003; Porumbu & Necsoi, 2013). However, the forms and extent of parental involvement are affected by factors including the family's social class, the parents' overall level of schooling (Tare, French, Frazier, Diamond,& Evans 2011), the level of the mother's education (Susan & Kinley, 2014), the mother's psycho-social health, material deprivation, the biological age of the children (Desforges & Abouchaar, 2003), and single parent status (Wanat, 1992).

Most of the studies exploring students' attitudes toward science described above have been conducted elsewhere, and there have been only a few such studies in Bhutan .For example, Tshering (1995) investigated the relationships between Grade 10 students' attitudes toward science and their achievement in science, and concluded that science achievement was correlated with attitude toward science. Rinchen's (2003) study titled "Bhutanese Girls' Perception of Science and the Impact of Science on Career Choice" provides insights into the critical factors—like social and cultural practices, parental expectations, the effects of rapid growth of the school system, and a failure to recognize the importance of guidance and role models—that contribute to Bhutanese girls' liking or succeeding in science and their influence on career choice. Over the past decade, there have been no studies in Bhutan devoted to students' attitudes toward science, despite the fact that Bhutan's Annual Education Statistics have reported a large gender gap every year in the number of boys and girls enrolling in the science stream and tertiary science–related fields. According to the Annual Education Statistics 2014, a total of 1,740 boys but only 1,144 girls enrolled in the science stream in public and private higher secondary schools in the year 2014. Likewise, the number of males(m) far exceeds the number of female(f) students in tertiary science-related fields like engineering and technology (m = 1,250, f = 510), forestry and agriculture (m = 389, f = 149), medical technology (m = 71, f = 59), medicine (m = 40, f = 24), public health (m = 16, f = 9), and science/mathematics (m = 342, f = 167), with the exceptions being nursing (m =122, f = 145) and architecture and design (m = 7, f = 8). Such inequalities in gender participation in most of the science-related fields have a negative impact in general on society. For example, "a predominantly male group of engineers tailored the first generation of automotive airbags to adult male bodies, resulting in avoidable deaths for women and children" (Margolis & Fisher, 2003. p. 3).

Moreover, since students' attitudes measured at any instant often show the context in which they are measured, it is not appropriate to apply the findings on students' attitudes toward science from one time period to another, and also from one society to another. Therefore, research on attitudes must be an ongoing field of investigation (Barmby, Kind, & Jones, 2008). Thus, the aim of this study was to explore the attitudes of Grade 10 and 12 science stream students toward science in the context of contemporary science education in Bhutanese schools, and to understand how gender, ethnicity, grade, and parents' or guardians' involvement in science at home with their children affects Bhutanese students' attitudes toward science. The following research questions guided the study.

- What is the level of attitude toward science of Grade 10 and 12 science students studying in public middle and higher secondary schools in the Thimphu district of Bhutan?
- How are the differences in attitudes toward science affected by personal characteristics such as gender, ethnicity, and grade level?
- Is there a relationship between parents' or guardians' involvement with their children in science at home and students' attitudes toward science?

METHODOLOGY

a) Research Design

The present study employed a mixed methods sequential explanatory design, which implies collecting the quantitative data and obtaining the statistical results in the first phase, and then a follow-up with a few participants to help explain or elaborate on those statistical results in the second phase. The second qualitative phase was connected to the first quantitative phase through the development of the interview questionnaire based on the quantitative results

b) Respondents

A total of 383 students from a population of 2,071 completed the survey questionnaire. The selection was based on proportional stratified random sampling to have samples representative of Grades 10 and 12, and also to make the sample size of each stratum proportional to the population size of the stratum. By calculating the proportions, it was determined that the sample size of 383 study participants should include 319 (83.3%) Grade 10 and 64 (16.7%) Grade 12 students. Within the sample, 53.4% (208) were female and 45.7% (175) were male. Additionally, 185 (48.3%) students were of the Sharchop ethnicity, 115 (30%) were Ngalop, 78 (20.4%) were Lhotsam, and only 5 (1.3%) were others.

