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A Study of Chinese College Students' Images of the Scientist

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Abstract

Using the Draw-A-Scientist Test (DAST), this study investigated Chinese undergraduates' images of scientists. The stereotype of the scientist was stable in Chinese undergraduates' conceptions as an elderly or middle-aged, intelligent, knowledgeable, hardworking and committed male. Chinese students tended to view the scientist as not well adjusted, dressing simply, serious, thin, living an introverted and unpleasant life. However, alternative images such as a smiling face and an optimistic outlook also emerged in a small portion of the participants' drawings of a scientist. Chinese students are impressed by the high social recognition and success of scientists. It is worth noting that most Chinese students imagined scientists as individuals working alone to conduct scientific studies. What is more, a considerable number of Chinese students regarded social contributions as the primary motivation for pursuing a scientific career instead of internal interests and passion for science.

Key words: Scientist image, undergraduate, China

Introduction

The images of scientists have been studied worldwide since the seminal study with American high school students conducted by Mead and Mertraux in 1957. A few years later, Beardslee and O'Dowd (1961) investigated the images held by American college students, and argued that the strong features of the images of the scientists are "highly intelligent individual devoted to his studies and research at the expense of interest in art, friends and even family".

A number of similar studies on college students have been carried out in different parts of the world. For example, Rubin and Cohen (2003) investigated Hebrew- and Arabic-speaking pre-service teachers' conception of scientists in Israel using the "Draw-A-Scientist-Test" (DAST) (Chambers, 1983). It was found that the image of the scientist is perceived as predominantly male, a physicist or a chemist, working in a laboratory. However, the Arabic-speaking students showed a preference for "classical Islamic scientists." Bovina and Dragul'skaia (2008) studied humanities and science students' representations of science and the scientists via a free word association test in a Russian college, and found that students from two groups produced positive and negative associations about science and scientists. Demirbas (2009) adopted the DAST to determine Turkish science teacher candidates' perceptions and attitudes with regard to science and scientists. Their study produced similar results that students imagined scientists as careful, intelligent, creative and hardworking and described scientists as wearing glasses, having a wired hair style, in a laboratory wearing a lab coat, having a beard and being bald.

Despite a considerable amount of research elsewhere, there have been few studies reporting college students' image of scientists from the People's Republic of China. Some have indicated that the perceptions of scientists held by students are related in some way to their attitudes toward science, locus of control, and self-efficacy (Finson., Riggs, & Jesunathadas, 1999; Schibeci, 1989, Erten, Kiray & Sen-Gumus, 2013). Besides, college students will eventually constitute an influential segment of the citizens whose views make up the public response to science. Therefore, in this study we attempted to investigate Chinese undergraduates' perceptions of scientists and might have some implications for science educators.

Method

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Participants

This study consisted of total 93 undergraduates in Huazhong University of Science and Technology (HUST), a top comprehensive research university in China. Student participants were randomly selected from different majors including engineering, art, education, economics, management, and philosophy. Fifty-five male students and thirty-eight female students participated in this study.

Research instrument

The Draw A Scientist Test (DAST) has been used in previous studies to determine students' views about scientists (e.g., Newton & Newton, 1992; Barman, 1999). The DAST was also translated into Chinese and adopted by Chinese scholars to probe K-12 students' images of scientists (e.g., She, 1998; Chiang & Guo, 1996; Zhang, 2005; Wu, 2010; Zhang, 2011.). For this aim, it was judged that using a questionnaire by revising the DAST would be appropriate in this study. The questionnaire involved five questions which had different contents and response types, as summarized in Table 1.

Table 1. The structure of the questionnaire

Question	Contents	Response Type
1	Physical image of the scientist	drawing a picture with some captions
2	Source of the image	Choosing among given options
3	Activity of the scientist drawn	Writing 3 activities
4	The scientists around us	Identifying someone and giving reason
5	Willing to embark scientific career	Answering Yes or NO and giving reason

Results and Findings

Questions 1: physical images of the scientist

This question was adapted from the DAST and Song and Kim's study (1999). Students were asked to draw the appearance of a typical scientist and to give some captions with relevant information, such as the age of the scientist, the characteristics of the scientist's appearance, what the scientist is doing and the environment of the scientist in the drawing.

The data from students' pictorial and written response were added together, but, if the same information appeared in the drawing as well as in the caption, this was counted only once. The data were analyzed according to Chamber's seven traits of standard image of scientist (lab coat, eye glasses, facial hair, research symbols, knowledge symbols, products of science, and captions). Researchers who have used the DAST have reported the images drawn were overwhelmingly male, so it would seem reasonable to add the sex of the scientist to the seven indicators of the standard image (Finson, Beaver, & Cramond, 1995).

Table 2 shows the percentages with which each of the eight traits occurred in students' sketches. The Chinese undergraduates' perceptions of the physical image of the scientist turned out to be similar to the results of previous studies. That is to say, "male" (91.7%), "weird facial hair" (73.8%), "eyeglasses" (56.0%), "lab coat (47.6%)" and "knowledge symbols" (41.7%) were the most popular features of the physical image of the scientist. Besides, 64.3% of the subjects in study described the scientist as being elderly or middle aged. It reflected that Chinese undergraduates depicted scientists as elderly or middle-aged, intelligent, knowledgeable, hardworking and committed. The typical drawings were seen in Figures 1 and 2.

Table 2. Physical image of the scientist drawn

Characteristics	Percentage (%)
Male	91.7
Wired hair style	73.8
Eyeglasses	56.0
Lab coat	47.6
Knowledge symbols	41.7
Captions	37.0
Products of science	21.4

Research symbols	17.9

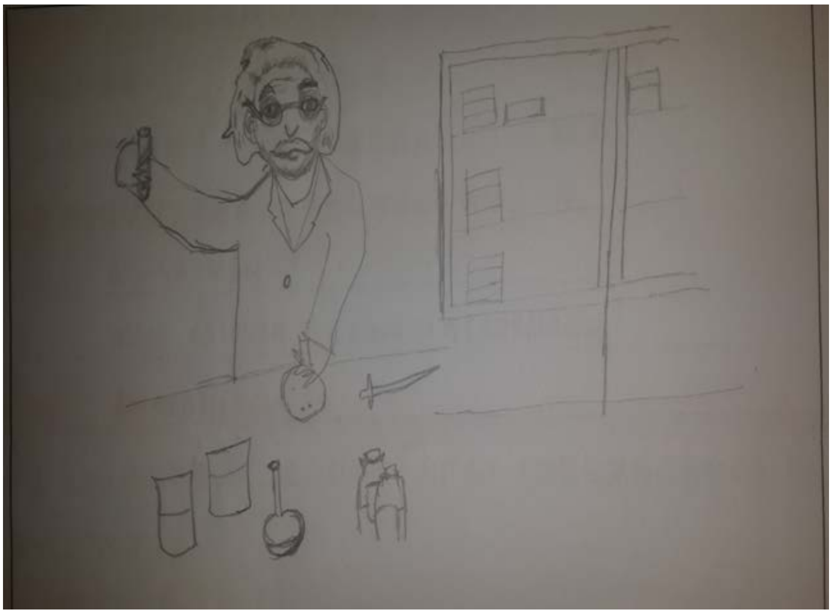

Figure 1. An Einstein-like image of the scientist by a Chinese undergraduate student

Figure 2. A Chinese scientist image by Chinese undergraduate

It is of interest that only 18% of the drawers presented research symbols such as flasks and testing tubes in their drawings. Out of the 93 participants, 60 undergraduate students identified the research filed of the scientist drawn, among which nearly half (45%) of the students suggested chemistry, followed by physics (25%), biology (21.7%), geography (3.3%) and mathematics (1.7%). This confirmed that the least showing of research symbols in student drawings is not because students do not pop up chemistry or physics field in their mind during drawing, rather it might attribute to undergraduate students' constant exposure to laboratories and contact with actual science researchers on campus, and therefore they sketched what they really saw in laboratory instead of old memories of chemistry equipment in school lab or fictional images of science lab.

In their written responses a significant proportion of students used terms such as "balding", "growth of hair", "wild-haired", "bearded", or "long sideburns" to describe the scientist they drawn. This implied that Chinese undergraduate students tended to view scientists as behaving strange and not well-adjusted. What is more, most undergraduates thought the scientist drawn was "thin" or "slim" which revealed that scientists were believed by Chinese undergraduates as working hard and living a low quality life.

However, contrasting perceptions of scientists also emerged. Out of the 93 undergraduates, 38.5% imagined scientists with “untidy dressing”, 23% portrayed scientists as “simply dressed”, while 38.5% depicted scientists as “dressing neatly” or “dressing in suits”. Similarly, with regard the facial expression of the scientist drawn, 22% of the subjects described as “committed”, 16.7% associated with the term “serious’, while 8.3% considered the scientist as “smiling”, “optimistic” or “eye-beaming”. This reflected that Chinese undergraduates began to view scientists as “everyday” people and reflect reality rather than fictional character being depicted.
Across the 93 pictorial representations of scientists, eleven scientists were given names by students. Four students used the name ‘Longping Yuan,’ a Chinese agricultural scientist known for developing the first hybrid rice varieties since 1970s. Four students used the name ‘Einstein,’ two students used the name ‘Hawking,’ and one used the name ‘Newton.’ These scientists are pervasively reported in the Chinese mass media (e.g., Hawking, Longping Yuan）or frequently presented in science textbooks (e.g., Newton, Einstein).

Question 2: source of the images

In this question, undergraduate students were provided five possible sources of information for images of scientists (magazines and newspapers, movies and TV, internet, textbooks and teachers, parents and friends) and asked to select one from which they mainly derived their knowledge of the scientist. The results were shown in Table 3.

In general, college student images of scientists were affected mostly by school education. 34.7% of the undergraduates indicated that they acquired knowledge of scientists from their school teachers and textbooks. The internet (28.4%) was the second source of information, followed by movies and TV (19.0%), and magazines and newspapers (11.6%). However, no one indicated parents and friends as the source of information (0%). This might account for the independent mind of college students as adults as well their usually living apart from their families in terms of physical distance.

Table 3. Source of the images of the scientist

Sources	Percentage (%)
Textbooks and teachers	34.7
Internet	28.4
Movies and TV	19.0
Magazines and newspapers	11.6
Parents and friends	0.0

Question 3: activities of the scientist drawn

Undergraduate subjects were asked to write three activities the scientist they drew might carry out as their work. It was found that the activities of scientists were generally imagined as observing and experimenting (29.4%), searching literature (16.5%), data analyzing and writing report (16.5%), thinking (11.8%), attending conferences and seminars (7.5%), and lecturing (2.5%), as seen in Table 4. It can be seen that Chinese undergraduates possessed beliefs that scientist predominately conducted scientific studies within laboratories (experimenting, thinking, data analyzing and so forth) and did not see much variation in their scientific work.

Table 4. Activities of the scientist draw

Activities	Percentage (%)
Observing and experimenting	34.7
Searching literature	28.4
Data analyzing and writing report	19.0
Thinking	11.6
Attending conference and seminars	0.0
Lecturing	2.5

It is of interest that although students in this study were given the opportunity to draw more than one scientist, only one student did so. This revealed that in most Chinese undergraduate’s minds, the scientist is an isolated figure and there is an unawareness of collaboration between scientists and team work among Chinese undergraduates.

Question 4: willingness to pursue a career in science

Over half of the Chinese undergraduates in this study did not have the occupational aspirations to be a scientist. The subjects of interest were asked whether they would like to pursue a scientific career in future. 42.5% of the subjects indicated they were thinking of being a scientist, and 54.8% of the students answered that they had no plan to be active in science field.

Across the students who had no intention to be a scientist, 37.2% expressed that their “personality is not suitable for scientific work.” 23.3% said that they were not “interested in science,” and 14.0% of the students did not feel they were competent to become a scientist. Students expressed concerns that to be a scientist required “full dedication to time consuming work”, “great determination”, and “patience and perseverance in boring research.” For these students, this image of a scientist implied that scientists were socially inept, introverted and fully devoted to his studies regardless of other demands on his or her time, even family. The kind of life a scientist lives is thought by Chinese students to be unpleasant and greatly limited by the nature of scientific work. If these features of the life of the scientist do not fit with the student beliefs about themselves and hopes for the future, it is not surprising that students would not consider an occupation in science.

Among the students wishing to enter the science field, 33.3% expressed that they would like to consider a career in science because scientists could “contribute to society, the country and human well-being.” 23.0% indicated an intention to become scientists due to their “interest in science.” 18.9% of the participants regarded “achieving personal value” as their motivation to enter science. This revealed that on the one hand Chinese undergraduates were impressed by scientists’ high social status and success; however, on the other hand, many of them tended to follow science out of patriotic devotion rather than from internal interest, curiosity or personal enthusiasm for science.

Summary

In conclusion, the images of scientist held by Chinese college students resembles in many ways the image held by college students from other countries across the world. The majority Chinese undergraduates hold the stereotypical image of the scientist as elderly or middle-aged, intelligent, knowledgeable, hardworking and committed.

Specifically, Chinese students tended to view the scientist as not well adjusted, dressing simply, serious, thin, living an introverted and unpleasant life. However, alternative images of the scientist also emerged in this study that a small portion of the participants depicted the scientist as smiling and optimistic. Besides, the high social recognition and success of the scientist as positive aspects of the scientist was impressed by Chinese students.
It was worth noting that most Chinese students did not see much variation in the scientist’s work. Most of them imagined the scientist working alone. It is interesting that a considerable number of Chinese students regarded social contribution as their primary motivation to pursue a scientific career, which revealed a kind of pat patriotism instead of internal interest and passion as their motivation to be active in science.

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Would a STEM School 'by any Other Name Smell as Sweet'?

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Would a STEM School 'by any Other Name Smell as Sweet'?

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Abstract

The purpose of the present study was to understand how students' math scores change on Texas Assessment of Knowledge and Skills (TAKS) after their schools changed into specialized, inclusive STEM high schools. The sample was selected from five schools in the state of Texas and included 142 students who could be tracked from 7th to 11th grade (2007-2011). The longitudinal data were obtained from the database at the Texas Education Agency (TEA). Paired t-tests by applying Wald Test of Parameter Constrained in Mplus 7 were computed, and the 95% CIs were interpreted to determine how students' math scores on Texas Assessment of Knowledge and Skills (TAKS) changed. Results showed students' achievement during their STEM school experiences had a statistically significant increase ($p<0.05$; $d=0.64$) from 10th to 11th grade. When considering longitudinal change, there was a statistically significant difference in the growth rates favoring STEM school participation ($p<0.05$, $d=0.34$), and both genders experienced practically important changes (Male, $d=0.30$; Female, $d=0.44$). The changes that occurred as schools earned STEM designation seemed to have a positive impact longitudinally. However, it is important to monitor schools to determine if the improvements are durable.

Key words: STEM, Inclusive STEM schools, TAKS, T-STEM academies

Introduction

Science, technology, engineering, and mathematics (STEM) education is critical for today's economy in the United States (U.S.) and abroad. Historically, mathematics and science have been perceived as the disciplines for only talented or gifted students (Stotts, 2011). However, today's economy requires every individual to be educated in STEM disciplines (Erdogan, Corlu, & Capraro, 2013; Young, House, Wang, Singleton, SRI International, & Klopfestein, 2011). STEM education for every citizen is also important to facilitate their personal and societal decisions related to health, environment, and technology in the 21st century (National Research Council [NRC], 2011). To provide such opportunities for each individual in our society, the U.S. needs STEM schools that every student can attend without impediment. In response, specialized STEM school initiatives (Thomas & Williams, 2009) have grown, especially after the report *Rising Above the Gathering Storm* (National Academy of Sciences, 2005). Specialized STEM schools are a candidate to be the nation's best resource for building a STEM workforce.

The idea of specialized STEM schools is not new. The origins of STEM schools trace back to the early 20th century. The need for a talented workforce has led people to establish such institutions so that the nations' economic growth could be guaranteed. The current incarnation of STEM schools is not only intended for students who are interested and talented in STEM disciplines, although there are STEM schools established for only those types of students. The National Research Council (2011) classified STEM schools under three categories: (1) selective STEM schools, (2) inclusive STEM schools, and (3) schools with STEM-focused career and technical education. These three types of schools have slight differences such as in how they select students. However, all three types of schools offer their students a distinguished curriculum and opportunities for research and inquiry with expert teachers and advanced laboratories. In addition, their main aim is to prepare students to obtain STEM degrees in college and pursue a STEM career (NRC, 2011). Despite the long history, we understand little about the contributions of STEM designated schools on student achievements.

The state of Texas has one of the largest inclusive STEM school initiatives in the U.S. The T-STEM initiative started in 2006 and is steadily expanding its scope. As of 2013, there were 65 T-STEM academies (26 campuses for grade 9-12 and 39 campuses for grade 6-12) serving approximately 35,000 students. The T-STEM initiative

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divided the state into 7 regions and each region incorporated a T-STEM center, which was designed to provide technical assistance to the T-STEM academies. These centers supported over 2,800 teachers in specialized areas of concentration (Texas Education Agency, 2013). The distinguishing characteristic of T-STEM academies was the "STEM blueprint" that guided schools in the transition to becoming a STEM school (Avery, Chambliss, Pruiett, & Stotts, 2010). The blueprint clearly explained the guiding principles of T-STEM academies, such as a challenging curriculum, practices related to the daily life, a wide range of STEM coursework, and learning opportunities to meet every student's needs. The blueprint also indicated that T-STEM academies cannot be selective at the time of enrollment but at least 50% of students they accept have to be economically disadvantaged and at least 50% of students enrolled have to come from historically underrepresented populations (i.e., female, diverse, and disabled; Avery et al., 2010; Young et al., 2011). Texas was unique in that it developed a systematic plan for T-STEM schools along with the requirements and expectations.

In the present study, we analyzed high-stakes tests (i.e., Texas Assessment of Knowledge and Skills [TAKS]) results for students who attended T-STEM schools. The sample was drawn from the schools designated to become T-STEM academies in the 2008-09 academic year. This longitudinal study began when students were attending non-STEM schools and followed them through their 11^{th} grade exit testing from a T-STEM designated school. Therefore, students had attended traditional schools and later began to attend specialized T-STEM schools. In particular, our research questions were:

1) What is the change of students' mathematics scores on TAKS between 7^{th} and 8^{th} grades before their schools transition to T-STEM schools? What is the change of students' mathematics scores on TAKS between 10^{th} and 11^{th} grades after their schools became T-STEM schools?
2) Does students' 7^{th} to 8^{th}grade mathematics growth rate differ as compared to their 10^{th} to11^{th} grade growth rate?
3) How do male and female mathematics performances change from 2008 to 2011?

The Nexus of Achievement and STEM Schools

TAKS is a standardized high-stakes test administered by the Texas Education Agency (TEA) and a commonly used indicator to measure the success of Texas schools at all levels (TEA, 2014). Although the Texas accountability system using this metric has identified T-STEM academies as performing above the state average (Young et al.), T-STEM schools still follow their students' progress closely to make sure that they meet the standards. T-STEM academies put special emphasis on students' performance on TAKS because it is important for students to become academically talented and for T-STEM schools themselves to attract prospective students. Therefore, in this study students' TAKS scores on mathematics were used to evaluate success of school reform with STEM designation.

School Reform with STEM Designation

Educational reforms in schools have aided the U.S. economy since 18^{th} century, especially during national crises. Educational reforms started by Benjamin Franklin continued with major changes in the educational system of the U.S., such as The Smith-Hughes Act of 1917 (Lunenburg & Ornstein, 1996; Parker, 1993). In response to international advancements, such as the launch of Sputnik, the federal government passed the National Defense Education Act (National Defense Education Act of 1958). Affected by the Civil Rights movement in the 1960s, the federal government passed the Elementary and Secondary Education Act (ESEA; Elementary and Secondary Education Act of 1965). In response to the *A Nation at Risk* report, the Educate America Act was passed (Educate America Act of 1994). The next move by the federal government was the No Child Left Behind Act, which was basically the reauthorization of the ESEA (No Child Left Behind Act of 2001). Educational reforms made by the federal government are likely to continue as the demands of society change.

Changing societal demands caused policymakers to think about and act on educational reforms. These reasons include but are not limited to (a) providing equity in education; (b) establishing vocational education; (c) advancing mathematics, science, and language art instructions; (d) creating an optional national curriculum; (e) setting high standards; and (f) creating accountability systems (Stotts, 2011). Among all these reasons, educational reforms almost always involved mathematics and science. Educational reforms in mathematics have shifted back and forth between traditional teaching of theoretical mathematics and progressive teaching of practical mathematics (Stotts, 2011). Educational reforms in science have always focused on making students think and act as scientists and connecting science to the real world (Ravitch, 1995; Seymour & Hewitt, 1997). The policymakers' reasons for initiating educational reforms resulted in changes that appeared strikingly familiar to U.S. stakeholders.

The final educational reform that caused the STEM education initiative was the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES; America COMPETES Act of 2007). This act aimed to enhance innovation in science and technology in the U.S. because science and technology are the key disciplines needed to be competitive among the global community in the 21st century (Corlu, Capraro, & Capraro, 2014). However, achieving the goals of such educational reforms has always been difficult.

Changes Due to STEM Designation

Only three studies have examined transitional STEM schools. Of these studies, one reported quantitative findings, one reported an aggregated synthesis, and one reported qualitative findings (Gourgey, Asiabanpour, Crawford, Grasso, & Herbert, 2009; Stotts, 2011; Young et al., 2011). The results were generally positive but none of the results were large. In two instances, the phenomenon of STEM schools was so new, the data was scarce and there was little in the way longitudinal robustness. Only one study reported results that were not academic in nature. There is too little information for determining the impact of transitioning to a STEM school.

At least marginally improved academic performance was reported in all three studies. In a matched study design there was a difference in academic performance favoring students in T-STEM academies, but the effect sizes were small (0.12 to 0.17) (Young et al., 2011). Further, 9th graders in T-STEM academies performed better in mathematics (Gourgey et al., 2009; Young et al., 2011), and 10th graders in T-STEM academies performed better in mathematics and science than their counterparts in the comparison schools. T-STEM Academies exhibited other important academic outcomes as well. For example, students in grade 9 were 1.8 times more likely to meet the benchmarks of TAKS reading and mathematics, and 10th grade students were 1.5 times more likely to meet benchmarks of TAKS reading, mathematics, science, and social science than their counterparts. When considering subpopulations, students from a low socio-economic background performed slightly better on mathematics compared to the previous year. Additionally, on average, Hispanic students demonstrated higher mathematics scores then previously demonstrated. However, a slight decrease was observed for African American and White students (Gourgey et al., 2009). Across the two studies, achievement was marginally improved, and in only one case was there a large improvement, and that was in the case of Hispanic students.

