The impact of computer use in the development of mathematics teaching in primary education

By

Nabil Alawadhi

Professor Mike watts, Thesis Supervisor

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Abstract

The educational system in Kuwait is intended to provide primary and secondary students with required skills in order to operate in the technical careers commonly undertaken. However, mathematics education lags significantly behind other countries in Kuwait. In the 1997 and 2008 TIMMS international studies of primary and secondary mathematics achievement, Kuwait ranked near the bottom on almost all scores. Thus, improving mathematics education in Kuwait is an issue of serious concern. This research focuses on the question of whether mathematics teaching and learning in Kuwaiti primary schools (grade 4) can be improved through the use of computer-based tools for practice drills and constructive mathematics play. An observational intervention was used in a classroom of 24 children, where students took a pre-test for mathematics achievement, then engaged in a series of exercises through the term and were retested at the end of the term. This was accompanied by a series of in-services and teacher interviews that were conducted within the school, in order to discover attitudes about mathematics teaching and learning and to train teachers in the suggested approaches and techniques. A combined qualitative and quantitative approach included analysis of test scores and interviews with teachers and students. The overall outcomes of the study did show a slight increase in mathematics achievement scores. However, more importantly it

showed an improvement in children's and teacher's attitudes to mathematics learning related to the introduction of constructive play activities (derived from the Cambridge University N-RICH program and selected for students based on level of achievement) Overall, the importance of this study is that it provides pragmatic information for Kuwaiti teachers and curriculum designers on improving mathematics teaching and learning.

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Chapter 1 Introduction

In the adult world, computers and mathematics share a conflicted, sometimes negative perception. Whether they are fun diversions, useful tools, or incomprehensible tools for specialists, computers and mathematics seem to go together in the minds of people everywhere. Despite this, many people feel they do not truly understand either mathematics or computers, relegating them to the area of technology that is for use rather than for understanding. This is consistent with the learning approaches that were used in mathematics teaching prior to the 1980s, as well as the introduction of the personal computer (PC) in the 1980s and the lack of exposure in their early lives. Today, children exhibit very different attitudes toward computers, often engaging in complex computational tasks that adults continue to struggle with. This is the legacy of growing up in a world where computers are taken for granted, rather than being novel (and expensive) technologies. However, the perception of mathematics held by children does not seem to have kept pace. In various conversations with children, it becomes clear that many consider mathematics to be an uninteresting subject used school at best, or a frustrating assault on their academic self-efficacy at worst. Clearly, there is little connection between the acceptance of computers and evolution of mathematics teaching and learning.

In the world of education the connection between computers and mathematics has been developing over some time. The theoretical discussions regarding computers in the mathematics classroom dates back to the late 1970s, when educators and computer scientists began to consider the role of computers in the classroom and, at the same time, began to reconsider the ways in which mathematics could be taught. However, this introduction of computers was not immediate, as computers of the time were still slow and expensive and were not generally conducive to positive classroom experiences. It is with the constructivist movement of the 1980s to today that computers in the classroom have emerged as a major tool for mathematics teaching and learning. The constructivist movement views learning not as a formalised approach of rote learning, but as a dialogue between the learner and teacher, where the learner actually constructs knowledge from various sources and in various ways. This movement revolutionised the learning process and changed the approach to mathematics learning. The research that is presented in this paper studies the effects of the introduction of computer-based mathematical activities, including both skill building and practice activities, and enrichment and manipulation activities, to a fourth-grade classroom in Kuwait, in order to determine whether this introduction has transformative potential in terms of student achievement and orientation toward mathematics.