For the interview, 28 participants were sampled, consisting of 15 science teachers (11 females and 4 males) and 13 (7 boys and 6 girls) Grade 10 and 12 science-stream students, using the purposive sampling technique. The selected science teachers had at least five years of science teaching experience.

The main reason for choosing Grade 10 and 12 science stream students as the respondents for this study was that they were at the end of middle and higher secondary education, which are the most crucial stages in the life of Bhutanese students, who will be in a better position to compare their experiences across the three disciplines of science (physics, chemistry, and biology) and form genuine opinions after having studied them separately for at least one year.

c) Data Collection Tools

The survey questionnaire used in this study consisted of three sections. The first was related to background information and demographic data; the second measured the students' attitudes toward science and consisted of 60 items, with each item rated on a 5-point Likert scale (from 1 = *strongly disagree* to 5 = *strongly agree*); and the third section measured their parents' or guardians' involvement in science at home, and consisted of 16 items rated on a 5-point Likert scale (from 1 = *never* to 5 = *always*) for each item.

Since attitude toward science often serves as an outcome and also a factor of science learning (Akçay et al., 2010), the items included in the questionnaire to assess attitude in this study investigated both attitudes toward science (self-concept in science, practical work in science, and future participation in science) and attitudes toward science learning (keenness to learn science, enjoyment of science learning, disinterest, teacher interaction), which were adopted from the studies of Kind, Jones and Barmby (2007) and Shah and Mahmood (2011), respectively. The items on attitude toward science learning in the questionnaire required the respondents to reflect on their experiences during their daily routine of science learning, both in school and at home, to elicit their general attitude, which would be more regular (Shah, Mahmood & Harrison, 2013), while the "attitude toward science" items sought the respondents' opinions on a number of statements and shifted their attention from their daily routine of science learning toward their past experiences and future plans with regard to science. The coefficient of reliability, based on Cronbach's alpha for all of the items in the second section of the questionnaire, was .921. The third section of the questionnaire relating to parents or guardians' involvement in science at home asked the respondents to reflect on the things that parents or guardians can generally do with their children relating to school science learning activities at home. The Cronbach's alpha coefficient of reliability for that section of the questionnaire was .814. Both alpha values indicated that the survey questionnaire was suitable for use in this study.

The overall obtained means of the students' attitudes toward science and the parents or guardians' involvement in science were classified into five different levels (1.00–1.50 very low; 1.51–2.50 low; 2.51–3.50 moderate; 3.51–4.50 high; 4.51–5 very high) developed using the equal interval classification method.

For qualitative data collection, a set of questions developed based on the quantitative results was used for the one-on-one semi-structured interviews. The questions were concise and open-ended, and basically sought the explanations to the "why" and "how" of the quantitative results, with regard to the students' perceptions and opinions of science, their feelings about science, the students' future plans with science, their views about their parents or guardians' involvement and its effect on attitudes toward science, barriers to parents or guardians' involvement, and the factors causing the differences in attitude between the genders and grades, and among the four ethnicities. The questionnaire was validated through the experts' review.

d) Data Collection Process

Approval to conduct the survey and interviews in middle and higher secondary schools in the Thimphu District was sought from the Department of School Education under the Ministry of Education, Thimphu, Bhutan. Subsequent to the department's approval, the Thimphu *Dzongkhag* (district) Education and the *Thromde* (municipality) Education offices each issued an official letter asking the principals of the schools under their jurisdiction to provide me with help and support. As per the appointments given by the principals of the selected schools, the survey questionnaires were administered to the randomly selected students. The students were given 30–40 min to complete the questionnaires. The quantitative data collection from the eight schools selected was completed within one and half months (from mid-July to August 2015), and the quantitative data was analyzed. The quantitative data analysis was then followed by the qualitative data collection. The teachers and students were interviewed. Care was taken to not include the respondents to the survey questionnaire in the interview to avoid the survey and interview questions influencing each other. Before the interview, the oral consent of teachers and students was sought and the interviews were recorded. Each participant interview lasted for 20–25 min. All of the participants were asked the same questions but with considerable variation in the questions' order, the exact words in the question, and follow-up questions. The interviews were all completed within a month (mid-September to mid- October 2015).

e) Data Analysis

The quantitative data was analysed using independent sample *t*-tests to compare the differences in attitudes toward science between the genders and between Grade 10 and 12 students. One-way analysis of variance (ANOVA) followed by Tukey honest significant difference (HSD) test were employed to determine the difference in attitudes toward science among the four ethnicities. A Pearson's correlation coefficient was computed to determine the relationship between students' attitudes toward science and their parents or guardians' involvement in science at home.