The use of school variables can provide some degree of understanding of the importance of transitioning to a STEM school. Variables such as students pursuing a college education, female representation in STEM courses, student confidence in their STEM success, and school rating were used. Students in a STEM school were more interested in pursuing a college education, and this result was not limited to STEM majors in college. There was a greater level of enfranchisement and enrollment of girls in taking advanced STEM courses (i.e., Advanced Placement Math and Science). Students' confidence to be successful in STEM courses increased as well as their risk tolerance. A school that was *Academically Unacceptable* became *Academically Acceptable* after being a STEM school for two years, a change that was attributable to increased achievement scores on high-stake tests. The higher achievement was also accompanied by an increase in post-secondary matriculation than had been reported historically (Stotts, 2011). While the variables of interest changed in a positive direction, it is important to determine what the prior performance was and the degree to which performance had changed.

Method

Data Sources

The sample consisted of 4 years of TAKS mathematics data for 142 (62 female) students attending five schools in Texas. The first measurement for the sample occurred when the students were 7th graders in 2007, and the other three repeated measurements subsequently occurred in 2008, 2010, and 2011. Because the same students were measured, the last measurement occurred in 2011 when they were 11th graders.

We purposefully selected the schools that became T-STEM academies in the 2008-09 academic year to be able to observe the growth differences of the students before and after their schools earned T-STEM designation. There were a total of 17 schools that became T-STEM academies in the 2008-09 academic year. While ten of these 17 schools served students in grades 6 through 12, the remaining seven schools only served students in grades 9 through 12; therefore, these seven schools were eliminated. Of the remaining ten schools, five schools were lost to missing data across the 5 year study. While students and not schools were the level of interest, the two were inextricably linked. Students who did not have a TAKS score in any one of the four measurement years were lost to the study. TAKS data were missing for one of three reasons: (1) leaving the T-STEM school, (2) transferring into another T-STEM school or other school, and (3) dropping out of school. Our baseline estimate of performance was when schools the students were attending were not T-STEM academies for the first two measurements in 2007 and 2008. The two subsequent measurements in 2010 and 2011 (when students were in 10^{th} and 11^{th} grades, respectively) were assessed after the schools had been a T-STEM academy for one year, 2008-09. We did not consider the academic year 2008-09 (2009-test scores) performance because it was the year the school, teachers, and students were undergoing the transformation. During the transformation year, teachers might still have been relying on familiar strategies, techniques, and materials; and administrators were still learning what to look for and how to facilitate the T-STEM Academy model.

Data Analyses

Several decisions were made about how the data would be used. The 2008-2009 academic year represented the year in which the change occurred. It functioned as the inflection point in the data analyses or as a point symbolizing a regression discontinuity (Shadish, Cook, & Campbell, 2002). Missing data were expected because the data were longitudinal. We first examined the missing data for characteristics of patterns. Once we determined that missing data were missing completely at random, we used the multiple imputation strategy (Rubin, 1987) by imputing 20 data sets. When more than 40% of the data were missing for any school, it was lost to the study. We used Mplus version 7 (Muthén & Muthén, 1998-2012) to conduct the analyses. Maximum likelihood restricted (MLR) was used as our estimation method. MLR is a robust estimation technique which disregards the assumption of normality (Muthén & Muthén, 1998-2012). Paired *t*-tests by applying Wald Test of Parameter Constrained were used to examine differences between growth rates of 7^{th}-8^{th} and 10^{th}-11^{th} grade performances for all students. We also examined the growth rate differences for males and females separately.

Two new variables were created by subtracting scores of 7^{th} grade from 8^{th} grade, and scores of 10^{th} grade from 11^{th} grade. Then, a paired *t*-test by applying Wald Test of Parameter Constrained was used on these two new difference (growth) variables by using 20 imputed data sets. The 95% Confidence Intervals (CI) were computed for means of 2007, 2008, 2010, and 2011 measurements of TAKS mathematics scores and for the differences, which were used in the paired *t*-tests. The 95% Confidence Intervals (CI) were also computed for the growth differences within female and male subpopulations. The reason for choosing to report CIs was because the APA Task Force on Statistical Inference (Wilkinson & the APA Task Force on Statistical Inference, 1999) strongly recommended the reporting of effect sizes and CIs. Therefore, CIs and Cohen’s standardized effect estimates were computed (cf, Navruz, & Delen, 2014; Thompson, 2007).

Results

What is the change of students’ mathematics scores on TAKS between 7^{th} and 8^{th} grades before their schools transition to T-STEM schools? What is the change of students’ mathematics scores on TAKS between 10^{th} and 11^{th} grades after their schools became T-STEM schools?

In order to see the trend of the means for TAKS mathematics scores in four years, 2007, 2008, 2010, and 2011, means and corresponding 95% CIs for means were drawn on Figure 1.

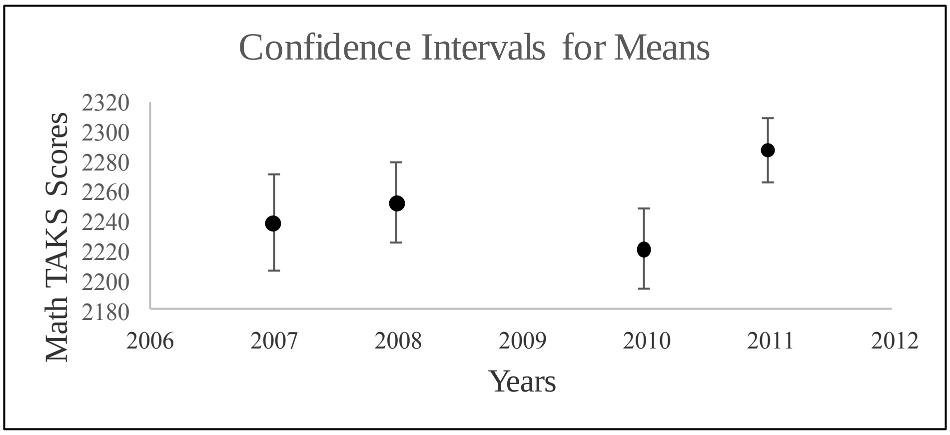

Figure 1. Dots show the means for the TAKS mathematics scores, and 95% CIs for means were shown.

Based on the mean estimates shown in Figure 1, there is an increase from grades 7 to 8 and grades 10 to 11. Notice the slope for 2007-2008 was positive but closer to zero than to 1, and 2010-2011 was greater than 1. Figure 2 shows the mean difference in 95% CIs. Confidence intervals provide information about the precision of the point estimate and spread of the data (Capraro, & Capraro, 2003; Thompson, 2006). In addition, CIs provide information about the statistical significance (Cumming & Finch, 2005). In this case (Figure 2), the 2 whiskers do not overlap by 50%; therefore, there is a statistically significant difference in performance at least at the .05 level (Capraro, 2004).

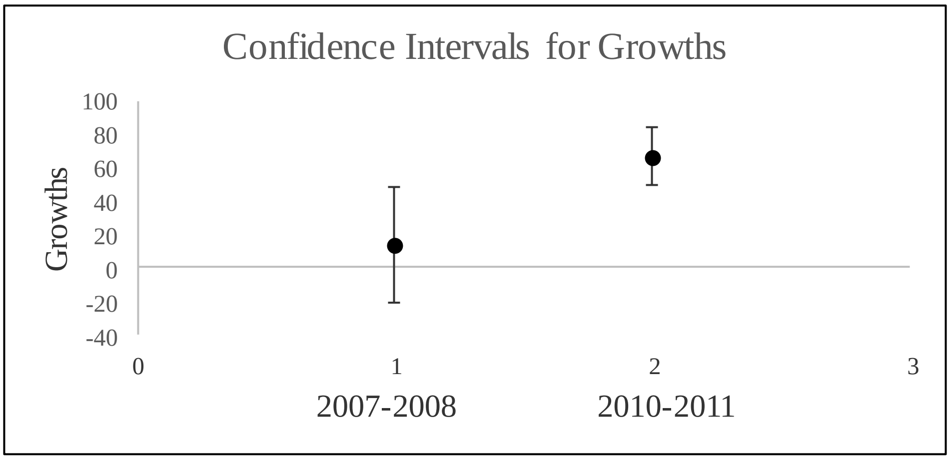

Figure 2. The first (1) 95% CI is for the mean of difference between scores in grades 7 to 8, and the second (2) 95% CI for the mean difference between scores in grades 10 to 11.

The mean differences were tested separately to determine whether or not they were statistically significantly different than 0. The mean difference between grades 7 and 8 was not statistically significantly different from 0 at .05 significance level (t (141) = .293, p= .769). The second mean difference for grades 10 and 11 was statistically significantly different from 0 at .05 significance level (t (141) = 3.572, p = .001).

Does students' 7th to 8thgrade mathematics growth rate differ as compared to their 10th to11th grade growth rate?

In the paired *t*-test, the mean difference scores, which were shown in Figure 2, were tested whether or not they were statistically significantly different from each other. In Mplus, a paired *t*-test can be conducted by testing a model fit to determine whether the difference of two means is equal to 0. Because we are testing the model in Mplus, the Wald Test of Parameter Constrained, which follows Chi Square distribution (Engle, 1984), was used. In our model, in order to test if the means of the differences were equal, the two parameters' estimates for the means were constrained to be equal. Based on the Wald test statistics, 4.639, with 1 degree of freedom produced a *p*-value smaller than 0.05, which meant we rejected the null for the equality of the growths between 7-8 and 10-11.

How do male and female mathematics performances change from 2008 to 2011?

In order to determine males' and females' growth rate pattern, 95% CIs for means of both groups were drawn. Figure 3 shows the differences of these growth rate differences with 95% CIs for both males and females.

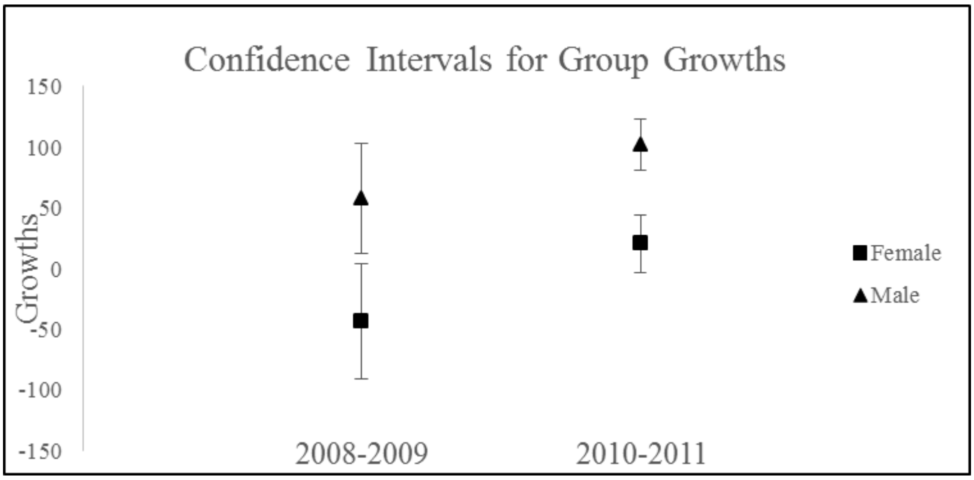

Figure 3. Both males' and females' 95% CIs are for the mean of difference between scores from grades 7 to 8 (2008-2009) and the 95% CIs for the mean difference between scores from grades 10 to 11 (2010-2011).

The mean differences for males from 7^{th} to 8^{th} grade showed a statistically significant increase (p < 0.05, d=0.49) while the mean of female scores yielded a statistically significant decrease (p< 0.05, d=-0.22). However, between 10^{th} and 11^{th} grades, both groups showed a statistically significant increase (Male, p< 0.05, d=1.06; Female, p< 0.05, d=0.21) on their TAKS mathematics scale scores. Means and SDs were provided in Table 1 and Cohen's *d* effect sizes were provided in Table 2. Figure 3 showed the 95% CIs for both male and female mathematics score growth when the students were in middle and high schools. The growth of male students' mathematics scores was statistically significantly higher than female students' scores in both middle and high schools. The growth rate difference for females (d=0.44) was slightly higher than males (d=0.30). For male students, the growth rate was positive in both cases.

Table 1. Mean, SDs, and 95% CIs

Grade	Male		Female		Overall	
	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI
7th	2238 (199)	[2194, 2281]	2238 (199)	[2189, 2288]	2238 (200)	[2205, 2271]
8th	2295 (158)	[2261, 2330]	2195 (150)	[2158, 2232]	2252 (164)	[2225, 2278]
10th	2211 (165)	[2175, 2248]	2232 (163)	[2191, 2273]	2220 (165)	[2193, 2247]
11th	2314 (128)	[2286, 2342]	2252 (127)	[2221, 2284]	2281 (132)	[2265, 2308]
8th-7th	57 (207)	[12, 103]	-43 (192)	[-91, -3]	14 (209)	[-21, 48]
11th-10th	102 (96)	[81, 123]	20 (95)	[3, 44]	67 (105)	[49, 84]

Table 2. Cohen's d Effect Sizes

Growths	Male	Female	Overall
	d	*d*	*d*
8th-7th	0.49	-0.22	0.07
11th-10th	1.06	0.21	0.64
(11th-10th)-(8th-7th)	0.30	0.44	0.34

Discussion

The purpose of the present study is to examine how students' mathematics growth on the TAKS changed after their schools turned into specialized inclusive STEM schools. To the best of our knowledge, this study is unique in terms of its sampling procedure compared to previous studies regarding STEM schools' performance. Previous research, although not experimental, has mostly compared two groups of students by applying either the propensity or exact matching procedure (Young et al., 2011). However, in the present study, rather than comparing two groups of students in terms of their school types (STEM and non-STEM), we observed the same students' mathematics growth on TAKS by comparing students' mathematics growth when their schools were non-STEM schools with their mathematics growth after their schools turned into specialized STEM schools.

To refer back to the title, *Would a STEM School 'by any Other Name Smell as Sweet'?*, Juliet in Shakespeare's *Romeo and Juliet* argues that the names of things do not matter; only what things are matters. The study indicates that regardless of what we call the schools, what they are is what matters. Looking at the results, findings indicated students' overall mathematics TAKS score growth between the 7^{th} and 8^{th} grade was not statistically significant. This might be explained by the fact that mathematics teachers in most traditional public K-12 schools focused on a teaching methodology aligned to a theoretical perspective of algorithmic mastery (Stotts, 2011). In order for students to experience positive growth in mathematics, they need to develop both a conceptual and a procedural understanding of mathematical concepts (Ashlock, 2005) simultaneously without scaffolding. STEM practices (i.e., Project Based Learning (PBL) and Problem Based Learning) in mathematics classrooms might be effective instructional methods for helping students learn mathematics meaningfully by simultaneously developing their conceptual and procedural understanding with necessary scaffolds situated in applied learning that is part of their STEM PBL lessons.

Another finding revealed that after the transition year for when students' schools turned into specialized STEM schools, their mathematics growth on TAKS between 10^{th} and 11^{th} grade was statistically significant. In other words, students' 11^{th} grade mathematics TAKS scores were statistically significantly higher than their 10^{th} grade mathematics TAKS scores with 0.64 Cohen's *d* effect size. This result is congruent with our assumption that the support, STEM School Vision, and professional development in specialized STEM instruction for teachers delivered by T-STEM centers were effective and appropriate; thus, their students' mathematics growth showed an increased pattern from 10^{th} to 11^{th} grade as opposed to their growth from 7^{th} to 8^{th} grade. It appears that the STEM high school model seems to be paying off.

The results showed a marked decrease in student performance in 2010 as compared to 2008. In 2009, the transition year, we expected performance to reflect some of what teachers had been doing prior to their school becoming a STEM school and some of what the teachers were learning they needed to do in a STEM school. The minor change in 2010 seems to indicate that the change in school focus impacted scores for the years 2009 and 2010. In 2011, after being in a STEM school for three years, students' scores exceeded their previous highest mean. Most importantly, the steepness (slope) of the gain far exceeded the steepness (slope) of the benchmark years. This seems to indicate that both the rate of learning and mean score increased beyond what would have been normally predicted from the first two time points. Students regained lost achievement in the transition years and at a minimum attained the same level of achievement had they continued to grow in achievement in a linear pattern across all the years.

It is important to consider students' growth rate changes as their school transitions to being a STEM school. Change in itself can be problematic; while the destination can lead to greater academic achievement, the change can also be the factor responsible for lower achievement during the transition period. To provide greater insights into the value of a school transitioning to being a STEM school, we examined the importance of the gains before and after the transition. The growth rate differences indicated a statistically significant difference and an increased rate of learning. Students seemed to be performing better after participating in a STEM school by the time they took their exit tests.

Students' mathematics growth rate after the students' schools turned into STEM schools was statistically significantly higher than their mathematics growth rate before their schools turned into STEM schools, with 0.34 Cohen's *d* effect size. In terms of comparing STEM and non-STEM schools, this finding is parallel with the findings of Gourgey, et al. (2009) and Young et al. (2011), which showed that 9^{th} and 10^{th} graders in STEM schools performed better than their counterparts in non-STEM schools. This increase in students' mathematics growth might be explained by T-STEM schools providing a challenging curriculum, a focus on educational practices related to real life, a greater variety of STEM courses, and new learning opportunities to meet students' needs (Avery et al., 2010; Young et al., 2011). These features of T-STEM schools may lead students to have more engagement with science and mathematics. Further, being exposed to a STEM culture may increase their interest in science and mathematics.

There is a national deficit of women entering STEM fields. Our findings indicated differentiation in gender. Male students showed greater average achievement than female students in both middle and high school. However, female growth showed a marked increase from middle to high schools. Males had positive growth; the slope was not as steep as the females' slope. Indeed, female growth rate difference was slightly higher than male growth rate difference. This might be due to the T-STEM schools' designation that emphasizes underrepresented subpopulations (ethnic minority, female, and low-SES) to decrease the mathematics achievement gap (NRC, 2011). One of the main aims of the STEM education initiative (America Competes Act of 2007) is to decrease the achievement gap between student demographic groups (Lynch, Behrend, Burton, & Means, 2013). The obtained effects might be explained by the fact that female students developed a more positive disposition towards STEM instruction when presented with the opportunities. It cannot be overlooked that the female students had a negative growth rate before being in a STEM school and a positive gain by the time they took the exit exam. The STEM pedagogical strategies that include group work and active engagement (e.g., PBL, Inquiry Based Learning, and Problem Based Learning), hands-on activities, connecting topics with real life applications, and increased cooperative and collaborative learning opportunities could have provided the framework for greater engagement (Myers & Fouts, 1992; Oakes, 1990). For these particular students they experienced enhanced performance as indicated by test score.

This study has several limitations. The first one is we had only had 142 students longitudinally to conduct the study. Our results would have been more robust if we had more data. However, student transfers between schools, dropouts, and moving out of state drastically reduced our sample size. Another condition limiting our sample size was that of missing data. Across the years, a student who for some reason does not take the test is lost to the study. Future study with both student and school level data that compares STEM and non-STEM schools would shed more light on the discussion of whether STEM schools fulfill the promise of greater student achievement in STEM courses.

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Hybrid Classrooms: Switchers and Stayers

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Hybrid Classrooms: Switchers and Stayers

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Abstract

The two-fold aim of this mixed methods case study was to determine the students' perception of learning in a hybridized statistics class and to determine if allowing students to change from hybrid to traditional learning platforms after midterms significantly increased their learning. Qualitative thematic elements emerged for "stayers" and "switchers" on items such as rationale for switching classes and speed of course. Quantitatively, no differences were found in the two groups' time spent online and progress on relevant objectives. However, the groups began with statistically significant differences and medium to large effect sizes in midterm exam grades ($p < .01$, $d = 2.66$), first project grades ($p < .01$, $d = .608$), and course grades ($p < .001$, $d = 2.21$). After switching, the projects, exams, and course grades were no longer statistically different Thus, when students were in the correct environment for their particular learning style and level of motivation, the learning was equalized. This study would need to be replicated with a larger audience before making any similar results projectable to other courses and universities.

Key words: Hybrid, Blended learning, Statistics courses

Introduction

Over the course of the last twenty five years, higher education made a paradigm shift from the traditional classroom to embracing the completely online environment. According to Simonson (2005), the majority of academic leaders believe that online learning is already superior to face to face learning. There is still debate in the quality of internet-driven education with respect to student learning and student satisfaction (Noble, 2003). For instance, Klesius, Homan, and Thompson (1997) said that student satisfaction in distance education was equal to the traditional classroom. This contrasts others who claim that distance education brings decreased student satisfaction when compares to face to face learning (Ponzurick, France, & Logar, 2000). The latter claim was best summarized by Jackson and Helms (2008) in that distance learning has received mixed reviews.

Merging the elements of a traditional course with the elements expected in an online environment (Lorenzetti, 2004; Mansour & Mupinga, 2007) has culminated into yet another modality of learning. This newest model is called hybrid learning or blended learning. Combining online components and face to face learning allows the students to first encounter new information outside of the classroom, before the class actually meets (Mansour & Mupinga, 2007). Young (2002) quoted Graham Spanier, former president of Pennsylvania State College, as stating that hybrid education was "the single greatest unrecognized trend in higher education today" (p. A33). Chris Dede of Harvard University agreed that students learn better online than in a face to face environment but to combine both is the best way (Young, 2002).

Despite these high regards of hybrid education, Jackson and Helms (2008) stated that while blended learning is expanding in the number of universities who utilize this method, hybrid courses did not minimize the weaknesses of either online or face to face learning. This may be because students and faculty cherished less time spent in the classroom (Jackson & Helms, 2008; Lorenzetti, 2004; Mansour & Mupinga, 2007), wider audiences were reached through the technology, and universities benefited from the increased cost-effectiveness (Mansour & Mupinga, 2007). Others cited the benefits as less time spent on travel, increased course availability and flexibility, and decreased student inhibitions for classroom interaction (Beard & Harper, 2002; Chamberlin, 2001; Guidera, 2004). Mansour & Mupinga (2007) emphasized that distance education ensured that students would engage in at least some of the class activities and Lorenzetti (2004) identified that hybrid learning

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encouraged more in-depth processing during in-class activities. Students claim that the greatest benefit to online education is the convenience and flexibility (Mansour & Mupinga, 2007; Ryan, 2001).