Background to the Problem

The constructivist teaching movement, which began in the 1970s, focuses on the role of learning through experience and individual construction of knowledge, rather than rote memorisation learning as a sequential, formalist logical process. This movement rejected the formalist view of mathematics and began to substitute a view that integrated learning and knowledge that allowed students to make sense in multiple ways of information they are presented with. It led to an approach in the elementary school environment where it was applied, which began to consider mathematics not as a series of formal rules or logics to be taught, but instead as higher order knowledge that could be gained through individual construction of understanding (Hickey, Moore and Pellegrino, 2001). This movement incorporated computers into mathematics learning as tools, or teaching aids, extending the focus on mathematics into other areas of the classroom (Vannatta and Fordham, 2004). The approach of integrating mathematics and computers has been shown to be successful in secondary and tertiary classrooms; in particular, the integration of mathematics and computer science has been highly effective in teacher education as well as training of engineering and high school students (Halpin, 1999; Windschitl and Andre, 1998). However, it is difficult to claim that computers in the primary school classroom have experienced this level of success. First, as successful as the constructivist movement may be, it has low penetration and is often not fully integrated into the classroom. Student teachers are trained in methods of constructivist mathematics teaching, which often includes the use of computers. However, it is often too late for student teachers to fully integrate this new method of learning mathematics into their own conceptions of mathematics. Multiple studies have found that, once in the classroom, teachers often revert to the use of the computer for classroom management or as a reward for students, rather than an integral mathematics teaching tool (Cuban, Kirkpatrick and Pack, 2001; Norris, Sullivan and Poirot, 2003). Given this, students in many classrooms such as those in the studies by Cuban *et al.* (2001) and Norris *et al.* (2003) do not have the opportunity to use computers effectively for mathematics learning. The goal of this research is in part to determine whether this is the case in Kuwait, as there is little research available in this geographic area.

The Kuwaiti Educational System and Performance

The discussion above may be particularly true in the case of Kuwait. Kuwait, a small nation in the Arabian Gulf region, has a strong public school system that provides education to the children of its citizens, as well as a robust network of private schools for non-citizens. (Some of these private schools are government subsidised, but Kuwait does not guarantee free public education to its non-citizen residents.) Kuwait's public schools have a standardised curriculum and teacher training program, and as such, are consistent in teaching methods, knowledge provided, and provision for learning throughout the country. This is very different form many Western schools, where a form of 'postcode lottery' determines which schools have adequate funding and which do not. (Of course, this does not address the varying quality of the private schools, which generally use the curricula of their home country and may have very different levels of education).

However, regardless of the standardisation levels, testing, or national curriculum, Kuwait's educational performance lags behind its capacity. Government funding for education has grown steadily over time in Kuwait, and the government's current focus is on increasing skills and capacity in preparation for a transitional economy (Ministry of National Education, 2004; UNESCO and International Board of Education, 2006). In particular, the educational system in Kuwait is being shifted and modified in order to cope with the expected economic changes that will occur as Kuwait nears exhaustion of its petroleum reserves (Ministry of National Education, 2004; UNESCO and International Board of Education, 2006).

This challenge is being approached by the Kuwaiti government as an oportunity to change the educational system in order to provide training for technology and service sector jobs. However, the Kuwait educational system continues to struggle in terms of achievment. Kuwait's performance on the Trends in International Mathematics and Science Study (TIMSS), which is conducted approximately every four years in order to determine the achievement levels of students in United States grades four and eight (corresponding to ages nine and thirteen), can be used to compare the performance of Kuwait to that of 36 other countries that take part in the TIMSS testing series. As of 1997, Kuwait ranked the second lowest of all countries in fourth-grade mathematics, coming in only slightly higher in performance than Iran (Mullis, Martin and Gonzales, 1997). Only 3% of Kuwaiti students tested at in the top two quartiles of achievement, with a mean scale score of 400 at the fourth grade level as compared to an international average of 529 (Mullis, Martin and Gonzales, 1997). For comparison, one of the top performers, Singapore, had a median score that was equivalent to the 95th percentile in Kuwaiti students (Mullis, Martin and Gonzales, 1997).

Between 1997 and 2007, the most recent year for which there is evidence, the mean scale score performance for Kuwaiti students actually dropped substantially, with a reduction to 316 (Mullis, Martin and Foy, 2008). This performance was worse than all participants in the 2007 TIMSS study, with girls averaging 333 and boys averaging 297 (Mullis, Martin and Foy, 2008). Only 26% of Kuwaiti students achieved benchmark figures that were established for this test, in contrast to 90% averages overall (Mullis, Martin and Foy, 2008). However, one peculiarity did emerge during this testing process. Specifically, students were found to perform better in 'application' domains than they did in 'knowledge' domains (Mullis, Martin and Foy, 2008). This is inconsistent with the expectations of the study: how could students be better at applying something than knowing what they were to apply? One answer may be in the idea of epistemologies of mathematics, or the philosophy or understanding of how mathematics is formed and how it works in the world around us (Shapiro, 2000). Being good at applying mathematics without actually understanding the concepts, according to Shapiro (2000), is consistent with a logicist epistemology, in which mathematics is considered to be a reliable tool in which rules can be applied to real-world situations to achieve predictable results. This is quite likely to be the approach taken by the Kuwaiti government in their movement to redesign the Kuwaiti educational system in order to allow for more consistent performance by students and in order to create a service and technology oriented curriculum. In other words, by changing the curriculum to promote real-world usage and applications of mathematical concepts, the Kuwaiti government may actually have made mathematics teaching in the country less effective, at least in the short term. Thus, a search must be made for ways that mathematics teaching could be improved.