For qualitative data analysis, the interview recordings of the participants were transcribed on an ongoing basis at the end of the day and reviewed with the recordings to ensure that nothing was left out. The transcript was studied repeatedly to look for themes or patterns among the data through a process of discovery. I interpreted the experiences, beliefs, and opinions of the students and teachers to form a narrative description of the meanings that I ascribed, interweaving the exact words of the participants, which I integrate with the quantitative results and presented under the Results and Discussion sections of this paper.

FINDINGS

Quantitative Data

The overall parents or guardians' involvement in science at home was at a moderate level (M = 3.32, SD = 0.77), while the general attitude of students toward science was at a high, positive level (M = 3.69, SD = 0.43). Females scored higher (M = 3.71, SD = 0.43) than males (M = 3.67, SD = 0.44) in their attitudes toward science, but an independent samples *t*-test showed no statistically significant difference at the $p < .05$ level in attitude toward science between genders (see Table 1). Levene's test for equality of variances for Grades 10 and 12 was violated, $F(1, 381) = 5.66$, $p = .018$. Due to the violated assumption of homogeneity of variance, a t statistic that did not assume homogeneity of variance was computed. A significant difference in the scores for Grades 10 (M = 3.67, SD = 0.45, n = 319) and 12 (M = 3.84, SD = 0.32, n = 64) at the .05 level of significance [$t = -3.75$, $df = 117$, $p < .001$, 95%

confidence interval (CI) for mean difference −0.27 to −0.09] indicated that the Grade 12 science students had more favorable attitudes toward science than tenth graders (see Table 1). The ANOVA was significant, $F(3, 379) = 4.55$, $p = .004$ (see Table 2), for the students' attitudes toward science among the four ethnicities—Sharchop ($M = 3.64$, $SD = 0.45$, $n = 185$), Ngalop ($M = 3.71$, $SD = 0.44$, $n = 115$), Lhotsam ($M = 3.76$, $SD = 0.37$, $n = 78$), and others ($M = 4.26$, $SD = 0.34$, $n = 5$)—and the assumption of homogeneity of variance was tenable using Levene's test, $F(3, 379) = 1.15$, $p = .329$. A post hoc comparison conducted using the Tukey HSD test revealed a significant pairwise difference between the mean scores of Sharchop and other ethnicities ($p = .008$) and also between Ngalop and other ethnicities ($p = .028$), while no significant differences were observed between the Lhotsam and others or among any two of the Ngalop, Sharchop, or Lhotsam ethnicities (see Table 3). The students' attitudes toward science was found to have a significant positive correlation with parents or guardians' involvement in science at home with their children, $r(381) = .35$, $p < .001$.

Table 1.*Comparison of t-Test Results for Attitudes Toward Science by Gender and Grade*

			N	Mean	Standard Deviation	Degrees of Freedom	*t*	*p*
Attitude toward science	Gender	Male	175	3.67	0.44	381	−0.917	.359
		Female	208	3.71	0.43			
	Grade	10	319	3.67	0.45	117	−3.75	.000
		12	64	3.84	0.32			

Table 2.*One-Way ANOVA for Attitudes Toward Science Among the Four Ethnicities*

		Sum of Squares	*df*	Mean Square	*F*	*p*
Attitude toward science	Between Groups	2.51	3	0.84	4.55	.004
	Within Groups	69.67	379	0.18		
	Total	72.17	382			