Unfortunately, the factors of convenience and flexibility are not necessarily the best measures for ensuring student success (Mansour & Mupinga, 2007). A majority of students do not consider their personal learning style in their decision to enroll in either online or hybrid formats (Mansour & Mupinga, 2007). Since not all students learn the same way, no method can claim effective results for all students in a one-size-fits-all approach. In short, neither the online nor the hybrid model is ideal for everyone (Young, 2002).

Other researchers found that the strengths and weakness of hybrid models forced tradeoffs in learning (Jackson & Helms, 2008). That is, in an asynchronous environment, the learning process is slow, and limits the type and amount of interaction between student and instructor as well as between student and student (Alger, 2002; Jackson & Helms, 2008; Mansour & Mupinga, 2007; Ortiz-Rodriguez, Telg, Irani, Roberts, & Rhoades, 2005; Jackson & Helms, 2008; Wang & Newlin, 2002). One researcher also asserted that hybrid learning environments are a stuck-in-the-middle strategy for learning. That is, hybrid models are "stuck in the middle of disparate pedagogies or extremes and appears to suffer from the strengths and weaknesses of either extreme" (Jackson & Helms, 2008, p. 11). They continue to present the same weaknesses of a totally online delivery, but the addition of the face to face component did not curtail those weaknesses (Jackson & Helms, 2008). While replete with research studies on the satisfaction of students in the various learning models, the body of literature appeared to lack direct comparative data for learning between the models.

The context of the study developed when a student named "Bob" came to my office to discuss his lack of progress after receiving his midterm exam grade. After considerable discussion, both realized that the student lacked the time management skills, internal motivation, and ability to independently synthesize the learning objectives of the course. In order for "Bob" to compensate for his personal learning deficiencies and potentially be much more successful in the course, I suggested that he switch to a traditional, seated version of the course. The same professor would adapt the grade book to avoid the formal drop and add process, which had passed the official drop date. "Bob" was to immediately begin attending the seated section of the class. With fairness in mind, the professor presented the same option to the other 17 hybrid course members, six of whom opted to make the switch to a traditional classroom. I had already developed the hypothesis that the hybrid students were not developing the same levels of understanding and synthesis that the fully-engaged, traditional seated students were developing.

The question of whether or not statistics should be offered in this format in the future and, if so, how I will change my teaching methods, directed my research. Therefore, the overarching research question was how does learning statistics in a hybrid format affect student learning? I divided this into the specific qualitative research questions of (1)Is there a central theme to the survey comments for why students were not achieving high marks and decided to switch to a traditional class? and (2) Is there a common element to students' satisfaction comments after opting to switch to a traditional classroom? Quantitatively, the research questions continued with the following inquiries: (3) Is there a significant difference in course averages?, (4) Is there a significant difference in time spent online?, (5) Is there a significant difference in course evaluation numerical ratings?, and (6) Is there an increase in regression line slopes for those who switched modalities of learning statistics?

This study is therefore a combination of phenomenological thematic analysis and a series of independent t tests for the quantitative element comparison. The two-fold aim of this mixed methods case study was to determine the students' perception of learning in a hybridized statistics class and if allowing students to change from hybrid to traditional learning platforms after midterms significantly increased their learning. This particular situation would provide a bridge for the gap in related literature to include research which directly compares the same group of students with the same professor, text, and assignments.

Methodology

The purpose of this study was to discover the essence of the struggling hybrid-format statistics student by exploring the experience and efficacy of learning statistics in a hybrid format as compared to the traditional format. The design of the study was mixed methods, or a combination of qualitative phenomenology and quantitative independent t testing methods. Such a dual method was employed to find the rationale for switching to a traditional class, as related in research questions 1 and 2. I also wanted to test the hypotheses stated above with quantitative research questions 3 through 6 to fully compare and expand upon both the scores indicative of learning and satisfaction. For the former, the essence of experiences about the educational experience of hybrid statistics students uncovered meanings, themes, and a general description of the experience through a set of extensive steps (Creswell, 1998). The quantitative elements retained the observational study design through data collection through the learning management system. Such data allowed for a series of independent t tests to compare the pre-switch and post-switch scores with respect to course averages, time online, evaluation scores, and score slopes while searching for statistical significance.

Participants

During the spring semester of 2013 a convenience sample of 18 students was obtained from a small private university statistics class that was built in a hybrid model. The class consisted of eight males and ten females who were second semester freshmen or sophomore status students enrolled in an applied statistics class. After receiving the results of their midterm exams, the students were given the option to switch from the hybrid section to a traditional, face-to-face classroom model with the same book, syllabus, assignments, and instructor. All students were allowed continual access to the online learning modules. Six students opted out of the hybrid model and 12 chose to remain in the hybrid course format.

Data Collection

Qualitative

As per the initial purpose of the study, the questions were developed to answer one part of the aim: to determine the students' perception of learning in a hybridized statistics class. After obtaining Institutional Review Board approval for interviewing participants, a questionnaire was administered to all 18 students representing both "stayers" and switcher groups. The inquiry asked six open ended questions regarding rationale for switching or staying in the scheduled class, as well as their personal feelings about that choice. For the staying students, the survey questions were: (a) Why did you decide not to switch from the hybrid to the traditional class for statistics?, (b) How have you benefitted from staying?, (c) Do you regret not making the switch to a traditional class?, (d) Why do you think others did switch?, (e) Would you encourage others to take a hybrid class?, (f) Understanding that the same content had to be covered in both traditional format and hybrid format, could you recommend ideas that might have helped you to learn better while in the hybrid format?, (g) Any additional comments. Similarly, the switching students were asked: (h) Why did you decide to switch from the hybrid to the traditional class for statistics?, (i) How have you benefitted?, (j) Do you regret the switch?, (k) Why do you think others did not switch?, (l)Would you encourage others to take a hybrid class?, (m) Understanding that the same content had to be covered, could you recommend ideas that might have helped you to learn better while in the hybrid format?, and (n) Any additional comments. The questions were chosen in order to provide a more robust set of answers to be coded for thematic evidence to guide further practice for teaching hybrid statistics.

Quantitative

The learning management system utilized by the university provided records and documentation regarding all facets of the quantitative research questions. That is, the course records concerning all grades were downloaded and then separated in to pre-midterm categories and post-midterm categories. The data points provide time series data to be graphed with Microsoft EXCEL and formed into best-fit regression lines. Next, further breakdown of the pre-midterm category allowed for specific categories of midterm, written research project 1, project 2, and project 3, and the final exam scores. Further data mining in the learning management system provided data outputs for log-in time in the course home, projects, tables, and weekly lessons. Finally, original summaries for the IDEA course evaluations provided hard data with respect to course summary of excellent teacher, excellent course, and progress on relevant objectives. The IDEA also provided information on specific learning objectives that were measured as part of the course evaluation: "gaining factual knowledge (terminology, classifications, methods, trends)" (IDEA, p. 2), "learning to apply course material (to improve thinking, problem solving, and decisions)" (IDEA, p. 2), and "learning to analyze and critically evaluate ideas, arguments and points of view" (IDEA, p. 2). These pieces of documentary evidence were chosen to answer the second aim of the study: to determine if allowing students to change from hybrid to traditional learning platforms after midterms significantly increased their learning. The hybrid and the traditionally seated courses were taught by the same professor, with the same text and assignment criteria to eliminate potential lurking variables.

Data Analysis

Qualitative

The survey questions were left open ended to create a more robust thematic analysis from the phenomenological constructivist perspective. The responses to the survey questions were collected by stayer/switcher group affiliation and coded by content analysis. The pattern-matching with modified analytic induction (Bogdan & Biklen, 1992) developed the central themes, thereby validating potentially meaningful connections to the hybrid and traditional statistics classroom experiences.

Quantitative

The data gleaned from the learning management system was separated first into the categories of “switchers” and “stayers”. From there, the samples of data were further refined to pre-midterm and post-midterm categories. As the data collected was from the distinct groups of stayer and switcher students to look for statistical significance, the follow up analyses were conducted after the end of the semester used a parametrical two-tailed independent t test as the primary statistical data analysis tool. The practical significance levels followed the standards set forth by Cohen (1988) for the descriptors of small, medium, and large effect sizes. The level of statistical significance was set at $p < .05$.

Results

Research Question 1: Central theme to survey comments

Questionnaires were given to each student originally enrolled in the hybrid class. Qualitatively, the students who switched presented a theme of feeling rushed, overwhelmed, and utterly lost. Out of the nine returned surveys, there were 13 statements which used the words time and speed. Additionally, seven comments stated a lack of understanding and retention of the content, six indicated issues with lack of interaction, and five acknowledged that they did not learn as well through the videos as they did in person. Four comments identified increased scores after switching, and three described appreciation for only having to go to class once a week. Moreover, none regretted making the switch. Eight out of nine would not recommend to others to take a hybrid. The one student who stated that he would encourage others to take a hybrid added the caveat “if feel that they can handle the workload.” Four students stated that hybrid students must be able to learn by themselves.

Other pertinent comments included the following: “you do not get the same teacher student interaction that you would in a traditional class,” “the traditional classes have proved to be much better than the hybrid classes,” and “I felt that in a traditional class, I would understand everything better, because I wouldn’t feel rushed and we would have had more time to go over the material.” One student commented that “you couldn’t ask the video a question,” while others mentioned “I felt overwhelmed,” “ I didn’t learn as well from the videos as I did in person,” and “I don’t regret the switch because I felt like I understood everything a lot better and I felt more confident in what we learned.” The two other thought-provoking comments included, “there are not many other options other than the videos due to the time limitations” and “not having class two times a week is a plus.”

Research Question 2: Students’ satisfaction comments

Additional commentaries from the course evaluations further defined the thoughts and opinions of those who switched from the hybrid course to the traditional seated version. For example, one comment from the results in the traditional class indicated a switcher: “I hated the hybrid class!! This was much easier.” Another from the same evaluation set stated, “I hated hybrid statistics. I had to switch because my grade was so low. I feel had I been in this class all year I might have gotten at least a C.” In contrast, an explanation from someone who could not or would not switch said that the “hybrid format was a challenge. However, the professor is one of the best professors I’ve ever had. She is a wonderful professor and definitely goes the extra mile for her students. I would happily take another class from her.” Only one student who remained in the hybrid course provided the open-ended statement of “good class; I liked the hybrid format.”

Research Question 3: Course averages

Quantitatively, the grades for the eighteen students in the hybrid course through midterms averaged to 71%, but when the course grades through the midterm exam were separated by those who stayed in the hybrid to those who switched, the numbers changed to 82% and 58%, respectively. When run as an independent t test assuming equal variances, the two-tailed test value was t (16) = 5.29, with $p < .001$. According to the standards set forth by Cohen (1988), these results had a large effect size with $d = 2.66$, $r = .800$. The post-midterm grades averaged to 74% and 67%, again respective to the same groupings. When run as an independent t test, the two-tailed test value changed to t (16) = 0.96 with $p > .05$.

When further refined to specific course objective indicators such as the midterm, final, and written research, the results were mixed. The midterm exam average of the "stayers" was 84.3 and the "switchers" were at 56.8, with a two-tailed independent t (16) = 4.69 ($p < .01$) and large effect size at $d = 2.21$, $r = .742$. The final exam resulted 75.3 and 75.1, respectively, with a two-tailed independent t (16) = 0.016 ($p > .05$). The three course projects revealed means of 86, 87.6, and 89 for the "stayers" and 63.4, 75, and 90.4 for the "switchers." Of the three class projects, only the first project which occurred prior to the switch to a traditional class was statistically significant with t (16) = 3.66, $p < .01$ with a medium effect size at $d = .608$, $r = .291$.

Research Question 4: Time online

The students' ecollege logged-in times were also analyzed, though in this instance an independent t assuming unequal variances was used due to the necessity of technology in the hybrid class and the potential lack in the traditional method "switchers." The results did not show any statistically significant differences in the time spent by students in the course home, projects, tables, or weekly lesson time summaries. The results of the average total amount of time spent in the online class or electronic companion to the seated class were 1953 minutes for the hybrid students and 1566 for the students who switched to the traditional class, but again the one-tailed test results were not significant with t (16) = 1.18 ($p = 0.13$).

Research Question 5: Course evaluation ratings

Next, the course evaluations were compared statistically. Raw scores from the IDEA evaluation system as implemented by the university in 2012 were used in comparison of hybrid and traditional course models for this professor. The "switchers" were included in the traditional model as they were in the seated class during the final course evaluations. The specific measures taken from the evaluation summary included scores for the categories of excellent teacher, excellent course, and progress on relevant objectives. The raw score for excellent teacher was a perfect 5.0 for the hybrid students and 4.79 (4.74 adjusted score) for the traditional class. In the excellent course classification, the scores were 4.5 (raw and adjusted) for the hybrid students and 4.35 (raw and adjusted) for the traditional students. More importantly, for progress on relevant objectives, the twelve hybrid class students scored a 4.2 (4.0 adjusted score) on a five point Likert scale while the traditional seated classes for the same class and professor averaged 4.54 (raw and adjusted) for 49 students, including those who switched to the face-to-face only format.

The raw data for each of the individual objectives rated as essential by the instructor also allowed for statistical comparisons. One of those essential objectives stated that "gaining factual knowledge (terminology, classifications, methods, trends)" (IDEA, p. 2) found two-tailed independent t test results of t (52) = -1.06 (p = 0.292), which did not demonstrate statistically significant differences between the hybrid and the traditional seated students. The other two essential objectives of "learning to apply course material (to improve thinking, problem solving, and decisions)" (IDEA, p. 2) and "learning to analyze and critically evaluate ideas, arguments and points of view" (IDEA, p. 2) displayed similarly insignificant results with two-tailed independent t tests of t (51) = -0.61 ($p = 0.361$) and t (52) = -0.92 ($p = 0.122$), respectively.

Table 1. Results of quantitative parametric research questions

Research question	Sub-category	Independent t, p-value	Cohen's d for Practical significance
	Pre-midterm comparison	t(16) = 5.29, p < .001	*d* = 2.66, r = .8
	Post-midterm comparison	t(16) = .96, p > .05	
3: Course averages	Midterm exam	t(16) = 4.69, p < .01	*d* = 2.21, r = .742
	Final exam	t(16) = .016, p > .05	
	Project 1	t(16) = 3.66, p < .01	*d* = .608, r = .291
4: Time online	Time online	t(16) = 1.18, p > .05	
5: Course evaluation ratings	Factual knowledge	t(51) = -1.06, p > .05	
	Apply concepts	t(51) = -.61, p > .05	
	Analyze and think critically	t(51) = -.92, p > .05	

Research Question 6: Regression line slopes

Finally, the grades of the six students who switched course formats were plotted in a time-series graph with best-fit regression lines. The slopes of the students' progress demonstrated change over time. For the measures of student learning, the greatest amount of change improved from -3.6 to .0131 (student #6, in Figures 11 and 12), while the others varied considerably. Figure 1 and Figure 2 show student #1 changing from a slope of 0.0148 to -0.0023 (decrease of 0.0171) while Figures 3 and 4 demonstrated an increased slope change from 0.0224 to 0. 0014 (increase of 0.021). The graphs of students #3, #4, and #5 are shown in Figures 5-10 and respectively show slopes changing from -0.0494 to 0.0085, -0.0098 to 0 .0209, and 0.0462 to -0.0051. The results of the six students' time-series graphs are shown below.

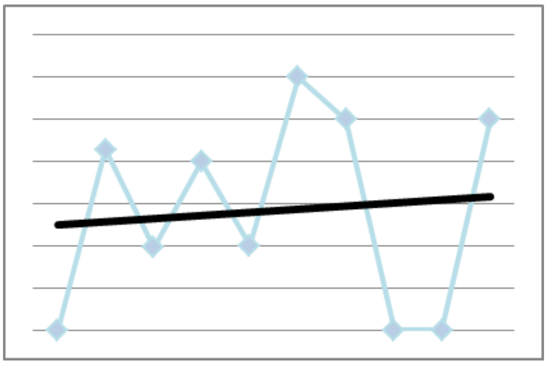
Figure 1: Student 1, pre-midterm

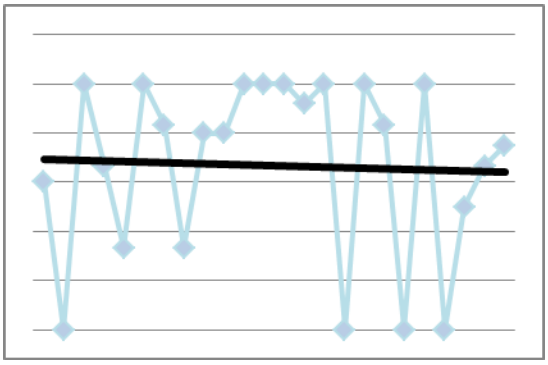
Figure 2: Student 1, post-midterm

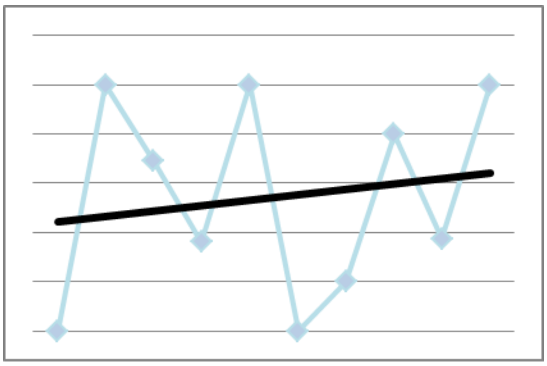
Figure 3: Student 2, pre-midterm

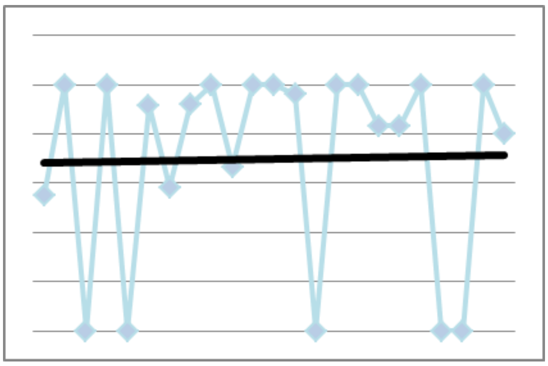
Figure 4: Student 2, post-midterm

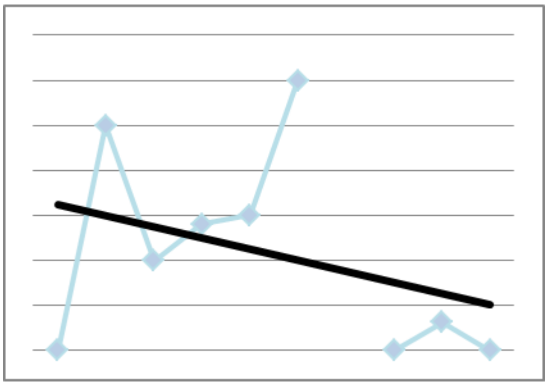

Figure 5: Student 3, pre-midterm

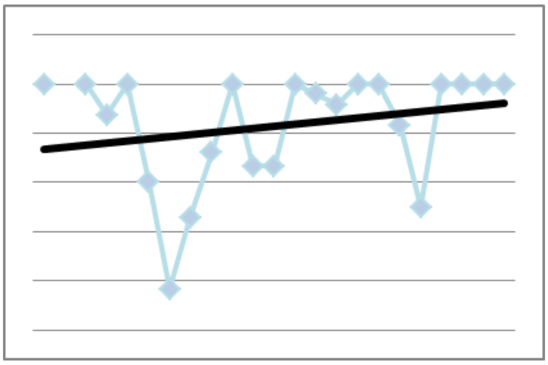

Figure 6: Student 3 post-midterm

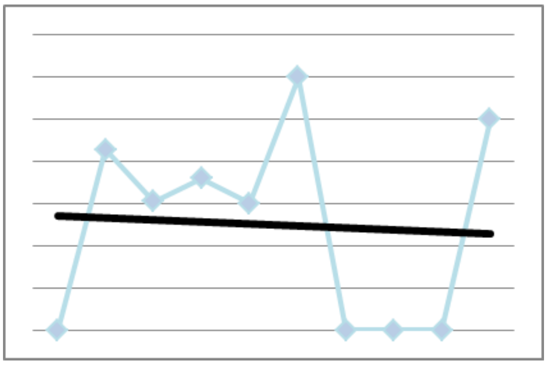

Figure 7: Student 4, pre-midterm

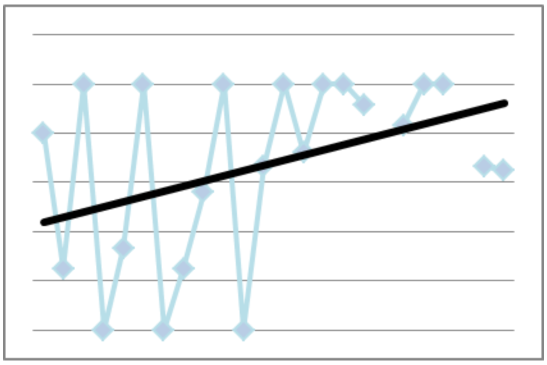

Figure 8: Student, post-midterm

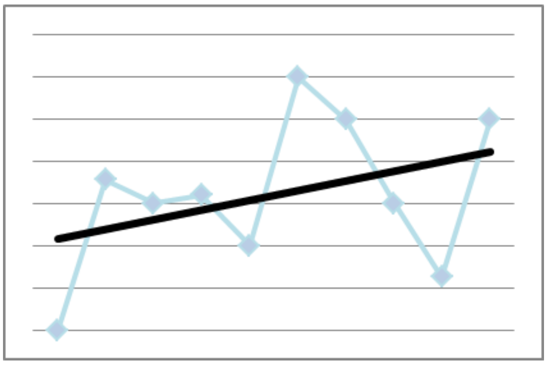

Figure 9: Student 5, pre-midterm

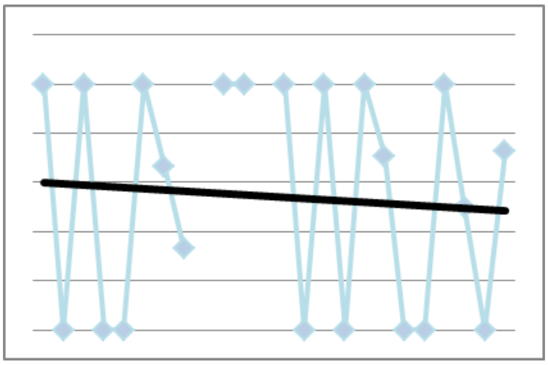

Figure 10: Student 5, post-midterm

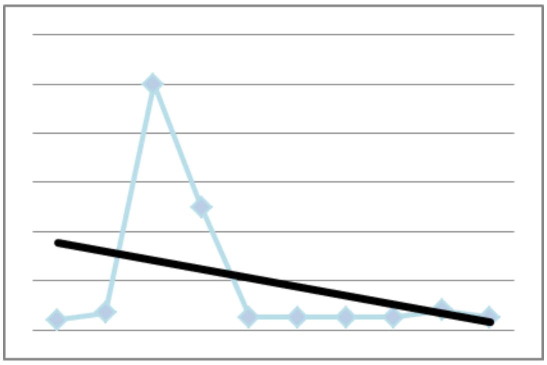

Figure 11: Student 6, pre-midterm

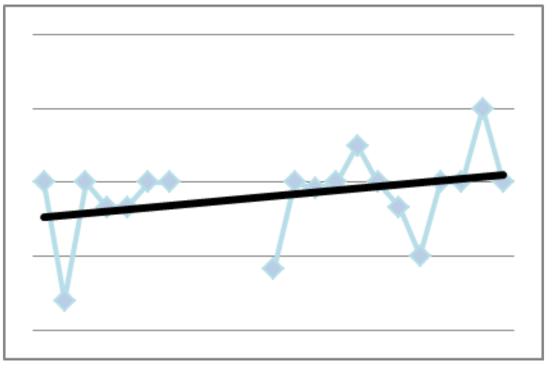

Figure 12: Student 6, post-midterm

Results and Discussion

In answer to research questions 1 and 2, when the students completed the questionnaires shortly after making the switch, a strong negative feeling toward hybrid classrooms quickly emerged. Of the students who switched, the theme of going too fast was prevalent. Multiple students commented that they needed more class time to digest the concepts. They also added the necessity for more interaction, validating the research of many prior studies (Alger, 2002; Mansour & Mupinga, 2007; Ortiz-Rodriguez, Telg, Irani, Roberts, & Rhoades, 2005; Jackson & Helms, 2008; Wang & Newlin, 2002). The comments on the final course evaluations registered similar attitudes.