The Introduction of Computers

The 2007 TIMMS study had one interesting finding that resulted from questions that were introduced for this study, due to the growing popularity of computers in the home (Mullis, Martin and Foy, 2008). Specifically, the study classified students according to whether or not they had computers and Internet connections in their home, and then reported average test scores by group depending on whether or not this was the case (Mullis, Martin and Foy, 2008). The resulting average for all students in Kuwait found that students that had computers in the home had a mean score of 331, while students with Internet connections in the home had scores of 328; this was compared to scores of 281 and 310 respectively for those that did not have computers and Internet connections in the home (Mullis, Martin and Foy, 2008). This report, frustratingly, did not provide standard deviations for these figures, precluding the ability to test whether the difference in means was statistically significant. However, it was indicative of the potential for a difference in mathematics learning and understanding based on computer and Internet access.

There is currently little evidence for the use of mathematics in the classroom in Kuwait. Although no formal studies have been performed, the overall consensus in informal discussions with teachers and administrators is that computers are under-provided in Kuwaiti schools and are not commonly used in the classroom; instead, they are relegated to classroom management processes for teachers, or may be used for non-tutorial purposes (such as arts, games, and word processing). Given the known role of the use of computers in constructivist teaching of mathematics in higher level classrooms (Connolly and Begg, 2007; Eckerdal, McCartney, Moström, Ratcliffe, Sanders, and Zander, 2006; Windschitl and Andre, 1998), it is considered that this same approach may provide a substantial improvement to the achievement of mathematics learning in the primary school classroom in Kuwait.

The Context of Teaching in Kuwait

Equally important to the teaching issues and processes that was discussed are the ideas and cultural impacts of the Kuwaiti teaching environment and educational system on the whole. This is because the teaching culture, the expectations set for children, and the overall achievement levels to which children are currently held will determine the overall effectiveness of the introduction of computer tools in the classroom. This is particularly true because Kuwait has a standardised national mathematics curriculum and text, and thus the overall structure of the educational system as a whole, as well as conditions within the individual schools (which was examined during the research process) will affect the outcomes of this study. In order to assist in understanding the current state of education within the Kuwaiti school district the current structure, functionality, and mathematical achievement of the Kuwaiti educational system has been examined. Of particular interest here is the current educational structure, the overall level of mathematics achievement within the fourth grade level and the improvements of this educational performance over time, as well as identification of any particular issues in training or methodologies that have been identified.

This section also presents an overview of previous studies into the impact of computer technology on teaching in Kuwait, of which I have identified a few. However, there is a severe paucity of information available on the issue of mathematics teaching practices and computer use in Kuwait generally; and this is therefore a gap I hope to fill with the current research. It does present difficulties for understanding the background and potential effects of the proposed research. In order to overcome this difficulty, and in order to improve the overall effectiveness of the research, I have also provided an overview of research available for neighbouring countries, although while these results will not be *directly* applicable, they will have some comparative relevance to the work at hand.

Structure of Kuwaiti's educational system

State education in Kuwait is free to citizens and compulsory according to the state constitution (Epstein and Limage, 2008). There are two articles of the constitution that address the issue of education. According to Epstein and Limage, 'Article 40 gives all

Kuwaitis the right to a free and compulsory education… Article 10 indicates that any father who does not enrol his children in school risks incurring a fine or a prison sentence' (Epstein and Limage, 2008, p. 110). Education includes basic instructional rights, and also transportation, books, stationery and supplies, food, and clothing through to the fourth year of university (Epstein and Limage 2008). However, provision for non-Kuwaiti students is less certain; while private schools are available for non-Kuwaiti children and those for Arab expatriate children may be generously supported by the state, those for children of other nationalities may be less certain (Epstein and Limage 2008). Epstein and Limage noted that the schools intended for immigrant children follow the curriculum of their own country, which could account for the difference in educational performance between the two groups. However, this has not been explored in the current research.