Table 3.*Tukey HSD Comparison for Attitudes Toward Science*

	Sharchop	Ngalop	Lhotsam
Ngalop	0.07 (*p*=.469)		
Lhotsam	0.12 (*p*=.178)	0.04 (*p*=.899)	
Others	0.62* (*p*=.008)	0.55*(*p*=.028)	0.50 (*p*=.055)

RESULTS AND DISCUSSION

a) General Attitudes of Students Toward Science and Their Perceptions of Science

The students' attitude toward science, as measured by the survey questionnaire, was at a high, positive level. This result is similar to a prior finding in Bhutan by Tshering (1995), who found that Grade 10 students (in the 1993 academic year) in middle and higher secondary schools had positive attitudes toward science. Moreover, the teachers' opinions about students' perceptions of science and the students' own opinions about science in the present study were closely aligned, fine, and balanced:

> Students, they love science but they find it difficult. They actually like science but because they don't have a proper base from Class 7, they cannot understand the concepts properly. So that's why they find it little difficult in higher classes—in 9 and 10. (Teacher 11, female, middle secondary school [MSS])

> Science is a fun subject but not always, though. Sometimes, it's hard to understand but then since it's everywhere around us, we can relate it to our environment and everything, and it's quite fun. (Student 12, female, Grade 12)

Among the three disciplines of science, almost all of the students found biology easy, and some found physics easy, while most of the students found chemistry difficult. However, the students basically loved science in general and wanted to follow science in the future, as they understood the importance of science, including the fact that science would give them a wide career scope. Unfortunately, most of the students had no knowledge about different careers in scientific fields, with the exception of two high-profile jobs: doctor and engineer professions.

> When it comes to science, they always think of science as, after learning science, they think of it as only doctors or engineers. Besides that, they don't have any other knowledge. (Teacher 13, male, higher secondary school [HSS])

This could be attributed to the fact that students might have heard about these careers from seniors or that they have encountered only these two science-related careers, which imply that teachers and parents need to make students in Grade 10 and 12 science streams more aware of the different kinds of careers in scientific fields, so that they can make proper choices with enough information at the crucial stages of their school lives. There is also a need for future researchers to investigate students' attitudes toward science, particularly chemistry and physics, to understand why students find chemistry and physics difficult and hence to plan a proper intervention.

b) Gender and Attitudes Toward Science

No significant differences were found in students' attitudes toward science in terms of gender. This finding is comparable to the results of the studies by Koç and Böyük (2012); Neathery (1997); Ong, Mesman, and Yeam (2014); Tshering (1995); and Yilmaz and Timur (2012). Science teachers and the current generation of students generally did not perceive females to be less interested in science or as having an unfavorable attitude toward science compared to males, or vice versa, but rather believed that females and males are equally proficient and capable in science.

> As such, we do not have much difference, and I don't see that science is very good among boys or very good among girls. They do equally, and as such, there is no remarkable difference that can be easily noticed. (Teacher 13, male, HSS)

Although gender had no effect on students' attitudes toward science, a difference in optional subject choices between male and female students at Grade 12 in the science stream was observed, with most females taking more or both of the optional subjects (biology and mathematics), while males were more inclined to take mathematics and to drop biology (Greenfield, 1996).

> We have 44 students in our class, and all the girls, including one boy, are taking biology. So, I think boys are more interested in mathematics than

> biology, while more girls are taking both of the subjects—math as well as biology. I think girls are more interested in biology and boys are more interested in math. (Student 8, female, Grade 12)

Thus, it seems that males were more interested in mathematics and the engineering and technology fields, while females were more interested in biology-related fields (Desy, Peterson, & Brockman, 2011; Özgün Koca & Şen, 2011); at the same time, females also took mathematics, as it has high subject value (since a basic level of mathematics is used in science subjects) and they wanted to keep their options open in both mathematics and biology-related career courses for admission into colleges. Such decisions by females also tended to indicate that the females were not as confident about their own academic ability (Craker, 2006) and have not yet completely decided what career they would like to follow.