The IDEA evaluation system further emphasized that learning strategies and time management skills might be the rationale for a student to take a certain course, rather than its modality. With respect to the quantitative research question 3, the fact that the students were statistically significant in their grades up to midterms demonstrated an initial discrepancy in either achievement or motivation. The effect size was quite large according to Cohen (1988), which means that the magnitude of difference in the treatment is large. The statistically significant differences in the first course project potentially indicated the same issue. As initially hypothesized, switching the students changed the behavior. That is, after the "switcher" students were placed into the traditional seated course and met twice a week, the grade differentials were no longer statistically significant. The effect size for the project one statistical test showed a medium effect of treatment, thereby considered practical and applicable to the general population. (It may be noted that attendance was not an issue for any of the students in the study as any students with attendance issues dropped the course immediately after the midterm exam and were thus excluded from any analysis.).

With respect to the time spent in the online components of the course for research question 4, the lack of significance was surprising. The hypotheses were one-tailed as the hybrid students, by nature of their coursework, should ideally spend more time in the online environment. The averages were certainly different for those who remained in the hybrid and were forced to interact with the content online to those who switched and were not obligated to immerse themselves in the content, but those large differences are not large enough to state that the means would be different in the population. What happened with respect to time was simply chance, or sampling error. The results also indicated that once the student switched to the traditional format, the students may have developed a certain level of comfort with in-class discussions, no longer felt the need to self-teach, and were potentially more able to disengage from learning activities. The switching students may also have become much more apathetic to learning outside of class, since the content would be taught by lecture, activity, and discussion in the classroom. Such a concept supports the work of Lorenzetti (2004) with respect to hybrid learning forcing student interactions and deeper processing. The results showed that post-switch, only 739 minutes were logged between the six switch students, averaging to about 15 minutes per week per student. The reality was that after week nine of the semester, only two students logged in any week. This number narrowed to only one student logging into the online class components after week 11. In fact, one of the switching students only logged into the course once in the entire 14 weeks for a total of 56 minutes.

As background knowledge to research question 5, the IDEA system rating page explained that "adjusted scores make classes more comparable by considering factors that influence student ratings, yet are beyond the instructor's control. Scores are adjusted to take into account student desire to take the course regardless of who taught it, student work habits, instructor reported class size, student effort not attributable to the instructor, and course difficulty not attributable to the instructor " (IDEA, p. 1). Thus, both scores were reported in the results section. The re-creation of the raw data set (from the back side of the IDEA evaluation page) found that the raw scores of the groups failed to demonstrate any statistically significant differences, contrasting other prior research (Ponzurick, France, & Logar, 2000). The results of the student evaluation system showed that both groups of students viewed the professor and the course in a favorable light. The similar numbers for teacher and course indicated similar positive experiences with the text, coursework, and teacher rapport, thereby isolating the course modality as the treatment variable. The interaction with the content, fellow students, and teaching style were the parts that were different.

The results of the progress on relevant objectives (research question 5), when coupled with the statistically significant differences in the beginning of the semester (research question 3) demonstrated that the grades for the students who switched were substantial. The IDEA evaluation system showed that there was no statistically significant difference in any of the three essential objectives between the two groups. More specifically, in post hoc analysis, the grades of the "stayers" were significantly greater than the "switchers" before the midterm exam. After placing students in what might be considered a more suitable learning format, the grades post-midterm were no longer statistically significant between the two groups. One interpretation is that of a significant gain for the students who switched formats to better accommodate their learning needs. This says that if the results were to be inferred upon the population, when students are in the correct learning environment for their particular learning style and level of motivation, all can succeed equally. Nonetheless, it should be recognized that the sample size and scope of this study are quite limited; this study would need to be replicated with a larger audience before making any similar results projectable to other courses and universities. In light of that, more research needs to be done in the area of measurement of student learning (Noble, 2003).

When the switching students' grades were plotted in a time series graph with a best fit regression line applied, the results were an inconsistent answer to research question 6. Three of the students' grades completely changed direction. They went from negative slopes indicative of rapidly decreasing grades to a positive slope showing academic progress. While those three students gave credence to the hypothesis that switching would be good for students who identified themselves as not being successful, the other three did not produce similar results. That is, the slopes of two of the six students changed from increasing to decreasing, and one went from rapidly increasing before midterms to flat-lining, albeit at a higher mean than before the increase. The slopes of the curves demonstrate that two-thirds of the switching students were able to improve their grades. Though not necessarily statistically significant, the best fit-lines are indicative of an increase in numerical assessment percentages for the majority. The time-series analysis of the grades does not fully support the original hypothesis for allowing the students to switch to a traditional format. This particular result exemplifies the debate of student learning put forth by previous studies (Noble, 2003; Ponzurick, France, & Logar, 2000). Moreover, the sample size was very small and precluded the results of this study to be generalized to others. Expansion of the sample size in replication studies would be imperative.

Conclusion

While I would volunteer to teach the hybrid course again, I would not expect for the results to be any different. According to Mansour & Mupinga (2007), students choose the take a hybrid course for its convenience, without thought to their learning needs. Unless this underlying cause is fixed, the problem of both the student and the professor feeling rushed to get through the mandatory content will remain, potentially revealing the depth of the weaknesses reported by Jackson and Helms (2008). In order for a hybrid course to be successful, the students must possess the requisite motivation and learning styles to accommodate independent learning: they must be able to learn both the "hows" and the "whys" on their own, thereby allowing more seated class time for synthesizing course concepts in large group activities. This idea negates Lorenzetti (2004), but corroborates the debatable benefits given by other researchers (Noble , 2003). Some potential effects would be deeper learning, better classroom discussions, and ensuing higher levels of analysis on course projects and papers. Another anticipated result would be greater levels of satisfaction with the course format.

For those who realize their limitations and stay within the realm of traditional seated courses, a hybrid of hybrids may serve them best. That is, if such students were to take a seated class using a "flipped" instructional model heavily embedded in technology, they may enjoy the learning process and receive the positive benefit to their learning. Inverted classroom theories employ the best of both worlds (Arnaud, 2013; Berrett, 2012; Davies, Dean, & Ball, 2013; Fickes, 2013) in that they utilize the hybrid idea of granting students electronic access to course concepts prior to class sessions and deeper learning pedagogies within the seated classes, but are taken at a slower pace by comparison. The inverted instructional model applied to a traditional class would only cover one concept a day, with time to digest and synthesize major concepts in between class sessions. This would allow for greater degrees of student engagement and less of a lecture format, more of what many envision a hybrid course to be.

In summary, the initial problem was that the hybrid students were not progressing on common learning objectives as the same rate as the seated students. In an attempt to fix the issue, the students were allowed to switch learning modalities. The research grew from ex post facto analyses to see if the switching students reaped the learning benefits as measured by evaluative comments at the end of the semester and grades. The quantity of the qualitative statements complimenting the course and professor were similar and many of the quantitative comparative tests lacked statistical significance. In the nature of this study it was a good thing. It meant that the original discrepancy between hybrid and traditional was eliminated.

Recommendations

Despite all of those thought-provoking and potentially applicable results, the overall effects of the study are inconclusive for the population as it is recognized that the sample size for this study was extremely small and generalizability is limited. Future studies might expand upon this course format research through an entire semester with much larger groups of students. Another area of prospective research would be to compile an interdisciplinary sample of data that focuses on students' level of analysis and synthesis of course concepts and again compare by course format.

Though the results may not be inferred to other populations as yet, there are lessons from this research that may still be applied to higher education. For instance, a suggestion for upcoming hybrid course sections would be to assess student learning styles on the first day of class and offer them to switch to a traditional class much sooner. Passing a copy of this article might also be beneficial, especially the qualitative sections concerning comments on why students made the switch and their success after the fact. Whether the students switch or not, recognition of the potential problems may substantially improve the experience for all.

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An Analysis of the Secondary Education Students' Scientific Attitudes

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An Analysis of the Secondary Education Students' Scientific Attitudes*

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Abstract

The aim of this study is to analyse the level of scientific attitude of the secondary education students. The participants of the study are a total of 634 sixth, seventh and eighth grade students attending those schools serving to the students with a lower, medium or higher socio-economic status in Aydın. Three different data collection tools were employed to gather the data of the study, namely "Scale of scientific attitude", "Scale of views about scientific knowledge" and "Personal information form". The findings of the study indicated that students have nearly positive attitudes towards science. It was found that the scientific attitude of the participants varies based on the variables of gender, grade level and family income. In addition, scores of the participants in the scale of scientific attitude are positively correlated with their academic achievement and their scores in the scale of views about scientific knowledge.

Key words: Secondary education students, scientific attitude, academic achievement.

Introduction

Scientific knowledge has been expanding through advances in science and technology. As a result these changes in 2004 Turkey adopted new educational programs nearly in all school subjects and the ultimate goal of this reform was declared to produce individuals who are science literate (Çepni, Ayvacı, & Bacanak, 2004).

Following the intoduction of the term "Science literacy" it was transferred into different domains and fields. One of its derivations is the term "Science and technology literacy". Given that the expansion of technological and scientific knowledge is fast noone can gain all the knowledge in these fields. Therefore, those individuals who are science and technology literate should be produced in order for countries to keep up with this changing process. In a similar vein, the program of science and technology course which has been implementing in Turkey aims at "Producing individuals who are science and technology literate regardless of the individual differences." (MONE, 2006). One of the dimensions covered under the term science and technology literacy is the nature of science and scientific knowledge (Kıray, 2010; Yenice & Özden, 2013; Erten, Kiray & Sen-Gumus, 2013; Lederman, Lederman, & Antink, 2013). However, Bybee (1985) argued that the term science and technology literacy is a complex entity which requires not only scientific knowledge, but also scientific skills, attitudes and values.

The dimensions of the science and technology literacy requires that individuals should possess scientific attitudes and values (MONE, 2006). Similarly, Beane (1990) argued that science and technology program also included affective points and characteristics which may occur as the students' attitudes or approaches (Yağbasan & Demirbaş, 2004). Therefore, it is safe to argue that the science and technology teaching cannot only contribute to the cognitive development of students, but also to their affective development.

The term attitude has been differently defined: "Attitude is an individual's mental position or behaviour which occurs in regard to a specific condition or event" (Harlen, 1996; cited in Türkmen, 2006). Ülgen (1997), on the other hand, defined "attitude as a biased reaction in relation to an object or an event." Turgut (1997) regards an attitude as a positive or negative reaction and behaviour of an individual in regard to an event, an object or a group of people.

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Literature on the attitudes towards science deals with the attitude towards science and scientific attitudes in different ways and makes a difference between them (Byrne & Johnstone, 1987). Because attitude towards science and scientific attitudes are two distinct patterns (Türkmen, 2006). More specifically, scientific attitudes are those to be possessed by individuals, whereas attitude towards science is one which is exhibited by individuals in regard to specific events (Türkmen, 2006).

Başaran (1976) defined scientific attitude as "Individuals' ability to interpret the events, situations and problems based on data as possible as far from their emotions." Most common characteristics of the individuals who have scientific attitude are as follows: "Being volunteer to recognise and solve the situation or problem he comes across; searching for the solutions related to the problem and juding the advantages and disadvantages of each to decide over which one is more appropriate; having trust in the solution he chooses, but also, criticising it, if necessary; using the solution without criticising it and evaluating the outcomes of his decision over the solution". Karasar (2007) argues "scientific attitude and behaviour are views which faciliate the problem-colving, producing scientific views, and practising research-related competencies." For him, those who acquired scientific attitude and behaviour are *"open-minded, skeptical and tries to find out the reason of the counter-arguments. They are independent in their views and observations, can postpone their decisions to have more evidence, they are attentive and perseverant in their studies. They can connect their current thinking to the previous thinking. They are modest and take into consideration the other possibilities in their judgement."*

Çilenti (1985) argued that in order to reach new knowledge in science people must have scientific attitude and the skills related to cognitive processes. At the same time, he defined scientific attitides as being curious, modest, skeptical, perseverant and honest. It is reported that scientific attitudes have two major dimensions: scientific dimension and affective dimension. The first dimension, scientific dimension, classifies the scientific attitude under three groups as follows: "G*eneral attitudes towards ideas and knowledge:* Such attitudes includes curiosity and being open to novice ideas, etc. *Attitudes towards the evaluation of ideas and knowledge:* Critical thinking, being neutral, data analysis are among the basic parts of these attitudes. *Deciding over scientific beliefs:* It includes the development of the relation between causes and effects (Byrne & Johnstone, 1987).

Johnston (1996) argued that scientific attitudes should be taught during the formal education process and that scientific attitudes are not only significant for science teaching and learning, but also for other fields due to the fact scientific attitudes faciliates learning in all subject matters (cited in Hamurcu, 2002). In a similar vein, Schibeci (1983) studied the relationship between science and attitudes and concluded that those students who gained scientific attitudes improved their attitudes towards science (cited in Demirbaş & Yağbasan, 2006). Therefore, it can be argued that if the scientific attitudes of basic education students are improved taking into consideration their cognitive and affective dimensions and the teaching process is planned in this regard the student learning will be significantly improved.

The review of the literature shows that studies dealing with the scientific attitudes of basic education students are rare (Pearson, 1993; Ata, 1999; Chuang & Cheng, 2002; Demirbaş & Yağbasan, 2005; Demirbaş & Yağbasan, 2006; Afacan, 2008; Duran, 2008; Yenice & Saydam, 2010; Mıhladız & Duran, 2010; Kılıç, 2011; Demirbaş & Yağbasan, 2011; Uzun, 2011). Of these studies, Pearson (1993) studied the perceptions of teachers and students in regard to scientific attitudes, their understanding of the nature of scientific knowledge and their perceptions of educational approaches. Ata (1999) deal with the development of scientific and social attitudes in secondary education students. Chuang & Cheng (2002) analysed the correlation between gender, ability in regard to biology, scientific attitudes, scientific process skills, logical thinking skills and student attitudes towards biology. Afacan (2008) studied the changes in the basic education students' perceptions about the relationship between science, technology, society and environment based on their scientific attitudes, the grade level and socio-economic environment of the school. Demirbaş & Yağbasan (2011) analysed the effects of the science and technology education program which began to be implemented in 2005 on the development of the students' scientific attitudes. Kılıç (2011) analysed the level of the scientific creativity and scientific attitudes among eighth graders and the effects of their demographical characteristics on their level of the scientific creativity and scientific attitudes.

One of the current goals of the science education is to improve student views about the nature of science and scientific knowledge. Uzun (2011) found a positive correlation between primary school students' views about scientific knowledge and their attitudes towards science. Based on this correlation, it can be argued that higher levels of views about scientific knowledge is one of the prerequisties for education individuals with positive scientific attitudes. Given that the relationship between the views about scientific knowledge and scientific attitudes has not been extensively analysed among the secondary education students, the current study provides a new insight to the field since it deals with both.

As stated earlier, scientific attitudes faciliate the student learning and contribute to the development of their critical thinking and problem-solving skills. Therefore, having information about the levels of scientific attitudes and the factors affecting these attitudes is crucial for reaching the vision of the educational program. Thus, it is significant and necessary to reveal the factors affecting the scientific attitudes of secondary education students and the correlation between their levels of scientific attitudes and their views about scientific knowledge.

Aim of This Study

The aim of this study is to analyse the level of scientific attitude of the secondary education students and the correlation between the level of scientific attitude, their academic achievement and their views about scientific knowledge. In parallel to this aim, the study tries to answer the following research questions:

- What is the level of the secondary education students' scientific attitudes?
- Do their scores from the scientific attitudes scale significantly vary based on the variables of gender, grade level and famiy income?
- Is there any statistically significant correlation between the participants' scores in the scientific attitudes scale and their academic achivement and their views about scientific knowledge?

Method

Design of This Study

The study, which is a descriptive research, has the model of relational scanning. Relational scanning models attempt to identify the change that occurs among variables and/or to determine the level of change that takes place (Karasar, 2007).

Sample and Environments

The participants of the study are a total of 634 sixth, seventh and eighth grade students from four different basic education schools in Aydın. The schools were selected following purposive stratified sampling method. Before the selection process, all the schools in Aydın were categorized based on the socio-economic status of the students they serve. The data on socio-economic status of the students were taken from Aydın provincial education directorate. Two schools from those serving the students with lower socio-economic status were selected randomly. For those schools serving the students with medium and higher socio-economic status, one school was chosen randomly for each category. Purposive stratified sampling method is mostly used to indicate, describe the characteristics of lower socio-economic groups and make comparisons among them (Büyüköztürk, 2008). Demographical characteristics of the participants are given in Table 1.

Table 1. Demographical Characteristics of The Participants

Gender	***f***	**%**
Male	306	48,3
Female	328	51,7
Grade Level	***f***	**%**
6.grade	212	33,4
7.grade	206	32,5
8.grade	216	34,1
Income Level of Their Families	***f***	**%**
High level	278	43,8
Medium level	159	25,1
Lower level	197	31,1

Data Collection Tools

The data of the study were collected through the use of two scales, namely "Scale of Scientific Attitudes" and "Scale of Views about Scientific Knowledge". Academic achievement of the students is used as their grades in the course of technology and science in the fall semester of the school year of 2011-2012. Data on the demographical characteristic of the students are gathered with the use of "Demographical Form".

The scale of scientific attitudes (SSA) was developed by Moore & Foy (1997) in order to identify the secondary students' scientific attitudes. The scale was adapted into Turkish by Demirbaş & Yağbasan (2006). The scale is made up of forty items and six sub-dimensions. Five of the sub-dimensions are about nature of science and working process of scientists. The other sub-dimension is about the views of students about science. In the original study, the Cronbach Alpha coefficient of the scale was found to be .76. In the current study, it was found to be.72.

The scale of views about scientific knowledge was developed by Çoban ve Ergin (2008). It is consisted of 16 items and three dimensions. Answers to the items are given using a Likert type scale. The dimensions and the items involved in each dimension are as follows: Dimension I "Scientific knowledge is closed" (items 1, 5, 8, 9, 10, 12, 15, 16), Dimension 2 "Scientific knowledge is justified" (items 2, 6, 11, 13, 14) and Dimension 3 "Scientific knowledge may change" (items 3, 4, 7). The Cronbach Alpha coefficient in the original study was found to be .72 for Dimension I, .69 for Dimension 2, and .66 for Dimension 3. Its overall Cronbach alpha coefficient was found to be .83. In the current study the following values were found: .70 for Dimension I, .66 for Dimension 2, and .60 for Dimension 3. Its overall Cronbach alpha coefficient was found to be .78.

Data analysis

The data collected were analyzed through the use of SPSS 17.0. The data were firstly analyzed with descriptive statistical techniques (frequency, arithmetical means, standard deviation and percentage).

In order to use t-tests and ANOVA for independent samples, the scores of dependent variable scores should distribute normally and variance should be homogeneous (Büyüköztürk, 2008). For this requirement, the scores of the students in two tools were analyzed in terms of normality. The results of the analysis showed that the scores did not distribute normally ($p<.05$).

In addition to descriptive statistics the Mann Whitney U-test and Kruskal Wallis H-test are employed in the data analysis. The Kruskal Wallis H-test indicated the statistically significant differences between groups. The Mann Whitney U-test was used to see the source of these differences. The level of statistically significance was set at .0167. The Spearman Brown range difference correlation was employed to identify the relationship between scientific attitudes, academic achievement and the students' views about scientific knowledge.

The scores of the participants in the scientific attitudes scale are used to reveal the level of their scientific attitudes. The related score ranges of the participants are given in Table 2.

Table 2. Score ranges of the participants in the scientific attitudes scale

Level of Scientific Attitude	Range
Low	40.00- 93.33
Average	93.34- 146.67
High	146.68- 200.00

Findings

As stated above, the first research question is "What is the level of the secondary education students' scientific attitudes?". In order to answer this question arithmetical means (X), standard deviation (SD) and minimum and maximum values of the students' scores in the scientific attitudes scale were found and are given in Table 3 below:

Table 3. Mean scores of the students in the dimensions of the scientific attitude scale and their total mean scores

Dimensions of The Scientific Attitude Scale and Means of Total Scores	N	X	SD	Min	Max
The Nature of Scientific Laws and Theories	634	18.6	2.54	8.00	30.00
The Nature of Science and Approaching Towards Events	634	22.5	3.31	11.00	30.00
Exhibition of Scientific Behaviour	634	21.8	3.24	14.00	30.00
The Nature and Aim of Science	634	18.9	2.16	12.00	26.00
The Place and Significance of Science in Society	634	21.2	3.33	7.00	30.00
Being Volunteer to Take Part in Scientific Research	634	36.9	6.17	16.00	50.00
Total	634	139.7	11.66	107.00	172.00

Table 3 shows that the total mean score of the participants for the sub-dimension of the nature of scientific laws and theories is X=18.6. It is found to be X=22.5 for the sub-dimension of the nature of science and approaching towards events. The total mean score for the sub-dimension of the exhibition of scientific behavior is found to be X=21.8. for the sub-dimension of the nature and aim of science the total score of the participants was found to be X=18.9. It was X=21.2 for the sub-dimension of the place and significance of science in society. It was found that the mean score for the sub-dimension of being volunteer to take part in scientific research is X=36.9. As a whole, it is seen that the students' scientific attitude is at the average level based on these total mean scores from the sub-dimension of the scale. The total mean score for the scale as a whole was found to be X=139.7. Again, this mean score indicates that the participants have scientific attitudes at the level of average as can be seen from the score ranges given in Table 2.