The country profile provided by UNESCO's International Board of Education (IBE) provides an excellent insight into the structure and design of Kuwait's primary and early childhood educational system. The compulsory educational period for Kuwaiti children is 6-13 years (UNESCO, 2006). Although most children receive their schooling through a school site, home schooling is also possible (UNESCO, 2006). Although not compulsory, kindergarten and preschool programmes are available to students; according to UNESCO figures (derived from Ministry of Education (2004) reports) as of 2006 a total of 87.7% of children entered compulsory education with previous educational experience from these programs. Funding is provided free to all Kuwaiti citizens, while foreign Kuwaiti residents have access to private nursery schools from age 2 through kindergarten entry age (UNESCO, 2006). Many of the better schools intended for expatriate children are registered with the Ministry of Education's private education department, but this is not required by law and schools for expatriate children may operate without these registrations (UNESCO, 2006). By age 7, 91.8% of children are enrolled in primary education (UNESCO, 2006).

The founding and development of the Kuwaiti educational system

Although the historical aspects of the Kuwaiti educational system are not the direct focus of this research, developing an understanding of how this issue has evolved does shed a considerable amount of light on the issue of the current state of the educational system. Thus, a short history of the development of the current system and its motivations can help to understand not only the current state of affairs but also how this has developed over time.

The first primary and early childhood education undertaken in Kuwait was religious education, as in common with many Islamic societies (Nashif, 1985). Development motivations of education prior to 1912 included a dual focus on the religious education (including learning the Qur'an, mastering written Arabic, prayers, almsgiving, and other aspects of Islamic practice and understanding) and the practical education (including reading, writing, and calculation) (Nashif, 1985). Nashif noted that even during this early stage of educational development, the ties between education and business (which continue to be a focus of the modern education) were present. First the primary system developed within the mosques, but by 1887 the development of the kuttab, or the traditional school, had taken place (Nashif, 1985). The private school, which focused on teaching of second languages and more advanced skills, was well underway by 1910, when the development of a modern school system was proposed

(Nashif, 1985). Nashif identified the opening of the Al-Mubarakiyah school for boys in 1912 as the first of what could be termed a public school, founded through a combination of school fees (determined according to the means of the pupil rather than through a set fee) and state funding derived taxes and other sources. The public educational system began to grow slowly, and at the same time the private school system also developed. 1921 the Ahmadiyyah School was established in the same way as the Al-Mubarakiyah School had been established nine years earlier (Casey, 2007). During this time education for girls began to be established as well, with a private primary school for girls being built in the 1930s (Casey, 2007). By the time the educational system was fully placed under state control in 1945, there were a total of 17 schools integrated into the school system (Casey, 2007). According to Casey (2007), in 1961, the total number of enrolled students in the Kuwaiti state educational system was around 45,000 (18,000 girls and 27,000 boys).

Throughout the middle part of the 20th century the public school system in Kuwait grew rapidly. Al-Dekhayal (2000) observed that expenditures on education in Kuwait grew from 0.08KD million in 1946/1947 to 370.20KD million in 1985/86 (adjusted to 1985 dollars). This funding included the compulsory primary education system, the secondary educational system and the university system established in 1966. This increased expenditure had a definite impact on the level of education for Kuwaiti citizens and non-citizens during this period (Sayigh and Ṣayigh, 1978). Table 1 demonstrates the growth in level of education between the 1957 Census and the 1970 Census in terms of primary, secondary and university level of education in Kuwait between these two periods, which shows a considerable growth in levels of education during this period.

However, it should be noted that this table is not indicative of a large growth in adult level illiteracy during the same period, which is not reflected within this chart (Sayigh and Sayigh, 1978). This growth in illiteracy has been attributed to Sayigh and Sayigh to an inflow of uneducated non-Kuwaiti citizens (tribespeople) who caused a temporary spike in the level of illiteracy during this period.

Educational Level	1957 Census				1970 Census			
	Kuwaiti Citizens		Non-citizens		Kuwaiti Citizens		Non-citizens	
	Total	%	Total	%	Total	%	Total	%
Primary and Intermediate	1,077	36.8	1,849	63.2	61,348	50.1	61,339	49.9
Secondary	197	5.1	3,700	94.9	7,094	19.9	28,585	80.1
University	51	3.8	1,309	96.2	1,347	3.3	13,023	96.7

Table 1 Growth in educational levels in Kuwait, 1957-1970 (Sayigh and Sayigh,1978)

Later development of the educational system included the development of a General Objectives Document in 1976, which spelled out the objectives of the Kuwaiti educational system (Al-Dekhayel, 2004). The overall objectives that were expressed within this document were summarized by Al-Dekhayel (2004) as follows:

1. Promoting belief in the principles of the Islamic religion, where these principles become a way of thinking and a style of life manifested in the pupil’s behaviour and social relations;
2. Introducing the pupils to the Arabic and Islamic heritage, customs and traditions;
3. Introducing the pupils to Kuwaiti history and to the evolution of Kuwaiti society;
4. Creating in pupils a strong feeling of belonging to their country of Kuwait, and to the Arab and Islamic worlds;
5. Strengthening cooperative and brotherly ties and the spirit of one family;
6. Preparing individuals for effective life in their society;
7. Developing the abilities of pupils to think scientifically;
8. Encouraging the study of modern sciences and their applications
9. Maintaining a balance between spiritual and materialistic values;

10. [And] encouraging technical and vocational education. (Al-Dekhayel, 2004, p. 65-66)

Many of these objectives can be traced directly to the beginning of Kuwait's educational system in the religious education of the late 1800s, but these educational objectives also show a clear connection to the issue of trade and nation building. As Al-Dekhayel (2004) noted, "Through providing education, the state has sought to achieve two general goals: The material satisfaction and the political socialization of Kuwaiti citizens (Al-Dekhayel, 2004, p. 66)." The overall focus of the educational system on providing not only a means of introduction to the Kuwaiti culture but as a means of reinforcement of Islamic and Kuwaiti cultural values has also been observed within the university system, and has been expanded to include many other forms of discussion and political focus (Tétreault, 2000). According to Tetreault, the university system has become a vehicle for opposing viewpoints; for example, the tension between feminist activists and traditional Islamist proponents has found a place in the university system. Thus, the modern educational system can be seen as a means of not only enforcing the current educational status quo but also of driving social change.

There are a number of issues in Kuwaiti education. One of the issues that is long-standing in Kuwaiti education is the difference in immigrant and native Kuwaiti educational levels, as well as a heavy reliance on immigrant teachers in the school system (Al-Moosa, Mūsá and McLachlan, 1985). In 1960, immediately before Kuwait gained independence, some estimates state that ninety percent of teachers in the Kuwaiti school system were non-citizens (Casey, 2007). Al-Moosa *et al.* noted in 1985 that there was a relative lack of native Kuwaiti involvement in the teaching system overall, including a lack of enrolment in teaching programmes as well as in university-level mathematics and science programmes (Al-Moosa, Mūsá and McLachlan, 1985). Because of this, much of the school system is dependent on the use of immigrant teachers in order to teach mathematics and science. There are few barriers to immigrant teachers joining the mathematics and science teaching forces as compared to other Gulf countries, but this does impact the overall achievement of native students, as noted by the 2007 TIMSS study, in which immigrant children outperformed their native Kuwaiti counterparts slightly (but statistically significantly) on the mathematics portion of the test. One difference between the Kuwaiti educational system and those of many other Islamic states is that the education of women is considered to be a priority and a requirement for the modernization of the economy, and as such women have not been excluded from the state educational system or restricted in terms of access to educational resources (Hatem, 1999).

State of Education in Kuwait, 2004-2008

According to the UNESCO's World Data on Education (2001) all citizens in Kuwait are guaranteed an education. The Kuwaiti government has proposed several long and short term goals for the educational system including, the preparation of the children of Kuwait to participate actively in the global economy of the 21st century, and developing a curriculum that teaches the children of Kuwait to respect their heritage while at the same time keeping up with scientific and social advances. Short-term goals for the system also include the improvement of education in terms of equality for female students, and increased use of modern technology in Kuwaiti classrooms. UNESCO (2001) goes on to discuss current priorities for the Kuwaiti Education system as well as the structure and function of each section of the school system. The school system integrates several schools for students with Special Needs including the visually and hearing impaired The school system is structured in four tiers, pre-school, primary school, secondary school, and the colleges and universities. UNESCO (2001) concludes by discussing statistical data on graduation rates as well as the number of Kuwaiti graduates that continue on to the college level.

According to the Kuwaiti Ministry of Education (2004, 2008) the current focus of the Kuwait government is upon improving what the Department of Education terms as “Pre-university Education”. This includes improving the academic performance of the students and the quality of teaching at all levels of pre-university education. Another major goal is to integrate successfully modern scientific and technological education, and equality for all students, male and female as well as special needs students while still retaining the cultural and religious traditions that make Kuwait unique.

The education in Kuwait includes both formal and non-formal educational institutions. At the formal level the structure includes, preschools, primary schools, secondary schools and colleges and universities. All other educational institutions in Kuwait are considered to be various types of informal education. Informal types of education include, vocational education, adult education, as well as the training programmes offered by various business interests in the State of Kuwait (UNESCO, 2006). The education system in Kuwait must also meet the needs of students enrolled in the country’s many religious and private schools at all levels.