> I don't really have an aim because if I had an aim, I would have dropped one of the optional subjects. I didn't drop any one of the optional subjects because I am scared that if I drop one optional subject and don't do better in the subject I take, I wouldn't get any one of them—either the biological or engineering fields. So, I am trying to take both, and then I will go in whatever I get. I am thinking that way. (Student 8, female, Grade 12)

Females appeared to have less positive belief in their own abilities in science and were concerned over thoughts like, "What if I don't perform well in the optional subject I have taken after dropping the other one?" Thus, they did not want to take risk. The males, on the other hand, were more confident of their intellectual abilities and their own estimation of the difficulty of the optional subject that they had taken and dropped. In addition, girls have been found to exhibit dependent behaviors, unlike boys, and tend to receive more advice on future science careers from teachers compared to boys (Paludi, 1998). Thus, their teachers advised them to take both of the optional subjects to have a wider choice of careers in both biology- and mathematics-related fields.

c) Grade and Attitudes Toward Science

One of the results of this very study indicated that Grade 12 science stream students had a significantly more favorable attitude toward science than Grade 10 students. This finding is similar to that of Yilmaz and Timur (2012), who found eighth grade students to have a more positive attitude compared to seventh graders; and Shah et al (2013), who found that students' attitudes toward science learning became more favorable with increasing grade levels. But this result cannot be directly compared with the results of several previous studies (Barmby et al., 2008; Greenfield, 1997; Neathery, 1997; Weinburgh, 2000), which observed a decline in positive attitude toward science with each successive grade because the present study compared the attitudes toward science of students in science streams and those in the mainstream, finding that there were few similarities and more differences. Thus, the homogeneity of variances between these two grades while employing a *t*-test was violated. This explains the unusual and distinctive quality of this study.

There are many factors that have caused the difference in attitude between these two grades, particularly how science is treated at these two grade levels in the education system while assessing the students' performance in science, the need to prepare for national board examinations, and social beliefs about science. But the main factor, which is more important than all other factors in causing the difference in attitude toward science between the Grade 10 and 12, might be the difference in how science is offered (as a general or optional subject) in the mainstream Grade 10 and in the Grade 12 science stream. As Grade 10 is a basic education level, science is studied as a general subject (along with six other subjects, English, *Dzongkha*[1], math, history & civics, geography, economics/IT). At Grade 11 (post basic education level), students joining the science stream to study science along with two language subjects, English and *Dzongkha*, have a choice between three streams (arts, commerce, and science), which they join mainly depending on their performance in science and mathematics in the Grade 10 board examination and also on the students' interest.

> In class ten students take all subjects. Including the science, they take history, geography, economics/IT (optional) and language subjects. In total they have lots of subjects—about nine. And their subjects of study are not narrowed down just to science. They have broad and diverse learning areas, but in Class12, when you pass from Class 10, we are allowed to choose our stream—commerce, art, and science. There our subjects get narrowed down according to our individual interest in the stream that we have opted for. If we take science stream, we are learning only science besides the language subjects. Therefore, I feel that the subject that they are learning is of their interests. Therefore, their attitudes toward science should be better I suppose." (Student 13, male, Grade 12)

Since only those students who have scored good marks in science and mathematics in Grade 10 and those who are interested or those who have decided on a future in science opt for the science stream in Grade 11, their attitudes toward science are more favorable in Grade 12 than in Grade 10. Thus, the present study concludes that if science is offered by the schools to interested students depending on their science performance in previous grades, their attitudes toward science will be better at higher grade levels.

In addition to the factors mentioned above, the second most important factor causing differences in attitude toward science between Grades 10 and 12 might be the difference in the number of years that students have studied science in its three separate disciplines. Up to Grade 8, science is studied as an integrated subject. Then, in Grades 9 through 12, science is learned according to the three scientific disciplines (physics, chemistry & biology). It takes time for the students to fully understand the three different sciences, and to bridge the gap in concepts between science taught as an integrated subject and the three disciplines of science. In Grade 10, students have had less than two years to become comfortable with learning science according to the three scientific disciplines, while Grade 12 science students have learnt science based on the three disciplines for the last three years and are thus more comfortable and have a more favorable attitude toward science. Therefore, even the science teachers noticed that teaching science to students in Grades 11 and 12 is easier compared to teaching science to Grades 9 and 10.