As mentioned above, the second research question of the study is as follows: "Do the scores of the students from the scientific attitudes scale significantly vary based on the variables of gender, grade level and famiy income?" The results of the analyses related to the second research question are given as follows:

In order to answer to this question and to reveal whether or not gender has a significant effect on the participants' total score and scores in the sub-dimensions of the scientific attitudes scale the Mann Whitney U-Test was employed. The results are given in Table 4 below:

Table 4. The results of the Mann Whitney U- Test in regard to the effects of Gender on the participants' total mean scores and scores in the sub-dimensions of the scientific attitudes scale

Dimensions of The Scientific Attitude Scale and Means of Total Scores	Gender	N	*Mean of ranks*	*Total rank*	*U*	*p*
The Nature of Scientific Laws and Theories	Male	306	317.48	97147.50	50176.50	.997
	Female	328	317.52	104147.50		
The Nature of Science and Approaching Towards Events	Male	306	326.65	99955.50	47383.50	.222
	Female	328	308.96	101339.50		
Exhibition of Scientific Behaviour	Male	306	322.61	98718.50	48620.50	.496
	Female	328	312.73	102576.50		
The Nature and Aim of Science	Male	306	302.08	92435.00	45464.00	.038*
	Female	328	331.89	108860.00		
The Place and Significance of Science in Society	Male	306	320.19	97979.00	49360.00	.719
	Female	328	314.99	103316.00		
Being Volunteer to Take Part in Scientific Research	Male	306	325.59	99630.00	47709.00	.282
	Female	328	309.95	101665.00		
Total	Male	306	322.69	98744.00	48595.00	.490
	Female	328	312.66	102551.00		

Table 4 indicates that of six dimensions of the scientific attitudes scale the scores for five were not found to be affected by the gender of the participants. These five sub-dimensions and the related mean scores are given as follows: the nature of scientific laws and theories (U=50176.50, *p*>.05); the nature of science and approaching towards events (U=47383.50, *p*>.05), the exhibition of scientific behavior (U=48620.50, *p*>.05), the place and significance of science in society (U=49360.00, *p*>.05) and being volunteer to take part in scientific research (U=47709.00 *p*>.05). In addition, the total mean score for the scientific attitudes scale as a whole was found not to significantly differ based on the gender of the participants and it was found to be U=48595.00 (*p*>.05). Only the scores of the participants in the sub-dimension of the nature and aim of science was found to differ based on the gender of the participants. Its mean score is U=45464.00 (*p*<.05). In this sub-dimension, it is further found that girls (331.89) have much more positive scientific attitudes in contrast to boys (302.08).

In order to reveal whether or not grade level has a significant effect on the participants' total score and scores in the sub-dimensions of the scientific attitudes scale the Kruskal Wallis H-Test was used. The results obtained are given in Table 5 below.

Table 5. The results of the Kruskal Wallis H-Test in regard to the effects of grade level on the participants' total mean scores and scores in the sub-dimensions of the scientific attitudes scale

Dimensions of The Scientific Attitude Scale and Means of Total Scores	Grade Level	N	Means of rank	*sd*	χ^2	*p*	Difference (p<,0167)
The Nature of Scientific Laws and Theories	6.grade	212	323.15	2	.546	.761	-
	7.grade	206	310.24				
	8.grade	216	318.88				
The Nature of Science and Approaching Towards Events	6.grade	212	324.36	2	5.796	.055	-
	7.grade	206	293.03				
	8.grade	216	334.10				
Exhibition of Scientific Behaviour	6.grade	212	285.17	2	12.427	.002*	6-8
	7.grade	206	319.60				
	8.grade	216	347.23				
The Nature and Aim of Science	6.grade	212	312.86	2	6.633	.036*	7-8
	7.grade	206	342.71				
	8.grade	216	298.01				
The Place and Significance of Science in Society	6.grade	212	318.30	2	.322	.851	-
	7.grade	206	322.21				
	8.grade	216	312.23				
Being Volunteer to Take Part in Scientific Research	6.grade	212	340.94	2	21.399	.000*	6-8, 7-8
	7.grade	206	342.39				
	8.grade	216	270.76				
Total	6.grade	212	324.82	2	3.108	.211	-
	7.grade	206	328.53				
	8.grade	216	299.79				

*$p<.05$

As can be seen in Table 5, grade level do not have any statistically significant effect on the students' scores in three sub-dimension of the scientific attitudes scale and on their total mean score. These three sub-dimensions and the related mean scores are given as follows: the nature of scientific laws and theories ($\chi^2_{(2)}$= .546, *p*>.05), the nature of science and approaching towards events ($\chi^2_{(2)}$= 5.796, *p*>.05) and the place and significance of science in society ($\chi^2_{(2)}$= .322, *p*>.05). It was also found that the total mean score of the participants in the scientific attitudes scale was not significantly affected by the grade level ($\chi^2_{(2)}$= 3.108, *p*>.05).

The scores of the participants in the remaining three sub-dimensions of the scientific attitudes scale were found to significantly differ based on grade level. These three sub-dimensions and the related mean scores are given as follows: the exhibition of scientific behavior ($\chi^2_{(2)}$= 12.427, *p*<.05), the nature and aim of science ($\chi^2_{(2)}$= 6.633, *p*<.05) and being volunteer to take part in scientific research ($\chi^2_{(2)}$= 21.399, *p*<.05). In order to identify which groups are the causes for the significant difference the Mann Whitney-U test was employed. The results showed that the scores of the sixth and eightht graders are significantly different in the sub-dimension of the the exhibition of scientific behavior. It was further found that this difference was in favor of the latter group. The other sub-simension of which the mean scores of the participants were found to vary based on grade level is the nature and aim of science. In this sub-dimension there is a statistically significant mean score differences between that of the seventh graders and that of the eightht grade and it was in favor of the former group. As mentioned above, the mean scores in the sub-dimension of being volunteer to take part in scientific research was also found to significantly differ based on grade level. In this sub-dimension, mean scores of all three grade level groups significantly differed and it was in favor of the sixth and seventh graders.

In order to reveal whether or not the income of the participants' families has a significant effect on the participants' total score and scores in the sub-dimensions of the scientific attitudes scale the Kruskal Wallis H-Test was used. The results obtained are given in Table 6 below.

Table 6. The results of the Kruskal Wallis H-Test in regard to Income Level of The Students' Families total mean scores and scores in the sub-dimensions of the scientific attitudes scale

Dimensions of The Scientific Attitude Scale and Means of Total Scores	**Income Level of The Students' Families**	**N**	**Means of rank**	***sd***	χ^2	***p***	**Difference (p<,0167)**
The Nature of Scientific Laws and Theories	1.High	278	329.56	2	2.426	.297	-
	2.Medium	159	302.73				
	3.Lower	197	312.41				
The Nature of Science and Approaching Towards Events	1.High	278	353.36	2	20.937	.000*	1-2,1-3
	2.Medium	159	303.92				
	3.Lower	197	277.86				
Exhibition of Scientific Behaviour	1.High	278	391.31	2	81.724	.000*	1-2,1-3
	2.Medium	159	268.57				
	3.Lower	197	252.83				
The Nature and Aim of Science	1.High	278	341.36	2	9.001	.011*	1-3
	2.Medium	159	305.69				
	3.Lower	197	293.36				
The Place and Significance of Science in Society	1.High	278	349.45	2	16.159	.000*	1-2,1-3
	2.Medium	159	303.10				
	3.Lower	197	284.04				
Being Volunteer to Take Part in Scientific Research	1.High	278	353.87	2	20.102	.000*	1-2,1-3
	2.Medium	159	296.91				
	3.Lower	197	282.79				
Total	1.High	278	384.46	2	68.190	.000*	1-2,1-3
	2.Medium	159	280.36				
	3.Lower	197	252.98				

**p*<.05

As can be seen in Table 6, the income of family has statistically significant effects on five out of six sub-dimensions as well as on total mean scores of the participants in the scientific attitudes scale. The only sub-dimension of which mean score was not affected by the family income was found to be the nature of scientific laws and theories ($\chi^2_{(2)}$= 2.426, *p*>.05). Those sub-dimensions of which mean scores were significantly affected from the family income and related mean scores are as follows: the nature of science and approaching towards events ($\chi^2_{(2)}$= 20.937, *p*<.05), the exhibition of scientific behavior ($\chi^2_{(2)}$= 81.724, *p*<.05), the nature of scientific laws and theories ($\chi^2_{(2)}$= 9.001, *p*<.05), the place and significance of science in society ($\chi^2_{(2)}$= 16.159, *p*<.05) and being volunteer to take part in scientific research ($\chi^2_{(2)}$= 20.102, *p*<.05). As stated earlier, the total mean score for the scientific attitudes scale was also affected by the family income ($\chi^2_{(2)}$= 68.190, *p*<.05). In order to identify which groups are the causes for the significant difference the Mann Whitney-U test was employed. The results showed that the mean scores of the participants in the sub-dimensions of the nature of science and approaching towards events, the exhibition of scientific behavior, the place and significance of science in society and and their total mean score in the scientific attitudes scale significantly differ among those from higher socio-economic status, those from medium socio-economic status and those from lower socio-economic status. It was also found that this difference was in favor of those from higher socio-economic status. In the sub-dimension of the nature and aim of science the mean scores significantly differ between those from higher socio-economic status and those from lower socio-economic status. This difference was found to be in favor of those from higher socio-economic status.

The third research question, as stated above, is "Is there any statistically significant correlation between the participants' scores in the scientific attitudes scale and their academic achivement and their views about scientific knowledge?". The Sperman Brown range differences correlation was used to see whether or not the participants' scores in the scientific attitudes scale and in its sub-dimensions were correlated with their academic achievement and their total scores in the scale of views about scientific knowledge. The results are given in Table 7 below.

Table 7. The results of the correlation concerning the relationship between the participants' scores in the scientific attitudes scale and their academic achievement and their views about scientific knowledge

Dimensions of The Scientific Attitude Scale	**Academic Achievement**			**BBYG Total**		
	N	**(rho)**	**p**	**N**	**(rho)**	**p**
The Nature of Scientific Laws And Theories	634	.055	.167	634	$.128^{**}$	.001
The Nature of Science and Approaching Towards Events		$.288^{***}$	.000		$.404^{***}$	.000
Exhibition of Scientific Behaviour		$.398^{***}$	.000		$.393^{***}$	.000
The Nature and Aim of Science		.044	.273		.014	.730
The Place and Significance of Science in Society		$.282^{***}$	.000		$.235^{***}$	.000
Being Volunteer to Take Part in Scientific Research		$.331^{***}$	.000		$.228^{***}$	.000
Total		$.475^{***}$	.000		$.433^{***}$	.000

$^{**}p<.01$, $^{***}p < .001$

Table 7 shows that there is an average, positive and statistically significant correlation between the total mean scores of the participants in the scientific attitudes scale and their academic achievement (r=.475, *p*<.001) and between their total mean scores in the scale of views about scientific knowledge and their academic achievement (r=.433, *p*<.001).

It was found that there is an average, positive and statistically significant correlation between the academic achievement of the participants and their scores in the sub-dimension of the exhibition of scientific behavior (r=.398, *p*<.001) and between their academic achievement and their scores in the sub-dimension of the being volunteer to take part in scientific research (r=.331, *p*<.001). It was also found that there is a low, positive and statistically significant correlation between the academic achievement of the participants and their scores in the sub-dimension of the nature of science and approaching towards events (r=.288, *p*<.001) and between their academic achievement and their scores in the sub-dimension of the place and significance of science in society (r=.282, *p*<.001). However, the academic achievement of the participants was found not to have any significant effect on their scores in the subdimensions of the nature of scientific laws and theories (r=.055, *p*>.001) and the nature and aim of science (r=.044, *p*>.05).

It was found that there is an average, positive and statistically significant correlation between the scores in the sub-dimension of the exhibition of scientific behavior and their total scores in the scale of views about scientific knowledge (r=.393, *p*<.001) and between the scores in the sub-dimension of the nature of science and its approach towards events and their total scores in the scale of views about scientific knowledge (r=.404, *p*<.001). It was also found that the total scores of the students in the scale of views about scientific knowledge has a low, positive and significant correlation with their scores in the sub-dimensions of being volunteer to take part in scientific research (r=.228, *p*<.001), the place and significance of science in society (r=.235, *p*<.001) and the nature of scientific laws and theories (r=.128, *p*<.01). However, their scores in the sub-dimension of the nature and aim of science (r=.014, *p*>.05) is not significantly correlated with the total scores of the students in the scale of views about scientific knowledge.

Discussion And Conclusion

In the study, it was found that the secondary education students have scientific attitudes at the average level. In other words, they have nearly positive scientific attitudes. Ata (1999) also deal with the scientific and social attitudes of the secondary education students and found that they have average or higher levels of such attitudes based on their reports. Demirbaş & Yağbasan (2005; 2011), again, studied the scientific attitudes of the secondary education students and concluded that they have positive scientific attitudes. Afacan (2008) also found that students have positive scientific attitudes. Kılıç (2011) concluded that the scientific attitudes of the eighth graders is at the average level, indicating that they have positive scientific attitudes. All these findings support the present finding of the study. Based on these findings and other findings it can be stated that the basic education science and technology education program which has been in use nearly for seven years is not very influential in providing the secondary education students with scientific attitudes and values.

In the study it is found that the gender of the participants does not have any statistically significant effect on their scores in the total mean score of the scientific attitudes scale and in the scores of the following sub-dimensions of the scale: the nature of scientific laws and theories, the nature of science and approaching towards events, the exhibition of scientific behaviour, the place and significance of science in society and being volunteer to take part in scientific research. On the other hand, the scores in the sub-dimension of the nature and aim of science is found to vary in favor of girls. Based on these findings it can be suggested that not all dimensions of the scientific attitudes differ based on gender and that only the sub-dimension of the nature and aim of science varies based on gender, being in favor of girls. There are studies which reveal no correlation between the total scores of the students in the scientific attitudes scale and their gender (Mıhladız & Duran, 2010; Demirbaş & Yağbasan, 2011). Therefore, it is safe to argue that the related finding of the study is supported by all these findings. On the other hand, there are other studies suggesting that the total scientific attitude scores of girls are significantly much higher than boys (Pearson, 1993; Chuang & Cheng, 2002; Kılıç, 2011; Uzun, 2011). The reason for the contradiction between this finding and previous findings given above seems to stem from the fact that the different participants and different measurement tools were used.

The grade level of the participants is found to have statistically significant correlation with their scores of the following sub-dimensions of the scientific attitudes scale: the exhibition of scientific behaviour, the nature and aim of science and being volunteer to take part in scientific research. However, no such correlation is found for the total mean score in the scientific attitudes scale and in the scores of the following sub-dimensions of the scientific attitudes scale: the nature of scientific laws and theories, the nature of science and its approach towards events and the place and significance of science in society. There are studies suggesting that the total scientific attitude scores of the students do not significantly differ based on their grade level (Afacan, 2008; Akdur, 2002). However, there are other studies suggesting that there is a statistically significant difference between the students' scientific attitudes and the grade level. For instance, Demirbaş & Yağbasan (2005) found that grade level has statistically significant effects on the students' scores in the following sub-dimensions of the scientific attitudes scale as well as on the total mean score: the nature of scientific laws and theories, the nature of science and its approach towards events, and the exhibition of scientific behaviour. The scores in other sub-dimensions were found not to significantly differ based on grade level. It is possible to argue that these findings are partly in parallel to the current findings. Mıhladız & Duran (2010) also concluded that seventh graders have much more positive scientific attitudes in contrast to others from different grade levels.

The family income was found to have significant effects in the students' scores in all sub-dimensions of the scientific attitudes scale except for the sub-dimension of the nature of scientific laws and theories. The same was also observed for the total mean score for the scale as a whole. More specifically, those students from higher socio-economic status families were found to have much more positive scientific attitudes in contrast to those from medium or lower socio-economic status families. Based on this finding it is possible to argue that higher socio-economic status families can provide their children with rich learning environment and therefore, encourage them to make research and scientific activities. In turn, such activities seem to improve the scientific attitudes of children. In the related literature there are studies which suggest that the students' scientific attitudes significantly differ based on family income (Çokadar & Külçe, 2008; Kavak; 2008; Mıhladız & Duran, 2010; Kılıç, 2011; Uzun, 2011). Uzun (2011) found that students from higher income families have much more positive attitudes towards science in contrast to those from other families. Kılıç (2011) found that the students from the families with more than 1500 TL monthly income have much more positive attitudes towards science in contrast to those from the families with a monthly income of 1001-1550 TL. These findings are in parallel to the current finding. However, Mıhladız & Duran (2010) found that basic education students from the medium socio-economic status families have much more positive attitudes towards science in contrast to those from other socio-economic status. Kavak (2008) reached a similar conclusion and found that basic education students from families with a monthly income of lower than 1200 TL have much more positive attitudes towards science in contrast to those from families with a monthly income of higher than 1200 TL. The both findings given above contradict with the present findings. It may be a result of the fact that the samples used and the measurement tools used are different in the studies mentioned above and in the current study.

In the study it was also found that there is a medium, positive and significant correlation between the total scientific attitude scores of the participants and their total scores in the scale of the views about scientific knowledge and their academic achievement. Therefore, the higher the students' scores in the scientific attitudes scale the higher their scores in the scale of the views about scientific knowledge and higher their academic achievement. The review of the related literature shows that there are studies which indicates that the students' scientific attitudes are closely related to their academic achievement (Gürkan & Gökçe, 2001; Alkan, 2006; Turhan, Aydoğdu, Şensoy & Yıldırım, 2008; Demirbaş & Yağbasan, 2011; Kılıç, 2011; Şişman, Acat, Aypay, & Karadağ, 2011; Uzun, 2011). There is no study dealing with the relationship between the scientific attitudes of secondary education students and their views about scientific knowledge. Therefore, the present findings provide new insights into the topic.

In short, the participants of the study have medium and positive scientific attitudes and their scientific attitudes vary based on gender, grade level and family income in some dimensions. On the other hand, their scientific attitudes, their views about scientific knowledge and their academic achievement are positively correlated at an average level.

Suggestions

Based on the findings obtained in the study the following suggestions have been developed for teachers and researchers:

- Not only in science and technology courses but also in other courses activities to improve the students' scientific attitudes should be carried out (for instance, activities which include the steps used by scientists, etc.).
- Given that both views about scientific knowledge and academic achievement positively contribute to the students' scientific attitudes, teachers should carry out specific activities to improve their views about scientific knowledge.
- In the current study the scientific attitudes of the students were quantatively analysed in relation to such variables as gender, grade level and family income. In future studies this correlation may be studied adopting both quantative and qualitative approaches to reveal it in a more detailed way.

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Radical versus Social Constructivism: An Epistemological-Pedagogical Dilemma

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Radical versus Social Constructivism: An Epistemological-Pedagogical Dilemma

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Abstract

In this paper, the author has discussed the epistemological and the pedagogical dilemma he faced in the past and that he is still facing within radical and social constructivist paradigms. He built up an understanding of radical constructivism from the works of Ernst von Glasersfeld and social constructivism from the works of Paul Ernest. He introduced the notion of constructivism including both radical constructivism and social constructivism in brief. Then he reconceptualized these forms of constructivism in terms of epistemological and pedagogical motivation leading to a dilemma. He emphasized how the dilemma within these paradigms might impact one's actions and how resolving this dilemma leads to eclecticism. He summarized that one paradigm world does not function well in the context of teaching and learning of mathematics (and science). Finally, he concluded the dilemma issue with epistemological and pedagogical eclecticism.

Keywords: Radical Constructivism, Social Constructivism, Epistemological-pedagogical Dilemma, Epistemological Eclecticism, Pedagogical Eclecticism

Introduction

Constructivism in mathematics (and science) education is a very popular term. However, it is understood and used by different scholars in different ways. What is constructivism? Why constructivism is radical or social? Does it matter if it is radical or social? These questions encompass some degree of epistemological and pedagogical dilemma facing by this author. From the time when this author inclined toward constructivism in terms of epistemology and pedagogy, the dilemma of radical or social constructivism has significantly impacted his thinking, believing, and acting as a student, teacher, teacher educator, and researcher of mathematics (and science) education. To him, each method or approach of research, teaching and learning mathematics (and science) has a backdrop to a philosophy and theory of learning and knowing from the time of Socrates and even before. Different approaches of teaching mandate different ways of learning and knowing by students and vice versa. Different forms of constructivism, including radical and social constructivism, have influenced the epistemology and methodology of research and also pedagogy of practice. Therefore, '*How students learn and know mathematics?*' is an area of interest to many mathematics education researchers (Ernest, 2010; Noddings, 1990; von Glasersfeld, 1995), especially who focus on constructivist worldview.

Many philosophers and scholars contributed to the theory, epistemology, and philosophy in general (e.g., Ernest, 1991 & 1998; Steffe, 1995; Steffe & Thompson, 2000; von Glasersfeld, 1995) and subsequently, they impacted teaching and learning mathematics (and science) in particular. However, these impacts have not been realized widely beyond research and scholarly publications. It seems that the lives in the classrooms today in different parts of the world seriously lack the conditions of meaningful learning and teaching of mathematics (and science). This author's epistemological and pedagogical dilemma is a consequence of such meager educational foundations and pedagogical practices of the schools and colleges where he spent a significant amount of time as a student and teacher. Many students do not have the opportunity to construct mathematics (and science) knowledge for themselves. They are forced to rote learn facts, formulas, and procedures.