The education system is set up so that students spend two years in preschool, five years in primary school, four years in intermediate or middle school, and three years in secondary school. This is similar to the set up in many Western schools systems in that students spend around the same amount of time at each level of education as they do in Western nations. Schooling is mandatory for all Kuwaiti children up to the time of their fourteenth birthday, which is significantly younger than in many other countries.

According to the Kuwaiti Ministry of Education (2008), the Kuwaiti education system faces several challenges as it heads into the 21st century. The first major challenge is that Kuwait is in a location that has suffered historically from political instability. Kuwait in its pursuit of fair and democratic government is not following the typical path of many Middle Eastern nations and in doing so the Ministry of Education is faced with the challenge of teaching young Kuwaiti citizens the principles of democracy, while maintaining a respect for Kuwaiti religious and cultural practices.

Another challenge that the Kuwaiti Ministry of Education (2008) faces in the 21st century is that of the economy. The main challenge in this regard is preparing students at the formal educational levels for an economy that will no longer be based on the oil trade as the oil supply in Kuwait is swiftly being depleted. Therefore the schools must prepare children for a society that relies more on the technology, and service sectors in terms of the economy. This means that students will need to have access to modern technology such as; the Internet as well as to advanced education in computers and the use of technology (Ministry of National Education, 2004; UNESCO and International Board of Education, 2006).

The final area in which the Ministry of Education (2008) is finding itself challenged is in protecting the cultural and social aspects of Kuwaiti society. This means teaching children to respect their Islamic and Middle Eastern heritage while at the same time promoting a democratic and modern society. These challenges are critical because how the Kuwaiti Ministry of Education chooses to confront these challenges determines how teachers at the Primary levels are educated as well as the regulations and curricula that will guide their teaching strategy.

Teaching Structure at the Primary Level

Schools in Kuwait much as elsewhere are divided according to region or district with a Supervisor or Superintendent over each regions schools at the preschool, primary and secondary levels. Either a principal or headmaster/headmistress generally leads schools at the primary level. The next tier of authority would be the schools administrative staff and the teachers and Para-professionals with janitorial and cafeteria staff being at the bottom level. Kuwait's Ministry of Education is promoting an environment of inclusive education, which means that students with learning disabilities and attention deficit hyperactive disorder (ADHD) are integrated into the classroom. This means that teachers must have the ability to successfully work with Special Education teachers and other professionals to encourage a positive environment for learning.

The Kuwaiti government is in the process of reforming the education system. This means that it is highly likely that the Teaching and Learning Structure at the primary level was undergoing changes in coming years primarily in terms of integrated education for male and female students, inclusive learning for learning disabled students and the increased use of technology in the classroom. These potential changes will most likely begin affecting teachers who are at the initial stage of teacher education in terms of changes in the approach to how and what they are taught at the University of Kuwait, and how they are exposed to teaching in the early years of their careers. (Ministry of Education)

The main focus of the Ministry of Education in terms of the teaching structure at the primary level is on the inclusion of Special Needs students into the regular classroom, as well as on curriculum development and staff development. Schools are also being asked to focus on continuing education through in-services and various other education opportunities for their teachers at the primary levels. This means encouraging teachers to seek out new learning experiences that will help them to further develop their teaching skills.

Changes in the teaching structure due to the educational goals of the Ministry of Education for the first decade of the 21st century are expected to impact the educational system in several ways. First, teachers are better prepared through their own educational experiences to educate students for the future. They will have a better understanding of computer and information technology and this will allow them to integrate these skills with their curriculum so that students will learn about and be comfortable with technology. Second, the changes in the system proposed by the Ministry of Education would allow teachers more participation in the day-to-day decision making of the school as well as more of a chance to participate in determining the course of education for all Kuwaiti children. Finally, the proposed changes would push teachers at the primary level to perform at a higher level and to expect the same out of their students.