d) Students' Attitudes Toward Science, Ethnicity, and Parent/Guardian Involvement

Significant differences in students' attitudes toward science between ethnicities (Sharchop and others; Ngalop and others) were found. However, this finding is not conclusive as it might be distorted by limitation of a relatively small sample in the "others" category (as this group is very small in the population itself), and there were no differences found in students' attitudes toward science between any two of the three major ethnicities (Sharchop, Ngalop, and Lhotsam). However, this finding could not be compared with the previous two

[1]national language of Bhutan

studies on attitude toward science in Bhutan as the "ethnicity" factor was not studied in either of those previous studies. In addition, almost all the teachers and students interviewed expressed the opinion that they had never looked into nor noticed any difference in attitude toward science among different ethnicities.

> I have not witnessed such a difference until now. Actually, I have just not tried to look to see if the ones who are not doing well are from which part of the country and the ones who are doing well are from which part of the country. They all seem kind of similar. Because, honestly, if you just see the people in the class, it's hard to distinguish who is from where—mostly they look the same. (Student 9, female, Grade 12)

However, they expressed the opinion that the difference in students' attitudes toward science might be due to the difference in parental involvement at home among families or might be due to the difference in how children are helped in science by their parents or guardians and not due to their ethnicity.

> I don't think that ethnicity has any influence over it. Well, it mainly depends on the difference in how they are brought up and how they are exposed and helped in science by their parents, and not because of who they are or from where they come. (Teacher 6, female, HSS)

However, it is apparent that the pattern and amount of parental involvement differs among families or ethnic groups (Hill & Taylor, 2004; Henderson & Mapp, 2002) and it is recommended that future research should be conducted to investigate the patterns and amount of parental involvement among the different ethnicities in Bhutan.

As expected, a significant positive correlation was also found in this study between students' attitudes toward science and parents' or guardians' involvement in science at home with their children. This finding is in accordance with the results of Alrehaly (2011) and Oundo, Poipoi, and Were (2014). When parents or guardians are involved in science, the children valued science learning and felt supported and motivated to learn. However, only the educated parents with a science background were able to be more involved with their children's science education in comparison to parents who lacked scientific knowledge. This is in agreement with the findings of Rinchen (2003) and Alrehaly (2011). Educated parents with a scientific background, as well as advising their children, providing moral support, materials and assistance in seeking information, and pictures for science projects through the Internet, often became actively involved in simple science experiments with their children using the materials available at home and made science learning a part of play or games.

> When we are spending time together, they ask questions that are related to science, making it a part of play and games. We try to answer them and finally we understand what is behind things. (Student 9, female, Grade 12)

Even though illiterate parents or parents who lacked a scientific background could not assist much in the science learning of their children, they were able to motivate their children to learn more science when the children saw their parents fascinated upon hearing some interesting common science facts shared by them after having learned them in a science class.

> Last year in chemistry, when I first learned about silicone, I was so intrigued because neither I nor my parents knew that the little packet (silica gel) was kept

> in our clothes and leather shoes to absorb moisture. So, I told them about that and they seemed fascinated and I got even more inspired by science. (Student 2, female, Grade 12)

Therefore, it is apparent that it is not necessary for the parents' level of education to be high in order for them to motivate or support their children's learning at home (Hoover-Dempsey & Sandler, 1997) and that students can benefit in various ways from the involvement of their parents (Henderson & Mapp, 2002), including students developing a favorable attitude toward science. This implies that teachers and schools should encourage parents to be actively involved in their children's science activities at home and to support their children's science learning even though there may be significant barriers to parental involvement.

SUGGESTIONS

The results of the present study add to previous evidence indicating that if science is offered to interested learners based on their performance in science in previous grade levels, students' attitude toward science will be better at higher grade levels.

There are several ways in which future research could extend the scope of this study and an interesting investigation might be to include parents or guardians as respondents in the study in order to understand the parents' perspectives on their involvement in science at home with their children, and to identify how parents or guardians' involvement varies among the four different ethnicities in Bhutan.

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