The argument in this paper is based on social constructivism (Ernest, 1991, 1995, 1998) and radical constructivism (von Glasersfeld, 1985, 1995, 1996) in relation to how these epistemological and philosophical

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perspectives might influence approaches and methods of research, nature of teaching, and learning of mathematics (and science). At first, the author introduced the notion of constructivism, radical constructivism, and social constructivism in brief. He reconceptualized these forms of constructivism in terms of epistemological and pedagogical motivation leading to epistemological and pedagogical dilemma. Finally, he concluded the dilemma issue with epistemological and pedagogical eclecticism. The author draws some of the ideas in this paper from his manuscript in an online version in a clearinghouse (Please see Belbase, 2011).

Constructivism

It seems imperative to introduce the notion of constructivism in epistemology, philosophy, and theory of learning. Constructivism is a system of beliefs (worldview) in which the construction of knowledge or process of knowing is compared metaphorically with the construction of a building or furniture or an artifact (Ernest, 2010). The act of construction depends on what tools an individual already has. The tools are prior conceptions of the world through experiences. An individual may construct knowledge of something based on what he or she already knows about it and how he or she reconceptualizes the new experiences based on earlier experiences. The process of knowing is related to one's cognitive, affective, psychomotor, mental, and metacognitive responses to the change within those conceptions (von Glasersfeld, 1995). Hence, one's construction of knowledge stands on what he or she already has in the form of prior knowledge and conception, and how the new experiences adapt to the new conceptions, schemes, or actions (Steffe & Thompson, 2000).

The role of teacher is a facilitator or guide for the students through authentic situations, settings, tasks, and assessments (Christie, 2005). He or she creates the classroom as a learning community (Bielaczyc & Collins, 1999). The role of students is to be cognitive beings who learn through active and constructive engagement in tasks, situations, interactions, and problems. The students become active and creative members of the learning community and contribute in each other's learning (Cooperstein & Kocevar-Weidinger, 2004). The curriculum is flexible, adaptive, and supportive to create learning environment. It is a guide for modeling better teaching-learning environment based on students' cognitive ability and developmental stages (Confrey, 1990). The pedagogy is beyond just teaching and learning. It is a process of caring each other (Hackenberg, 2010). It is a process of connecting self with others and the environment. It is a process of raising awareness and wisdom in the students and also in the teachers (Richardson, 2003). Pedagogy is not a way of preaching by teacher for the students. Constructivist pedagogy dissolves in the process, action, interaction, and is mediated between different states of being with time, space, characters, and actions (Hatfield, 2013).

Constructivism has many faces- trivial, constructionist, cultural and social, radical, critical, feminist, and postmodern constructivism. One can be a trivial constructivist or a constructionist. Others can be critical or feminist or postmodern constructivist in terms of how they practice teaching and learning mathematics and how they conceive and implement the respective epistemologies. The intent of this paper is to highlight radical and social constructivism as competing paradigms for research and pedagogies for education. Hence, this paper focuses on radical and social constructivism as the two competing paradigms as most debated, contested, and used in research, teaching, and learning mathematics (and science).

Radical constructivism

Radical constructivism has been a major philosophical and psychological theory in mathematics and science education. Ernst von Glasersfeld and others have applied this philosophy and theory in research in mathematics and science education, especially in teaching experiments. This philosophical paradigm stands on two basic principles:

Knowledge is not passively received either through the senses or by way of communication, but it is actively built up by the cognizing subject. The function of cognition is adaptive and serves the subject's organization of the experiential world, not the discovery of an objective ontological reality. (von Glasersfeld, 1996, p. 2).

These two principles founded the basis of radical constructivism as an epistemology in research and pedagogy in teaching and learning of mathematics (and science). The paradigm of radical constructivism assumes that the mind is like an organism undergoing through an evolutionary process (Wuketits, 1984). The metaphor of the evolved mind, to this author, is the cognitive re-construction of the experiential world that continues adaptation to better and clearer conceptual or mental percepts or schemes through reorganization of this world (Ernest, 1995; von Glasersfeld, 1995). The mind is like an organism that undergoes continuous evolution, analogous to Darwin's theory of natural selection. The mental process takes the path toward more favorable thinking, believing, and acting for a better survival, existence, and power. Here, the selection process is governed by the adaptation of the mind to the experiential world. The metaphor of the world is the subject's experiential world consisting of schemes, perceptions, values, and knowledge. The Newtonian absolute space is rejected and is replaced by the subjective world of the individual (Ernest, 1995). There might be an objective reality as absolute 'REAL', but there is no way to know it meticulously (von Glasersfeld, 1995). Whatever we claim as reality that we know about the world are mere subjective experiential world(s). The construction of meaning out of the world is an individual mental process. There might be a mediation of social and cultural activities in the process of knowing about the world. More viable cognitive processes are adapted into the mind, whereas counterproductive processes are suppressed and eliminated with time.

A radical constructivist teacher may adapt differentiated instruction based on students' cognitive, affective, and developmental stage. He or she uses creative and constructive situations to present, discuss, test, decide, and apply a model in problem solving. He or she tries to evoke students' interest to the subject matter and the context (von Glasersfeld, 2001). Students build their concepts of what they learn through active cognitive and adaptive process. They embrace the reflective and reflexive thinking and reasoning about content, process, and product (Leo, 1990). However, radical constructivism is not beyond limitations. These limitations are related to social and cultural adaptation of knowledge and knowing. The role of language and interactions among peers or community of practice has not been well conceived in this paradigm. The excessive focus on individual process of knowing and constructing knowledge has created a ground for dilemma. This process led this author toward adaptation of social constructivism.

Social constructivism

Ernest (2010, p. 43) stated, "Social constructivism regards individual learners and the reality of the social as indissolubly interconnected." That means social constructivism identifies individual efforts in learning or knowing in relation to the social context. He further asserted, "Human beings are formed through their interactions with each other as well as by their individual processes. Thus, there is no underlying model for the socially isolated individual mind" (p. 43). This view reflects back to Vygotsky's (1930, 1978) 'mind and society' and 'mind in society'. Social constructivism is the paradigm in which the metaphor of mind is like a connected network of self and others (Vygotsky, 1978). An interpersonal communication and interaction plays a significant cognitive role. The mind is seen not only in an individual context, but it is expanded to a broader social and cultural context, and construction of meaning is considered as a social phenomenon. The role of the individual mind in the construction of meaning is valued in a broader context in relation to others (persons and the environment). The mind constitutes a social entity which creates meaning through conversation, dialogue, interaction, and social and cultural exchanges of ideas (Ernest, 1995). The metaphor of the world is associated with socially constructed world. The individual world is a part of the collective social world. It assumes that there is no isolated individual reality far from socially and culturally constructed world. The metaphor of the world is like a socially and culturally connected experiential world. It does not deny the existence of absolute reality out of a shared world. However, social constructivism does not discuss the nature of reality out of a shared social and cultural world. Personal experiences of individuals become social and collective experiences when they are shared, interacted, transmitted, reconstructed, and retained as knowledge. Therefore, knowledge of the world is constructed out of shared experiences either from the society and culture and/or from the physical world. Even the physical world is interpreted in the context of society and culture. Teaching and learning of mathematics are then tied to the social responsibilities and values (Ernest, 1991 & 1998; Wilding-Martin, 2011).

The dynamic interplay of these metaphors (of the mind and the world) helps us to understand the multiplicities of epistemological and philosophical bases and interpretations of mind and body, being and existing, performing and acting, and relating and connecting things in the natural, social, and cultural arena. This author thinks that the metaphor of the mind and the world is helpful to understand the ontological, epistemological, methodological, and axiological standpoints of an individual or group. The role of teacher is to create constructive interactive environment for students to learn from discussion and peer or group work. Students construct knowledge through interaction in the class and out of class. They play an active role in learning and constructing knowledge through participation, negotiation, and shared values.

Constructivists believe that knowledge is constructed personally and socially based upon experiences. Noddings further asks "What has the assumption to do with judging the status of the general knowledge claim? How do we judge when one knows and when s/he does not?" (Noddigs, 1990, p. 11). To the author, these questions are significant indicators of epistemological and pedagogical dilemma incurred by radical and social constructivism.

The role of teachers, students, curriculum, and pedagogy needs further clarification. It seems that social constructivism lays excessive focus on the language game and interaction as means of constructing knowledge and knowing. The language and interactions can be means of knowledge and knowing, but they do not clearly state what happens in the mind and brain in terms of schemes, perceptions, values, and knowledge. Excessive dominance of social and cultural phenomena has a danger of limiting mental and brain interactions in one's creative efforts. Every knowledge in the world were initiated somewhere by somebody at a time and later it became shared knowledge. These issues influenced the author's ability in judging and distinguishing social and radical constructivist epistemologies and pedagogies through reflective and reflexive interplay within his experiences as a student and teacher. At this point, the author would like to go back and elaborate how he reconceptualized radical constructivism.

Reconceptualizing Radical Constructivism

The author's initial stage of teaching and learning mathematics (and science) began from behaviorism. This kind of practice focused heavily on realist-traditionalist approach of teaching, learning, and even doing research (Belbase, 2006; Belbase, Luitel, & Taylor, 2008). Following reflection on how he learned mathematics as a student at the school level shows a glimpse of this trend:

My learning of arithmetic was limited to numbers and purely bookish numbers, my algebra was limited to variables in the exercises and it never exemplified social and cultural issues. …. Mathematics should serve as an eye of the society in seeing the world, it should be a tool of society for analyzing the social justice and equity, and it should be a way of living, the practice of democracy starting in our classrooms. (Belbase, 2006, p. 66)

The sense of disgraceful classroom practices of mathematics led to his understanding of mathematics as a difficult, decontextualized, and disengaging subject irrelevant in day-to-day life (Luitel, 2009). The bookish knowledge did not relate to any of the practical aspects in social and cultural life. Learning meant simply reproducing the content knowledge even without knowing the meaning of what we did, how we did, and why we did the way we did in mathematics. The context of learning mathematics also influenced this author's teaching of mathematics at the early days of teaching career. Following reflection shows that his teaching was a kind of preaching of mathematical procedures to the students:

I asked Rupak about the day's lesson. He said that it was to start values of trigonometric ratios of standard angles. I made a chart on the board for the values of 0, 30, 45, 60 and 90 degrees of Sine, Cosine, Tangent, Cosecant, Secant and Cotangent ratios in a tabular form. …. When all the students finished their writing, I told them to read silently the values of trigonometric ratios for ten minutes. I moved front and back in the class while they were reading the values from the table. After ten minutes, I asked them to stop reading and be ready to reproduce. (Belbase, 2006, pp. 139-140)

The author reproduced the same notion of teaching as he was engaged in learning while he was a student. He taught mathematics the way he was taught when he was a student. He engaged students in the same process of rote memorization and reproduction of content and in many cases, students might not even know what they were doing and why they were doing. This scenario was how his personal journey of teaching began at the earlier stage of his teaching career. The epistemological and pedagogical significance of these reflections lies within the historical development of this author's personal philosophy of teaching and learning of mathematics from traditionalism to constructivism (Belbase, 2006).

This author participated in different professional development short courses offered by the Ministry of Education of Nepal and different degree courses at universities. These professional development trainings and education led him to develop his personal epistemology and pedagogy of mathematics (and science) oriented toward constructivism in general and radical constructivism in particular. He came to know that radical constructivism as a viable epistemology and pedagogy in mathematics (and science) education. He had a sense of realization that students can construct their mathematics (science) knowledge through individual practice, conceptualization, schematization, and creation of a model of their own learning path. The very notion of active construction, but not the transfer of knowledge, motivated this author toward radical constructivism as a viable philosophical and pedagogical practice.

A motivation toward radical constructivism

The epistemology and theory of radical constructivism have a backdrop on Piaget's constructivist theory of knowing. Von Glasersfeld (1995) clarified how he interpreted Piaget's constructivism and came up with the landmark epistemology of radical constructivism. He worked on the theory of schemes, perturbations, accommodations, and equilibrium. He summarized Piaget's learning theory, "*That cognitive change and learning in a specific direction takes place when a scheme, instead of producing the expected result, leads to perturbation, and perturbation, in turn, to accommodation that maintains or re-establishes equilibrium*" (von Glasersfeld, 1995, p. 68). The condition of perturbation is similar to von Glasersfeld's idea of subjective experiential constraint. These perturbations or constraints are associated with Vygotsky's (1978) zone of proximal development (ZPD). This stage could be the zone within which the learner feels a gap between what he or she knows and what is his or her potential to know. Because of these zones, an individual feels that his or her existing experience contradicts with new experiences and develops state of readiness for learning (by resolving the tensions between existing scheme and a new scheme). It seems that this readiness is associated with Steffe's idea of epistemic students. "Epistemic students are dynamic organizations of schemes of action and operation in the researcher's or the teacher's or students' mental life" (Steffe, n. d., p. 17; Steffe, 2011, p. 21). Steffe further clarifies that the schemes of actions and operations include accommodations in the schemes. This reorganization of the experience in terms of schemes and operations relates to knowledge and knowing in mathematics (and science) (Steffe, Moore, Hatfield, & Belbase, 2014).

A constructivist epistemology deals with what knowledge is, and from where it comes (Von Glasersfeld, 1991). Von Glasersfeld further claims that "the constructivist theory does not fit the conceptual patterns of traditional epistemology, precisely because it posits a different relation between knowledge and that 'real' outside world" (p. 170). Knowing is not about what is real in the world, but it is what one can conceptualize about the world. Von Glasersfeld (1989) stated, "Knowledge is not passively received, but actively built up by the cognizing subject" (p. 162). An individual actively builds up knowledge through reorganization of his or her mental state and brain state through a functional relation (Belbase, 2013). This view relates to what Ernest (1995) accepts that constructivism well acknowledges that knowing is active; it is an individual mental process that goes on while knowing, and it is a personal phenomenon. Largely knowing is based on previously constructed experiential knowledge. Ernest (1995) further points to politics and states that it has to do with giving respect to those positions with which we disagree. Ernest (1995) claims that radical constructivism values multifaceted pedagogy with its heart being sensitive to *individual construction*. This view has a great significance in pedagogy although he seems sceptic to the individual nature of construction, and he purports his arguments in favour of *social construction*.

A radical constructivist teacher does not assume his authoritative role in class. Rather, he or she brings democratic ideals in the classroom, providing enough opportunities to the students to learn from their participation in various activities. These activities relate to creating new experiences or re-adjusting prior experiences while constructing knowledge by students. The teacher considers that his or her role in the class is like a facilitator or a guide to the students (Belbase, 2011). He or she considers the students' active role in learning and creates such environment in which students feel free to learn at their pace, ability, and interest. The teacher acknowledges the role of students as co-authors or co-researchers or co-teachers in the class. Learning does not mean to just assimilating with new information, but it also involves constructing meaning and making sense of what they do, how they do and the why they do the way they do. Then the focus is on thinking and the meanings attributed to experience by the learners (Hein, 1991). Learning is an active process that involves the construction of meaning, and it is a mental process at an abstraction level and also a brain process at the physical bodily level. Other characteristics of constructivist learning are- "learning involves language; learning is a social activity; learning is contextual, and learning takes time" (Hein, 1991, subheading principles of learning, n. p.). The notion of social activity and context for learning are similar to what Ernest (1995) claims. He states that "all knowledge being constructed by the individual (learner) on the basis of his or her cognitive processes in dialogue with his or her experiential world" (Ernest, 1995, p. 14). This notion clearly means that learning is a self-cognition and re-organization of one's experiences while adapting to the social, cultural, and the natural environment. It seems that radical constructivism considers role of teacher and students as collaborators and the social, cultural and natural environment serve as a background for their (students') construction of knowledge.

The process of cognizing schemes, operations, and actions seems to be a progressive one since it always goes from simple to complex in an ordinary situation, whereas, in some cases, it may flow in any direction depending upon the maturity of the learner, self-directed goal of learning, and complexity in the learning environment. In this context, the author would like to emphasize what Noddings (1990) states about critical imagination in teaching and learning:

The great strength of constructivism is that it leads us to think critically and imaginatively about the teaching-learning process. Believing the premise of constructivism, we no longer look for simple solutions, and we have a powerful set of criteria by which to judge our possible choices of teaching method. (P. 18)

Noddings' statement about the constructivist approach takes us to think beyond the actual teaching and learning process, and to consider creative, critical, and imaginative thinking as overarching themes of constructivist pedagogy that Ernest (1995) emphasized. To this author, these qualities of constructivist teaching and learning are the things that he can imagine about any ideal method of teaching-learning that focuses on students' productive and constructive engagement in mathematics (and science) rather than teacher's imposition of contents to their brain or mind.

Radical constructivism, a person who is in favor of this epistemology, neither discards nor accepts the existence of an ideal equation that can truly represent the context (e.g., population growth/change of a species at a place). There is no way to know such ideal equation from the experiential world even if it exists. There is a limitation of human experience to know the ultimate reality. An equation or model can be viable representation of such reality in the world. Nonetheless, such equation may not portray an absolute representation. Hence, viability is a way to judge the usefulness and rationality of knowledge by "fitting within or sliding between its constraints" (Hardy & Taylor, 1997, p. 137).

Ernst von Glasersfeld's theory of radical constructivism considers two ways to look at viability as a legitimate process to establish knowledge. He draws the idea of viability from Piaget. He states that:

Piaget's theory of cognition involves two kinds of 'viability' and, therefore, two kinds of instrumentalism. One is at the sensory-motor level in which viable action schemes are instrumental in helping organisms to achieve goals through sensory equilibrium and survival in their interaction with the world they experience. The next is at the level of reflective abstraction. (von Glasersfeld, 1995, p. 68)

His second principle of radical constructivism assumes these viable functions at the sensory and abstract level to modify and accommodate with the new or existing mental schema or constructs in the mind. While doing this, we try to overcome the conceptual (or schematic) obstacle or constraint that may come to our experience. Our effort to overcome these cognitive, experiential constraints leads us to learning and accommodating new schemes. Then, reflective and reflexive thinking as a cognitive process (of thought experiments) becomes a major part in the construction of new knowledge. That means thought experiment can be a helpful tool to judge the value and applicability of the model. "Insofar as their results can be applied and lead to viable outcomes in practice, thought experiments constitute what is perhaps the most powerful learning procedure in the cognitive domain" (von Glasersfeld, 1995, p. 69). That means radical constructivists can begin making such model at conceptual level and experiment in the real world to judge whether the model produces desired outcome or not. The modification and recreation of such models and schemes continue forever in a teacher's life. This author thinks that viability is associated with establishing the usefulness of methods and findings of such procedures as alternatives to the traditional criteria of objective truth (or Truth). Ernest (1995) further indicates that "one's representations of the world and other human beings are personal and idiosyncratic" (p. 14). For him, "such a view makes it hard to establish a social basis for interpersonal communication, for shared feelings and concerns, let alone for shared values" (Ernest, 1995, p. 14).

The notion of subjective knowing and learning puts this author into a state of epistemological dilemma. How does an individual (if isolated from the social and cultural arena) construct knowledge? What tools are available to him or her? How does the individual knowledge contribute in the broader collective or shared knowledge? These questions led this author further toward epistemological dilemma in radical constructivism.

Epistemological dilemma in radical constructivism

This author thinks that radical constructivism does not explicitly take account of social interaction. There is no explicit discussion about the role of social interaction in the construction of meaning and self-adaptation of mental schemas while shaping one's knowing or learning from the experiential world. This view does not mean that it does not take account of social interaction at all. This author further thinks that there can be various ways to look at the issue. One of them is the role of language in the construction of knowledge and learning. Language acts through semiotics in construction of meaning and learning. Radical constructivism shares some aspects of the language game through semiotics (Uden, Liu, & Shank, 2001) through which a child makes meaning of any object or event is a social process. The semiotics perspective claims that knowledge construction is mediated through signs, but these signs are again schematized within mind and brain through active cognition of an individual. Without such cognition, there is no meaning of a sign or symbol. The signs are visual, auditory or any other sensual forms that can be perceived by the brain and mind in terms of specific constructs (not just communicative structures). The semiotics within a language game is also a part of such cognitive and adaptive function toward learning.

There is interaction of a child with an object, or text, or any artifact through semiotics. Semiotics clearly takes meaning from social interaction in a direct way (face to face communication) or in an indirect way (communication through artifacts). That means social interaction is a necessary condition for learning and making sense of what one learns, but to this author, it is not a sufficient condition for learning. The active participation in community of practice brings individuals into a common platform to share each other's knowledge, ideas, and theories. After sharing they might go through some modifications if necessary. The shared knowledge, ideas, and theories become social knowledge. However, the social aspect is only an accessory part of learning as all social interactions do not result or confirm into a state of knowing or learning. Social interaction is an aspect of symbolic interaction (Thompson, 2000). One who participates in the interaction, to this author, does not mean that he or she is constructing knowledge. At least not, in the same way, as the speaker intends. The meaning of symbols through utterances (speech words, sentences) may change or may be different from the speaker to the listener. The structure may be the same, but the meaning can be different because the way meaning is constructed depends on how one conceives of those symbols (words, sentences, pitch of the sound, etc.). It is always a personal or individual matter that takes place differently, even within the same context. Then, it is clearly a secondary aspect of constructing knowledge or learning. True learning takes place in one's brain and mind. Interaction of mental state and brain state through an operator or function (whatever it may be) leads to conceptual change in mental state and some physical change in brain state (Belbase, 2013). Therefore, to some extent, learning is an individual responsibility, and teacher is simply a facilitator to help students in carrying out that responsibility. This view raises some questions in relation to radical constructivist epistemology. How does radical constructivism relate the individual and social interaction? Is knowing of mathematics a purely individual, idiosyncratic experience? How do we know one has learned something or not? As a teacher, how can one help others (students) to learn? Do students take responsibility for their learning? Is it possible at the early childhood or elementary level? These issues further extended to this author's pedagogical dilemma.

Pedagogical dilemma in radical constructivism

It seems that there is no direct control of a teacher in one's construction of knowledge or learning, though there can be an influence, in a way, how the students learn or do not learn as intended. Although radical constructivism acknowledges, adapts, and incorporates the role of social interactions in the process of constructing knowledge, this author thinks that it is not yet clear how such processes influence mind and brain. How individuals make sense of shared knowledge? The social and cultural norms, values, and practices are sometimes against individual growth and development. In such a case, individuals have to use their epistemic and pedagogical courage to move beyond social and cultural chains. However, this does not mean that radical constructivists ignore the role of social interaction, but it is not explicit. Piaget's idea of perturbation, disequilibrium, and coming into equilibrium; von Glasersfeld's idea of constraints, and Vygotsky's idea of ZPD are somehow associated with social interaction.