Teachers

The teaching profession in Kuwait is exclusively female at the primary educational level, with all 5,145 teachers being female as of 2006 (UNESCO, 2006). Of these teachers, 76.1% are trained teachers. Training at this level is provided by the Faculty of Basic Education and the Faculty of Education (University of Kuwait) (UNESCO, 2006). Both of the programmes result in the attainment of a standard bachelor's degree, but the training focus of the two programmes are somewhat different. The Faculty of Basic Education focuses on kindergarten and primary teachers, training them in cultural, academic, and vocational subject areas (UNESCO, 2006). The Faculty of Education (University of Kuwait) offers programmes for kindergarten, primary, intermediate and secondary teachers (both male and female at the intermediate and secondary level), as well as a diploma of pedagogical training and diploma of pedagogical guidance (UNESCO). This training structure makes it approximately evenly likely that the teachers that was studied in this research was derived from either the Faculty of Basic Education or the Faculty of Education (University of Kuwait), which demonstrates why it was important to examine the curricula of both programmes in order to determine how teachers are trained regarding the use of technology.

The educational history of Kuwait in relation to the Middle East

Although Kuwait's educational system is not directly related to any other in the Middle East, it does share certain characteristics. Some of these characteristics include the establishment of compulsory education at an early stage, combined with restriction of this compulsory education (a remnant of the region's colonial past); the introduction of Islamic religious curriculum and private schools and the division of schools between religious schools and modern development schools (not only a push toward religious independence but a move toward defiance of the hegemonic colonialist structure of the compulsory educational program); and a modern movement toward education as a means of developing human capital (Akkari, 2004). As Akkari (2004) noted, "Free, publicly provided education has been a central tenant of the social contract in every country in the Middle East and north America since independence (Akkari, 2004, p. 146)." As the author noted, the completion rate and compulsory educational rate, as well as the literacy rate, is very high in most countries in the Middle East and North Africa as compared to other regions (Akkari, 2004). However, mean years of schooling tend to be very low especially in the Gulf countries (including Kuwait). Unfortunately, Kuwait has one of the biggest gaps between per capita income and educational performance index (EPI), an educational quality indicator that combines net enrolment rate, gender equity and school completion rates (Akkari, 2004). As Akkari (2004) noted, this indicated a certain unwillingness to convert financial resources to educational capital, which could negatively impact the Educational funding in Kuwait, is relatively low compared to other countries as well. According to the UNESCO survey, funding for public schools per pupil at the primary level was equal to 22.76% of the GNP per capita in 2004 (UNESCO, 2006). This is similar in ranking to Saudi Arabia, Oman and Qatar within the region (Akkari, 2004). However, unlike many other countries within the region Kuwait does not have a serious problem with gender inequity; in fact, girls outperform boys in many aspects of education, including mathematics achievement according to the 2007 TIMSS study (Akkari, 2004; Mullis, Martin and Foy, 2008).

Kuwait's Educational Performance (With a focus on Mathematics)

Although Kuwait does not yet rank in the top level of performing countries in primary mathematics teaching, its performance has been improving in some areas over the past decade. The Trends in International Mathematics and Science Study (TIMSS), conducted by the International Association for the Evaluation of Educational Achievement (IEA), compares the academic performance of 36 studies in primary mathematics and science at grade levels corresponding to United States grade 4 and grade 8 (reflecting students primarily aged nine and thirteen respectively). These studies, which occur every four years approximately, provide the capability to directly compare mathematics performance in the given years against that of other countries. Studies from 1997 as well as 2007 have been used to form comparisons of Kuwait's performance in comparison to other countries as well as identify areas of improvement of reduction in performance.

1997 TIMSS Study – Performance and attitudes

In 1997, Kuwait's primary results were focused on Year 5 students, the Kuwaiti equivalent of the grades 3-4 tested internationally (according to the US equivalent system). Kuwait was higher than many other countries in the number of years of formal education required, which the 1997 report stated the probable use of student retention practices in lower grades (Mullis, Martin and Gonzales, 1997). At this time, median performance in Singapore (considered a high performing country) was approximately equal to the 95th percentile performance in Kuwait (Mullis, Martin and Gonzales, 1997). Kuwait's average performance was higher than only Iran's, and was significantly lower than all other countries in the study. The study found that only 3% of Kuwaiti students tested reached the top 50% level in international achievement markers. The mean scale score for the mathematics performance was 400 at the grade 4 level (compared to a mean performance of 529), and 392 at the grade 8 level (compared to a mean of 520) (Mullis, Martin and Gonzales, 1997). However, students did show improvement in the middle of the scale between estimated grade 4 and grade 8 performances, with an increase of 125 points over this time period. Estimates of percent correct on standardised tests were similarly poor, with only 32% correct overall at the grade 4 level (Mullis, Martin and Gonzales, 1997). The best percent correct rankings were for whole numbers and geometry (36%), while the worst scores were for fractions and proportionality (25%) and data representation, analysis, and probability (26%) (Mullis, Martin and Gonzales, 1997). In comparison, the international average for basic data representation, analysis, and probability tasks at the grade 4 level was 60%. In contrast to other patterns, expatriate students (those with neither parent born in the country) outperformed their citizen peers with an average score of 416 on the test (Mullis, Martin and Gonzales, 1997).