Feeling or experiencing a constraint may be due to personal experience toward an object or phenomena or it may arise due to social interaction when there is a state of disequilibrium in terms of experiences. Ernst von Glasersfeld (1991) admits that a social interaction plays a key role in the construction of individual knowledge, but as a radical constructivist, he argues that the understanding and making meaning of an object or phenomenon is purely an individual process. He states, "Experiential worlds belong to individuals, but in the course of social interaction these individual worlds become adapted to one another and come to form a *consensual domain*, i.e. an area where the interactor's mutual expectations are more or less regularly realized" (von Glasersfeld, 1991, p. 5). There might be some compromises in the meaning or sense of the object or the phenomenon even when individual differences still may exist. Individual interest, creativity, passion, perseverance, and efforts are key in construction of knowledge and knowing. Ontologically, an individual is the basis of social. Epistemologically, social is the basis of understanding an individual. Social cognition is the basis of individual cognition at first degree and then individual cognition may reflect back to the social cognition (Bandura, 1989). Therefore, teaching and learning and any form of knowledge construction at individual level is questionable.

The extreme form of individuation in the pedagogy of radical constructivism was questioned by many scholars at the Montreal meeting of the Psychology of Mathematics Education in 1987. The major questions were related to- ontology, metaphysics, and solipsism (Steffe & Kieren, 1994). How teachers can help students construct mathematical ideas? Why teacher is necessary for the classroom? Why students need support from the teacher or others who know the subject matter? These issues raised a pedagogical dilemma within the author's mind. If knowing is subjectively abstracting the experiences, then what is the form of knowledge about the objective world beyond our experiences? How can we foster teaching and learning of mathematics and science at the level of generality? How can we develop a sense of shared values through individualistic knowing and learning? These dilemmas lead this author toward a reconceptualization of social constructivism.

Reconceptualizing Social Constructivism

Earlier, this author reflected on his early stage of learning and teaching mathematics that were heavily influenced by behaviorist and traditional-realist perspectives. His continued learning and teaching approach to be modified and somewhat improved with new experiences through trainings and further education. In this context, he reflects (in the following paragraph) on how he slowly moved from being a traditional behaviorist to a constructivist teacher.

Students came into the class at ten in the morning. I had already kept some cardboard boxes, some pencils, markers, cardboard papers, print papers and a roll of masking tape on a table. I welcomed the students in the class. I wrote the topic of the day "Algebraic thinking" on the white board..…… I let them discuss for fifteen minutes. The discussion on the topic continued for fifteen minutes. The students shared their views before reading the paper and after reading it. Then they summarized their views in print paper in three groups. Each group presented their views and opinions turn by turn by fixing the written print papers on the wall. (Belbase, 2006, pp. 185-186)

This reflection portrays how he was trying to change his epistemology and pedagogy from the traditionalism to the constructivism. The way he was teaching mathematics and mathematics education showed a shift in the paradigm, to some extent. The way he tried to facilitate the students' learning, the way he tried to engage the students in discussion, reflection, and sharing in the class involved some level of constructivism in general and social constructivism in particular.

This issue relates to '*how knowledge is constructed'* in the classroom through shared responsibilities between teacher and students. It may be a good idea to begin this discussion from mathematics and objects of mathematics. What is mathematics and what constitutes objects of mathematics? Mathematics as a process of systematic study of numbers, shapes, and various relations in the nature and natural phenomena may be a positivistic view. Whereas mathematics as the systematic study of human constructs of interpretation of various phenomena may be inclined toward the constructivist view. Domain of mathematics within positivist and constructivist epistemology may be different. The positivist epistemology considers mathematics as empirical studies of natural and social phenomena as its domain. The constructivist epistemology considers mathematics as interpretation and construction of models for various phenomena. Then from this point of view mathematical knowledge arises from negotiation of personal and social constructs and the shared meaning of any phenomena. Classroom teaching and learning is a context to create such knowledge and knowing of social, cultural and scientific phenomena as object of mathematics. This view goes further toward how we make sense of social constructivism and how it motivates us toward epistemological and pedagogical actions, as a metaphor of metamorphosis. The classroom process is a social reality. The teaching and learning involves multiple actors and hence it is also social reality. The research as a collective creative endeavour involves many aspects including social and cultural norms of the community of practice and hence the process and outcome is social reality. These ideas motivated this author toward social constructivism as an epistemology and pedagogy.

A motivation toward social constructivism

The metaphor of metamorphosis from traditionalism to constructivism seemed to be guided by Ernest's (1991) philosophy of mathematics and mathematics education (Belbase, 2006). Reading about constructivism, especially social constructivism, was a great eye opener to this author. Three major epistemological domains in the philosophy of mathematics- logicism, formalism, and constructivism – and how they view mathematics and mathematical processes provided this author an insight about his contemporary approach of teaching and learning of mathematics. Ernest (1991 & 1999) together with Driver, Asoko, Leach, Mortimer, and Scott (1994) helped this author in moving toward a constructivist approach in general and social constructivism in particular.

There are certain characteristics of social constructivism. The three grounds for social constructivism for mathematics (science) can be stated as: *"The basis of mathematical knowledge is linguistic knowledge, conventions and rules, and language is a social construction; interpersonal social processes are required to turn individual's subjective mathematical knowledge, after publication, into accepted objective mathematical knowledge; and objectivity itself will be understood to be social"* (Ernest, 1999, p. 42). These three criteria for mathematical knowledge as a social construction helped this author to orient toward social constructivist epistemology and pedagogy, to some extent. The linguistic basis, transformation of subjective to objective knowledge, and nature of objectivity as social formed the ground to develop social constructivism to a dominant philosophy and psychology of mathematics education. This view connects further to Driver et al. (1994). From a social constructivist perspective of Driver et al. (1994), mathematical and scientific knowledge originates from personal constructs of individual mathematicians, scientists or researchers in a raw form. The raw knowledge is brought to the scientific community for further processing. Processing of knowledge means bringing that raw knowledge into discussions among the members of the community (e.g., students, teachers, researchers, scientists, and parents) through publications, oral presentations, group discussions, and sharing among each other. This kind of practice may broaden the original knowledge with more inputs or comments or critiques from the stakeholders and scientific community (Ernest, 1999). The shared knowledge becomes a socially accepted and socially constructed knowledge that can be considered as 'taken for granted' knowledge within the community.

Hence, from a social constructivist perspective, the notion of learning is associated with the collective building of knowledge through negotiation, agreements, and common practices. While doing this, every person plays the role of a learner or a learned depending upon the context and complication of things that he or she deals with at the moment. A more experienced person guides a less experienced one in the process of learning. Therefore, learning is not just a personal or individual interpretation of things, nevertheless it is a collective interpretation of things through which the less experienced members get exposure to the community of practitioner from where he or she learns the culture of knowing, doing, thinking, and reasoning. This notion relates to social and cultural adaptation. The construction of knowledge depends on how individuals as members in a community play different roles actively (or passively) and make a contribution to the social process of generating knowledge. In this process, language plays a significant role. The construction of new knowledge is a language game by giving meaning to our words, actions, and experiences. This view seems somewhat counter-intuitive to radical constructivism. In radical constructivism, language, in the form of communication, does not carry meaning from person to person. Nonetheless, each individual actively constructs their meaning through individual cognitive, adaptive, and idiosyncratic process and experience. Language and communication (in the form of interaction) is not the end of construction of knowledge or learning, however it is only a part. The construction of knowledge is deeper than what is communicated, shared or interacted. The idea of social and cultural adaptation through language games pushed the author toward epistemological dilemma.

Epistemological dilemma in social constructivism

Ernest (1991 & 1999) and Driver et al. (1994) helped this author to change epistemological and pedagogical paradigm from traditionalism to constructivism in general and social constructivism in particular. Ernest (1995) compared different paradigms in terms of metaphor of mind and the world that helped the author to understand other constructivist paradigms. Later on, this author continued reading the different forms of constructivism that helped him to know more about radical constructivism of Ernst von Glasersfeld (von Glasersfeld, 1989, 1990, 1991 & 1995) and Steffe and Thompson (2000). These readings helped this author to compare the two paradigms- radical and social constructivism- and added in the growing dilemma.

The cycle of objective and subjective knowledge seems problematic to this author. The notion of objective and subjective interpretation of experiences, schemes, and personal constructs cannot be judged simply from the social phenomenon. Ernest (1991) states that-

Social constructivism links subjective and objective knowledge in a cycle in which each contributes to the renewal of the other. In this cycle, the path followed by new mathematical knowledge is from subjective knowledge (the personal creation of an individual), via publication of objective knowledge (by intersubjective scrutiny, reformulation and acceptance). Objective knowledge is internalized and reconstructed by individuals, during the learning of mathematics, to become the individuals' subjective knowledge. Using this knowledge, individuals create and publish new mathematical knowledge, thereby completing the cycle. Thus, subjective and objective knowledge of mathematics each contributes to the creation and re-creation of the other. (Ernest, 1991, p. 43).

The objective-subjective cycle as part of social constructivism in mathematics education seems contradicting within itself. It emphasizes the publication of individual knowledge of mathematics to convert it from subjective to objective. How do publication and dissemination make mathematical knowledge an objective? The publication is a way to share the knowledge from individual to the community of practitioners. Sharing in the community does not mean that it is accepted by the community. It does not mean that other mathematicians and researchers take such mathematical knowledge as taken for granted. There are always critiques and appraisals of any knowledge of mathematics (and science) when it is shared, interacted, and published. This is how the author's dilemma toward social constructivism grew further. This dilemma becomes strong with the notion of shared knowledge of Driver et al. (1994).

Knowledge is constructed through social conversations and activities about shared problems through which meaning is interpreted by involving persons-in-conversation with the help of skilled members (Driver et al., 1994). The process of appropriation through involvement in the social activities also may help individuals to gain control over the tools, to some extent. The metaphor of learning as discovery or a new invention assumes that learning is as an individual process through which individual makes meaning of things or phenomena, and constructs ideas out of them. This idea reminds me that "If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry" (Driver et al., 1994, p. 5). In this statement, Driver et al. emphasized access to physical experiences, concepts, and models of conventional science. By this process intersubjective knowledge is converted to objective knowledge through public acceptance (Ernest, 1991). That means the public domain of mathematics as knowledge is an objective knowledge, even when it begins from subjective knowledge. Whereas, the author's understanding of objective knowledge is the one that is universally unique with time, place, society, and culture. At the beginning stage or in a crude form, to some extent, mathematical knowledge is localized and culture-dependent. It has a root somewhere in some cultures. It is originated at a place and in time with an individual effort. A group of practitioners of mathematics and research in mathematics within a community may have different mathematical developments than other groups. If other groups of practitioners do not agree with the initial group, then the conflicting knowledge cannot be taken for granted. That is why any knowledge in mathematics or in science is contestable, fallible, and subject to revision. Therefore, within this paradigm, epistemological and pedagogical notion of social knowledge of mathematics seems problematic.

Social constructivism is a populist term in mathematics (and science) education. Social and cultural adaptation, in many cases, kills individual creativity, and it simply helps individuals to follow the tradition as an unquestionable system. Probably, there should be a balance in construction and enculturation (in both social and cultural forms). Enculturation does not help society and individual to make a radical change or progress. Enculturation, to the author, is an analogous to Darwin's theory of evolution in which change is a gradual process. If we accept and continue following the same traditions or the same practices of knowledge as social and cultural, we will not be able to make progress further or even if it is made, then it will be a slow process. In this context, technological knowledge is growing so fast, and we never had a social and cultural bound to define it, explore it, and extend it. The radical progress in technology at present is through radical view of knowledge construction, dissemination, and sharing. The individuals who spend their lifetime in such development may not gain much from the social process except post development critiques and questions. If social and cultural process is adapted, then knowledge construction becomes evolution, nevertheless not a revolution. This view raises some questions. A social process of knowledge is possible only through individual efforts in terms of leadership in knowledge through research, publications, and interactions. The social nature of knowledge construction raises some questions: What is the nature of knowing as shared experience? How does the individual experience merge to the social experience to be generalized knowledge? How does the shared knowledge maintain its value across the communities of practices? Is knowing mathematics (and science) simply playing a language game? These questions put this author into a state of further dilemma. The dilemma extends further in the form of pedagogical dilemma.

Pedagogical dilemma in social constructivism

Ernest (1991& 1999) and Driver et al. (1994) claim that social constructivism emphasizes the construction of mathematics (and science) knowledge through interaction, communication, and sharing by means of a language game. This author may agree that one's interaction with the world provides a context to learn mathematics (and science). However, this context itself is not the knowledge. Ernest (1991) accepts that "The knowledge of the child develops through interaction with the world" (p. 181). Then, interaction with the peers, elders, juniors, and teachers provides such learning context to the students. Within this paradigm, the teacher is the one who at first intervenes in their learning in the classroom acting as a facilitator. The role of the teacher as an interventionist is essential for enabling students to construct 'cultural tools' (Driver et al., 1994). These different cultural tools may be associated with certain ways of doing things (such as using a formula), writing symbols, defining things or phenomena, making assumptions, and using tools and techniques to solve problems. However, to this author, mere interactions do not generate knowledge, and they do not promote learning unless there are individual awareness and goal toward what to learn, how to learn, and why to learn. In many cases, teacher's intervention is necessary in order to make sure that students are spending their time in productive learning, not just wasting resources in the name of group projects. However, students' personal awareness toward what they are doing, how they are doing, and why they are doing the way they are doing (in mathematics and science class) seems more important.

Learning at the individual level can promote different experiences of the same objects or phenomena in different contexts, and consequently they may have differing 'conceptual profiles' developed in learners' mind (Driver et al., 1994). There can be existences of such competing conceptual profiles in the minds of students, and they can use these profiles wherever they can fit them depending upon contexts. Such differing conceptual profiles, even when they contradict each other, may exist as separate entities, and students can utilize appropriate profile depending upon the situations they come to deal with at time. These conceptual profiles may have different views of the same object or phenomenon, and they exhibit them wherever and whenever they feel comfortable. They may develop these conceptual profiles with respect to different ontology and epistemology. These conceptual profiles may represent layers of reasoning, understanding, and making sense of things or phenomena in different social and cultural contexts. Developing a new conceptual profile as a result of an amalgamation of existing profiles or an independent profile may not supersede or replace the existing profile. That means, the conceptual profile may exist in one's mind as a quantum of thinking or reasoning from a different perspective. Forming and retaining these conceptual profiles, to this author, is an individual process. How social constructivism influences such profiles is not clear.

The existence of such conceptual profile may be problematic about the notion of 'conceptual change' because students do not necessarily abandon their common-sense-ideas as a result of science (and mathematics) instruction, and they will have such ideas available to them for communication within appropriate social contexts (Solomon, 1983 as cited in Driver et al., 1994). "Human beings take part in multiple parallel communities of discourse, each with its specific practices and purposes" (Driver et al., 1994, p. 6). This process also helps to create such differing 'conceptual profiles' in students' mind. When learning science and mathematics is viewed from the perspective of 'conceptual change', then the existence of such 'conceptual profile' is a problem because, to the author, these conceptual profiles may be an obstacle in conceptual change. The existence of differing conceptual profiles may not lead to conceptual change. Nonetheless, it may generate a new conceptual profile. This author thinks that when students already have such differing conceptual profiles through experiences in different communities of practices, then 'conceptual change' may not happen in a real sense because students may not exhibit such change in a different context. Also, the notion of conceptual profile puts a shadow on the social constructivist notion of objectivity of mathematical knowledge as a shared and public entity. The existence of different conceptual profiles challenges the notion of shared knowledge as objective.

This author agrees with Gray (1997) when he states that "constructivist classrooms are structured in such a way that learners are immersed in experiences within which they may engage in meaning-making inquiry, action, imagination, interaction, hypothesizing, and personal reflection" (n. p.). Also, constructivist learning focuses on autonomy and ownership of learning by the learners in relation to what to learn, why to learn, when to learn, and how to learn. Then, obviously there may not be simple rules for learners to orient them in a more efficient learning. This issue raises a few questions- To what extent language game contributes in mathematics pedagogy? What are the parameters of teaching and learning mathematics beyond communicative function? How do social constructivist teaching and learning of mathematics contribute to reflective and reflexive thinking? These questions led this author further toward thinking about adapting to both radical and social constructivism. There is no one best way in making decision about what works and what does not work in classroom practice. Both radical and social constructivism has limitations in terms of epistemology, methodology, and pedagogy. Then making epistemological and pedagogical choice is based on one's wisdom.

Conclusion

This author came to realize through personal experiences and readings through relevant literature that there is no one best way to describe how we come to know what we claim to know and how we teach or facilitate the students' construction of knowledge. Therefore, eclecticism (a pluralistic approach) in epistemology and pedagogy is necessary to use these theories and philosophies as tools not as ultimate paths to follow. This kind of thinking led the author toward epistemological and pedagogical eclecticism.

Epistemological eclecticism

The paradigmatic tensions between radical and social constructivism can be resolved through a balanced thinking and acting within the scope of radical and social constructivism and beyond. This author believes that the personal construction of knowledge is important for learning and making sense of the world (i.e. mathematics and science). This insight came from radical constructivism (by von Glasersfeld) which states that "the function of cognition is adaptive, and serves the subject's organization of her experiential world, not the discovery of an objective ontological reality" (Heylighen, 1997, n. p.). The subjective role in knowing can be linked with awareness and consciousness. One's awareness and consciousness are reflected through his or her relation to other selves and the world. Then, knowing mathematics (and science) is always connected to the world. Hence, the radical constructivist notion of knowing is not limited to one 'self', however it is more connected to the other 'selves' of the same individual or other individuals. Whereas, the social constructivist notion of knowing is related to shared consciousness and awareness among different selves. The notion of the language game of constructing shared meaning of mathematics and science is a way to bring individual selves into a greater "SELF" through social and cultural semiotics. Then, mathematics (and science) knowledge becomes 'collective commons' despite critiques and uncertainties. This greater 'SELF' is a cognizing subject, either at individual or community level, and its function of cognition is dynamic that serves reorganization with new experiences and it seeks justification of knowledge through legibility. This greater 'SELF' is realized through common uses of language, common social and cultural values, and common adaptation to new knowledge. The notion of common is not blind common but a critical common. Understanding of the two paradigms in terms of conflicting epistemological and pedagogical practices may take us to an unhelpful dilemma leading to confused state and frustration. However, bringing ideas from both paradigms as a unified theory of knowing and teaching-learning might help us in using them in diverse social and educational contexts.

The author concludes that one can never be a perfect or complete social or radical constructivist, but there is an overlap and shift from one paradigm to the other and vice versa in practical life. Construction of knowledge through research, teaching, and learning may not always be only a social or individual phenomenon. There could be a dynamic tradeoff between these paradigmatic movements. In some cases, knowledge construction may begin from an individual effort through laborious experimentation, observation, or intuition and then becomes social after sharing in public or community of practice. In other cases, this process could begin as a social phenomenon with interaction in groups (e.g., focus group discussion) and then becomes a source of individual knowledge for the researcher after his or her analysis and interpretation of the raw data. Again, publication and dissemination could make it social or public knowledge through critiques and comments by others. Students, teachers, teacher educators, and researchers may utilize the multiple ways for construction, validation, and dissemination of knowledge, no matter either the origin is an individual or a community of practice.

Pedagogical eclecticism

For this author, teaching is a social function, and learning could be a private one. Even the social interactions are not learning in themselves, but they are only context in which an individual is challenged or critiqued or suggested through which he or she can conceptualize knowledge. Either empirical or intuitive, experiences are always private and hence construction of knowledge can be a private function. The social function enhances and motivates this private domain of construction. Hence, an individual learns something means he or she constructs knowledge through the cognitive function of self-adaptation to the new ideas or schemes through perceptual experience or introspection. "The role of the teacher is then assumed to provide guidance to the students, but their guidance is tentative and cannot ever approach absolute determination" (von Glasersfeld, 1990, p. 37). The teacher, in the process, becomes a part of intervening force for the child's cognitive adaptation. His or her intervention in the learning process is simply as a guide to encompass the direction and pace of learning. The teacher may help students to orient toward the task, arouse their interest on tasks, and help them organize their tasks. This author thinks that the main pedagogical implication of radical constructivism is associated with clarity and description of the role of the teacher and students. The role of a teacher is simply as a facilitator or guide for learning and creating a learning environment, and the role of the students is like active learners who construct knowledge by active involvement in the learning process. The students' role as learners is more important as constructors or co-constructors of knowledge with the teacher and peers than simply as receivers of knowledge. Both students and teachers take their responsibilities and understand their respective roles.

The construction or co-construction of knowledge and knowing is more a personal, subjective phenomenon than objective reality, though the students get involved in social interaction within or out of class. Ellerton and Clements (1992) discussed radical constructivism in terms of "ownership of mathematics learning by the learner, quality of social interaction as a basis for quality of mathematics learning, and principles for improving the quality of mathematics teaching and learning" (pp. 4-7). These ideas can be further extended to social constructivism. The issue of ownership, quality of learning, and social interactions are also concerns of social constructivism. Only level of interpretation to the contexts might be different. This view further can be linked to Cobb (1990) that students construct their mathematics, this construction is a process of externalization of what they already constructed with flexibility of problem solving and progressive abstraction of conceptual objects of mathematics. This objective can be achieved through teaching and learning mathematics with collaborative action, shared responsibility, shared ownership, effective, communicative function, formal and informal contexts for learning, and autonomy. Hence, pedagogical eclecticism may contribute back to the epistemological eclecticism with a more delicate and inclusive method of knowing and constructing new knowledge.

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Investigating the Leadership Practices among Mathematics Teachers: The Immersion Programme

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Abstract

This study examines the leadership practices, through its peer-mentoring programme called the 'Immersion Programme', specifically in a mathematics department in one of the colleges in Brunei Darussalam. The main aim of the programme was to prepare mathematics teachers to teach mathematics lessons effectively in any secondary year levels and at the pre-university levels. Data were collected through open-ended online surveys. This study involved the participation of one organiser, six mentors and three mentees. The qualitative reports indicated that teachers could have interchangeable roles that exhibit leadership qualities in multiple or overlapping ways, such as simultaneously being a mentor as well as a mentee at the same time. This programme helps to provide the mentors and mentees with the opportunity to learn from each other and share ideas and knowledge which are relevant to improving student learning in mathematics. Mentees were receptive to ideas as their main priority was to teach mathematics lessons effectively and in turn, to improve their students' learning outcomes and success. Indirectly, these were their motivation in doing and continuing with the immersion programme. The leadership portrayed in this study strategises the professional learning experience within the context of the college.

Key words: Leadership, Peer-mentoring, Mathematics teachers, Leadership roles

Introduction

In 2009, Brunei Darussalam underwent major changes in the country's general education structure known as the National Education System for the 21st Century or *Sistem Pendidikan Negara Abad ke-21* in the Malay Language and better known as the SPN21 (Ministry of Education, 2013). According to the Ministry of Education (2013), one of the rationales for the change is to improve students' achievement primarily on one the core subjects namely English Language, Mathematics and Science. In Brunei, Mathematics has always been one of the subjects that challenge school students at all levels from the primary, secondary and post-secondary levels (Ang & Shahrill, 2014; Daud & Shahrill, 2014; Hamid et al., 2013; Mahadi & Shahrill, 2014; Matzin et al., 2013; Mundia, 2010a, 2010b, 2012; Nor & Shahrill, 2014; Pungut & Shahrill, 2014; Salam & Shahrill, 2014; Sarwadi & Shahrill, 2014; Shahrill, 2009; Shahrill et al., 2013; Shahrill et al., 2014; Wahid & Shahrill, 2014; Yatab & Shahrill, 2014). Therefore, in order to help raise students' students' learning outcomes and success in Mathematics, schools need to have quality Mathematics teachers that are equipped with strong Mathematics subject matter knowledge, especially on the levels that they are teaching (Shahrill, 2009; Shahrill & Clarke, 2014).

In a local news article reported in the Brunei Times during the launch of the book Ministry of Education: The Strategic Plan 2007-2011 by the former Minister of Education, Khairunnisa Ibrahim reported that the Minister highlighted the educational system will be deficient in achieving the objectives outlined in the strategic plan without quality, efficient and effective officers, teachers and staff roles (Ibrahim, 2007). These objectives included improving the teaching and learning effectiveness and to produce effective leaders. Leadership has been defined in many different ways. Yukl (1998) stated "most definitions of leadership reflect the assumption

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that it involves a process whereby intentional influence is exerted by one person over other people to guide, structure and facilitate activities and relationships in a group or organization" (p. 3). According to Shahrill (2014), within the school contexts, the principals and the teachers are responsible in shaping the students' future, and importantly, the school culture and values. As for teachers, an effective leadership is critical for the success of educational organisation.

Meanwhile, Low Leng Mey of the Brunei Times reported that Mr P. Rajoo, a consultant from the PR Quality Management Dynamics, Kuala Lumpur facilitated the Cascading Workshop on the Ministry of Education's 2012-2017 Strategic Plan. Mr Rajoo believed that the plan should be focused on three strategic areas of education: teaching and learning excellence, teachers' professionalism and accountability, and institutional efficiency and innovativeness (Low, 2012). From this workshop, mentoring programmes had been identified as one of the strategies to achieve these objectives.

Shillingstad and colleagues (2014) highlighted the contributions mentor teachers, also known as teacher leaders, have made in the development of beginning teachers' leadership skills. These mentor teachers were seen to have exemplary leadership qualities to their mentees and colleagues. Gallacher (1997) defined mentoring as "a caring and supportive interpersonal relationship between an experienced, more knowledgeable practitioner (mentor) and a less experienced, less knowledgeable individual (protégé or mentee) in which the protégé receives career-related and personal benefits" (pp. 196-197). Typically, mentoring is seen as a senior colleague, categorised as the more experienced, guiding and supporting the junior colleague, the less experienced, as they progressed in their early career teaching profession (Eby & Allen, 1997; Heeralal, 2014).

What Constitutes Good Mentoring?

There are many benefits with having mentoring programmes among the teachers in schools. This includes giving support and guidance to beginner teachers to increase their confidence in the content knowledge and instructional practice (Bodie, 2009), and also to help in their transition to the culture of a new school and environment (Tillman, 2005). Stanulis and Floden (2009) stated that novice teachers without adequate support takes 3 to 7 years of teaching experience in order to reach their maximum impact on student learning. So induction programmes like mentoring are aimed to accelerate this process and minimise the amount of time it takes for a novice teacher to be most effective in promoting student learning.

The significance of conducting mentoring programmes in schools is often associated with improving beginning teachers' personal and professional development, which has significant contribution to students' learning outcomes. However, it was highlighted by Ingersoll and Smith (2004) that induction programmes in schools are designed more "as a bridge from student of teaching to teacher of students" (p. 24), and not as replacements for pre-service or in-service teacher training programmes. However these studies mainly discussed about the mentoring from the perspectives of novice or beginning or early career teachers. Yet, none mentioned what happens to those who are already at the mid-stage or prime stage of their teaching careers. Apart from the many on-going professional development courses or workshops offered by the ministry or educational organisations, where and who they turn to, in their own school settings, when they need support in teaching a new Mathematics topic or topics that they have not taught for a period of time?

Tillman (2005) discussed how mentoring can act as a catalyst for transformative leadership; however she only focused on the leadership role of the principal of the school. Although the mentors and mentees hold more informal leadership roles than the principal, it is worth mentioning that they are also responsible in making the programme a success. Communications between the mentee and the principal, and providing a set of specific strategies for mentoring new teachers were among the few problems being discussed by the mentees in this study. So the importance of having strong leadership in conducting such programmes successfully cannot be understated. Depending on the needs, backgrounds and the experiences of the mentees, there are several mentoring models that may be considered. It takes considerable insight and skill for a leader in an organisation to understand the current culture and implement changes successfully (Yukl, 1998). Orland-Barak and Hasin (2010) investigated five case studies of 'star' or exemplary mentor practices in the contexts of the Israeli school system. These exemplary mentors exhibited characteristics of good mentoring traits such as good organisational skills, establishing and sustaining good interpersonal relationships with colleagues, and their abilities to think, behave and act as leaders.

The investigation in this study examined the leadership practices in the Mathematics department of a college through its mentoring programme called the 'Immersion Programme'. This study aims to investigate the leadership practices among the Mathematics teachers in the college and their experiences while being involved in the Immersion Programme. The leadership practices will be discussed in the context of the organiser, the mentors and the mentees. Hereafter, we will refer a mentee as the teacher with less experience specifically in a particular Mathematics subject or level, while the more experienced teacher is identified as the mentor. One of the main uniqueness of this programme lies in the fact that the number of years the mentor or the mentee had in their teaching career is not the driving factor how they are chosen in the first place. In fact, mentors are chosen on the basis of their competency in teaching a particular Mathematics topic or area. In other words, even those who are categorised as beginning teachers but competent in teaching, for example, Mechanics, can be a mentor to a more experienced individual but inexperienced in teaching Mechanics.

The Immersion Programme

The Immersion Programme is a peer-mentoring programme that has been carried out for the past three years in one particular college in Brunei. The main aim was to produce competent teachers for any Mathematics levels from Year 7 to pre-University when needed by providing practical initial training for teachers who have just begun teaching a new level, new to a particular branch of Mathematics (such as Pure Mathematics, Statistics or Mechanics) or those who have not been teaching that level or branch of Mathematics for a while.

The idea was that the mentees will not only observe how a more experienced teacher (mentor) conducts their lessons, but the mentor will also be observing how the mentee conducts his or her lessons as well. In the Immersion Programme, the mentees are also involved in the learning experience of the material just like the students in the college, which included having to do all the work being given. Then, the mentor and mentee can set formal or informal sharing sessions, discussions and feedbacks regarding their personal and professional practices and experiences. Specifically, the programme focuses mainly on helping mentees in familiarising themselves with the structure of the curriculum, and increase their confidence in regards to their content knowledge. However, due to the heavy timetable scheduling, only the teachers teaching the pre-University levels were able to participate in the Immersion Programme and some of the mentors were not able to observe the mentees' classes. This was a serious setback in accomplishing their goals and had limited the full effectiveness of the programme.

Methods

Design

The research approach we adopted for this study was a qualitative field survey approach. A qualitative approach was used because we needed to investigate the leadership practices of the Mathematics teachers in the college. Furthermore, our goal also was to learn about the experiences of the organiser, the mentors and the mentees in relation to enhancing the teaching and learning of Mathematics.

Setting

The college is located in the Brunei-Muara district in Brunei. Although the Brunei-Muara district is the smallest district, approximately 570 square kilometres, it is also the most populated amongst the four districts in Brunei. The population of Brunei is less than half a million. With the capital city Bandar Seri Begawan located in the Brunei-Muara district, this is where the largest concentration of primary and secondary schools, colleges and higher institutions in the nation can be found. The college, on the other hand, is a co-educational government institution located about 10 km from the city. This college caters to Year 7 to Year 10, and two years of pre-University levels of secondary schooling.

Participants

As mentioned earlier, only teachers teaching the pre-University levels were able to participate in the Immersion Programme. Thus, this study involved the participation of 1 organiser, 6 mentors and 3 mentees. All participants are female except for one male teacher. The collective range of years these teachers had been teaching Mathematics was between 7 to 27 years. And, their educational qualifications ranged from those with bachelors to master degrees.

Survey Instruments and Data Collection

All the participants who were involved in this study were asked to complete an online survey. Consent forms were also distributed informing them that participation was voluntary and we will not reveal their names in our reports. In reporting our findings, only pseudonyms will be used.

For the survey instruments, three sets of questionnaires were developed specifically targeted to three sampled categories, the organiser, the mentors and the mentees who had participated or are currently participating in the programme, at the time of the study. It is also important to note that we built our survey questions based on the six open-ended survey questions used by Stanulis and Floden (2009) in their study. Provided in Appendix 1 are the questions given to the respondents in our study. We developed the questions in order to extract as much information as we can from the participants in order to help us analyse the collected data qualitatively.

Qualitative Analysis and Results

In total, 10 responses to the online survey were collected. The procedures for analysis of the collected surveys involved reading all the comments of the open-ended questions. We then looked for overall patterns and completed an overall summary of the comments from the participants. During the analysis, we found several findings worth highlighting (note that all names used here are pseudonyms).

Firstly, the programme allowed the participants to have interchangeable roles that exhibited leadership in multiple or overlapping ways. For example, the organiser of the programme is also the head of the Mathematics department. Being the head, Siti had many administrative tasks assigned by the college, but that did not deter her from volunteering in being a mentor. Surprisingly, Siti, who had 11 years of teaching experience, was mentoring a senior colleague (Riaz) who had 27 years of teaching experience. When asked about her expectations prior to entering the programme, Siti wrote, "*I was nervous and uncomfortable being observed everyday.*" However, as time progressed, she reflected on the benefits and wrote, "*I'm more used to being observed in class as I have been observed everyday, and I get to share with my colleague strategies and knowledge*".

Riaz, whose involvement in the programme as the mentee was voluntary, stated that he chose Siti as her mentor because "*she has been teaching Mechanics for quite some time and Mechanics is her field of specialisation*". In addition, Riaz planned to teach Mechanics the year after and he needed to "*refresh my knowledge in Mechanics because the last time I studied Mechanics was in 1978*". Siti (the mentor) and Riaz (the mentee) attended meetings twice a week throughout the academic year. Siti also described her role during the meetings with her mentee as "*to guide my mentee throughout the programme, in and outside class, to answer my uncertainties from my mentee, and to treat my mentee just like I treat any student in class*". Riaz also volunteered to be a mentor to another Mathematics colleague. He was not the only teacher who did so. There were two other Mathematics teachers, Yuli and Yasmin, who also have interchangeable roles in being a mentor as well as a mentee at the same time.

The second finding worth highlighting was that not all participation in the programme was voluntary. Yuli's participation as a mentor and a mentee was not voluntary. She also stated that when she was a mentee, her mentor was chosen for her. However, she wrote several benefits in her participation such as learning new methods of teaching and observing how her mentor communicated with the students. Yuli added that the drawback in participating in the programme as a mentee, "*not every teacher is willing to let you observe their lessons*".

The third finding is on the level of confidence that Yasmin and Riaz reported from the perspective of their involvement in being mentees. Yasmin wrote, "*It would help me gain confidence in the delivering the appropriate content*," whereas Riaz saw the benefit in having "*more confidence in teaching the subject matter*". To possess confidence was anticipated by Siti when she was asked to describe the benefits of participating in the Immersion Programme,

> Mentors get to be more confident as they are being observed everyday. Mentors also get to be more conscientious when teaching. For mentee, it helps them to prepare for their own class and anticipate problems that they themselves may face in during the same lesson.

Furthermore, Siti, who should be acknowledged in initiating this programme, also added the improvements she expected to see in the school after introducing the programme, "*I expect teachers to be more confident in teaching, be more knowledgeable and be more aware of what they teach in their classroom.*"

Discussion

The discussions presented below will be based on the leadership roles of the respective sampled categories involved in the Immersion Programme.

Leadership Role of the Organiser

Siti, who was the head of the Mathematics department, realised the need to produce Mathematics teachers who are competent in teaching any year level, from Year 7 to pre-University, when needed. She felt that simple observations of lessons without any proper interventions from a more experienced teacher would not provide sufficient help for the mentee teachers to improve their professional and personal competence, so she articulated a clear plan to achieve this objective by introducing the Immersion Programme. Here, Siti had the chance to lead the Mathematics department in transformative ways where she offered support and guidance for the teachers to increase the efficacy of the department. Also, she attempted to develop a relation-oriented leadership style in conducting this programme, where she considered the skill levels, experience and level of confidence in a particular subject when choosing the mentors.

Her role in this programme focuses on a collaborative style of leadership, as she also participated in being a mentor and also monitors the progress of the mentees through discussions regarding their personal and professional development. She uses this as a platform to show her colleagues what is expected from a mentor-mentee relationship in order to maximise the teachers' learning experience in this programme. In this way, she also helped other teachers to develop their own leadership skills that are relevant in improving the teaching and learning of Mathematics in the college. Hence this programme provided the head of the Mathematics department an opportunity to go beyond being an instructional leader as the organiser to a more transformative and collaborative leader.

Siti also mentioned her intention to share this programme with the whole school so that other departments may benefit from the mentoring programme as well. This shows her vision as a teacher leader to help transform the whole school in improving the teaching quality and students' learning outcomes in all of the subjects.

Leadership Role of the Mentors

Leadership practiced by the mentors of this programme focuses on being the role model for the mentees to inspire and motivate the mentees who are faced with the challenges of teaching the Mathematics subject in their year level. Mentors who volunteered in this programme realised their responsibility to provide support and guidance in helping other teachers in any way they can. Mentors who participated in this study reported mostly on helping mentees on familiarising themselves with the content of the subject by informing certain components that needs highlighting and emphasising, and also the areas where students mostly have difficulties in. In doing so, mentors are able to ensure consistency in the curriculum implemented in the school by helping mentees to understand the curriculum and use it to plan instruction and assessment in their own classroom.

This programme helped to provide the mentor and mentees with the opportunity to learn from each other and share ideas and knowledge, which are relevant to improving student learning in mathematics. Mentors advised beginning teachers with different ways of approaching a particular concept to help in exploring and implementing effective teaching strategies. Although some of the mentors participating in this study admitted that having their peers to observe their teaching had made them nervous and uncomfortable, they also realised that this has helped them to be more confident and conscientious when teaching.

Leadership Role of the Mentees

From the results of the study, the mentees were responsible for realising and acknowledging their roles as a teacher and a leader for their students. Their involvement in the Immersion Programme was voluntary because they felt the need to be confident in teaching new levels or branches of Mathematics, improve on their content knowledge and to be able to deliver the appropriate curriculum. They were sincere and had a sense of self-awareness of what they were lacking whereby they wanted to change and improve on themselves first (personal professionalism) before they wanted to improve the students. They were also very committed in attending their mentor's classes throughout the academic school year.

Mentees have a big role in the Immersion Programme because they are the ones needed to be proactive. They were expected to not only initiate discussions and ask for feedback from the mentor but to also be respectful and open-minded in accepting and considering all the criticisms, advices and suggestions given to them. It is worthwhile to highlight the mentees' willingness to learn from their mentor regardless of their years of teaching experience or age differences. They were humble as their main priority was to improve the students' learning outcomes and achievements. Indirectly, this was their motivation in participating and continuing with the Immersion Programme.

Mentees have the experience of learning the materials similar to students when observing their mentor's class, so they were expected to be punctual, disciplined and professional in terms of completing their work and their performance in tests. Furthermore, since they became students themselves, it eliminated the feeling of being disconnected with their own students and had more understanding to the class environment. Being able to observe a more experienced teacher had helped the mentees to be more confident, understand the subject matter better and have a more organised and structured curriculum for teaching their students. To be a great leader, you must first become a great follower. Mentees must possess the characters of being a great follower of the mentor in order to be able to be the great teacher leader of their own classrooms.

Conclusions

The qualitative reports indicated that teachers can have interchangeable roles that exhibit leadership qualities in multiple or overlapping ways, such as being a leader to their own students and colleagues, and at the same time, handling the many administrative roles tasked by the college. This programme helped to provide the mentors and mentees with the opportunity to learn from each other and share ideas and knowledge, which are relevant to improving student learning in mathematics. It is worthwhile to highlight the mentees' willingness to learn from their mentors regardless of the number of years of teaching experience possessed by the mentors or in terms of their age differences. Mentees were receptive to ideas as their main priority was to teach mathematics lessons effectively and in turn, to improve their students' learning outcomes and achievements. Indirectly, these were their motivation in doing and continuing with the immersion program. The leadership portrayed in this study strategises the professional learning experience within the context of the college.

The findings regarding the organiser and the mentors exhibiting leadership characteristic traits that we have reported here resonates to some extent to the cases of exemplary mentoring practices reported by Orland-Barak and Hasin (2010). Regardless of the roles they assume, teacher leaders will shape the schools or colleges in terms of improving the students' learning, and influencing practice among their peers (Shahrill, 2014). Mentioned earlier are just some of the uniqueness or the distinctive features that we can summarise from the Immersion Programme; a mathematics teacher can be a mentee despite the teachers' age or seniority, and the mentee experience life as a 'student', to sit in the class with the actual students, doing the same classwork and homework exercises; and it is the only department in the college conducting this type of mentoring programme.

The Immersion Programme is an innovative approach to provide teaching and learning excellence. As was mentioned earlier regarding the article reported by Low Leng Mey of the Brunei Times (Low, 2012), we may have identified a mentoring programme that is in line with the 2012-2017 strategic plan of the Ministry of Education in Brunei. Other departments in the college, and other schools and colleges in the nation should also implement mentoring programmes such as this. It should be inclusive of teachers from all backgrounds and levels of experience, and not only limited to teachers who are new to teaching a particular level. Teachers have various styles of teaching and there is always something that can be learnt from one another. In the speech prepared by John F. Kennedy, he stated, "leadership and learning are indispensable to each other". This intrinsic relationship between leadership and learning is vital to not just for student learning but also for developing the skills and abilities of future generations of leaders.

The findings shared in this study may have implications for educational practice. In developing teacher education programmes, previous studies (such as Bodie, 2005; Ingersoll & Smith, 2004; Stanulis & Floden, 2009; Shillingstad et al., 2014) typically discussed about mentoring beginning/novice/early career teachers by more experienced teachers. However, as far as is known, not many discussed about mentoring those who are considered to be at the mid career stage or even at the prime stage of their careers. Perhaps, the leadership and relationship approaches entailed in the Immersion Programme may be taken as one of the exemplary mentoring practice that needs to be shared. As stated by Shahrill and Clarke (2014), "It is through first recognising distinctive features of local pedagogies and then connecting these to learning outcomes that research is likely to inform teacher education and increase the effectiveness of classroom practice" (p. 13). This study has tentatively identified some of the distinctive features of mentoring practices in Brunei, particularly in relation to exhibiting leadership qualities of a teacher tasked as the organiser or the mentor. Several avenues for further research are suggested by the findings. In particular, further investigation on the contribution and impact of the mentoring practices on students' learning.

Limitations of the Study

The present study has two main limitations. Firstly, this study was limited to only one selected college in Brunei. It is not known whether other schools or colleges have similar mentoring practices as portrayed in this study because as far as is known, none has ever been reported. Moreover, caution should be taken when interpreting the findings to this particular college only. Secondly, although the results shown here are mainly positive, there is more to be learned about the quality of the Immersion Programme. The programme itself had several setbacks that limited its full effectiveness, thus further development needs to be done to monitor the progress after the initial implementation.

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Appendix 1

The survey questions given to participants

Organiser	Mentor	Mentee
• What initiated the department to introduce this programme for the staffs?	• Please indicate the year level you were teaching during the Immersion Programme.	• Please indicate the year level you were teaching prior to doing the Immersion Programme and the year level you were observing during the programme.
• What is the purpose/ objective of the Immersion Programme?	• Is/ Was your involvement in the Immersion Programme as a mentor voluntary. If so, why did you choose to participate in the Immersion Programme?	• Is/ Was your involvement in this programme voluntary? If so, why did you choose to participate in the Immersion Programme?
• Describe your role as the organiser in this programme.	• What was your expectation prior to entering the programme?	• What was your expectation of the programme prior to your involvement?
• Are any of the other departments in this school doing similar programme?	• Describe your role during your meetings with your mentee?	• How and why did you choose your mentor?
• Is the Immersion Programme only essential to teachers teaching a new level in the mathematics department?	• What did you discuss about while leading your mentee? (e.g. application of effective instructional techniques in a Mathematics topic, classroom management and discipline, and student achievement, communicating with parents, content knowledge etc.)	• How many meetings with your mentor have you attended during the programme?
• How are the mentors chosen?	• How many meetings with your mentee have you attended throughout the mentoring process?	• Describe the benefits and drawbacks (if any) of participating in the Immersion Programme.
• What is expected from the mentor-mentee relationships?	• What specific activities were you involved in with your mentor during your individual meetings (e.g., observations and feedback, co-planning etc.)?	• What specific activities were you involved in with your mentor during your meetings (e.g., observations and feedback, co-planning etc.)?
• How long does the mentoring process usually take?	• Describe the benefits and drawbacks (if any) of being the mentor in this programme.	• What was/ is the main challenge that you were/ are facing while doing the Immersion Programme?
• How often do the mentors and mentees usually meet for discussions throughout this programme?	• How important do you think for new Mathematics teachers to be involved in the Immersion Programme?	• Describe what you wish you could have learned from your mentor that you did not learn.
• Describe the benefits (if any) of participating in the Immersion programme.	• Describe whether you were able to have open and candid conversations with your mentee and why (or why not).	• Describe whether you were able to have open and candid conversations with your mentor and why (or why not).
• What are the challenges and limitations of carrying out this programme?	• What changes would you make about the programme?	• What changes would you make about the programme?
• What improvement did you expect to see in the school after you introduced this programme?	*Optional:* • Please indicate your year of experience as a teacher. • Please indicate your academic background. • Please indicate your current role in school.	
• Have your objectives been achieved so far?		