Attitudes of students

A number of attitudes regarding mathematics were examined as well as pure achievement levels on a single standardised test by this study. Kuwaiti students in this grade did feel it was important to do well in mathematics (96%), indicating that the underachievement of Kuwaiti students is unlikely to be a function of a cultural disregard for mathematics in general. Students also reported spending about two hours per day on mathematics homework (Mullis, Martin and Gonzales, 1997). However, the excessive use of homework was not necessarily considered to be a positive feature, as the curvilinear relationship of the question in most countries demonstrated that students that did well in mathematics spent about an hour per day on homework, and that that did not do well spent either more or less time (Mullis, Martin and Gonzales, 1997). However, more Kuwaiti students than students in other countries agreed that natural talent or ability and good luck were necessary to do well in mathematics (92% and 76% respectively), while relatively fewer believed that memorizing the textbook and studying hard were necessary (Mullis, Martin and Gonzales, 1997). (However, the number of students that believed that hard work was required was still relatively high at 87%, and memorization scored at 89%). 76% of Kuwaiti students reported liking mathematics a lot, while only 3% of students reported disliking it a lot. The overall attitude toward mathematics reported by students was either positive (40%) or strongly positive (53%) (Mullis, Martin and Gonzales, 1997).

Teachers and classrooms

Kuwaiti teacher attitudes towards mathematics tend to be traditional. For example, 80% of Kuwaiti teachers consider the ability to memorize formulas and procedures to be important; approximately 95% of teachers believe mathematics is a formalized representation of the world, while approximately 98% believe that some pupils have natural mathematical talent and some don't (Mullis, Martin and Gonzales, 1997). In contrast, only about 47% of Kuwaiti teachers believe that creative thinking skills are important, and only 62% think understanding real-world mathematics is important (Mullis, Martin and Gonzales, 1997). The average number of hours spent teaching mathematics in the classroom was 2.9. However, teachers devoted considerable resources to teaching mathematics, with daily or weekly planning meetings reported by most. Unfortunately, inadequate physical facilities and lack of resources negatively impacted mathematics teaching at this time as well (Mullis, Martin and Gonzales, 1997). A high student-teacher ratio was also considered to negatively impact this teaching performance. The average number of students reported was 32. The overall picture this report presented of Kuwait's students and teachers was of a group of individuals that wanted to learn and facilitate learning, but were hampered by lack of resources and time available to do so.

2007 TIMMS Study

Unfortunately, the average scale score for Kuwait grade 4 equivalent participants dropped between 1997 and 2007, falling to 316 (lower than all participants other than Qatar and Yemen) (Mullis, Martin and Foy, 2008). The scores of girls were considerably higher than boys in this case, with the average score for girls being 333 and boys 297 (Mullis, Martin and Foy, 2008). Rather than using quartiles, the 2008 study used benchmark figures; the total percentage of students that made the benchmark figures was only 26%, in comparison to an international percentage of 90% (Mullis, Martin and Foy, 2008). Performance in mathematics content domains (including number, geometric shapes and measures and data display) were almost at the median score, but students achieved better results in applying (326) and worse in knowing (305); results for the reasoning cognitive domain couldn't be determined (Mullis, Martin and Foy, 2008). As in 1997, neither parent being born in the country was correlated to a higher test score.

Most interesting, the 2007 TIMSS study examined the effects of a computer in the home on average test scores. It found that students with computers in the home and Internet connections had higher test scores than those that did not have computers or internet connections (331 and 328 as compared to 281 and 310 respectively) (Mullis, Martin and Foy, 2008). This lends some support to the notion that computers in the home improve student performance dramatically.

The 2007 figures did not dictate a dramatic change in student attitudes or practices during this time period either. Students still spent around 2 hours per night doing homework, demonstrated a highly positive attitude toward mathematics, and indicated a strong belief that mathematics was an important subject of study (Mullis, Martin and Foy, 2008). However, improvements in teaching practice and attitudes were apparent. Rather than near the bottom, Kuwait ranked in the middle when considering topics intended to be taught and the percentage of students taught TIMSS topics. Kuwait was also higher in the number of elementary mathematics teachers with undergraduate degrees as compared to many other countries (Mullis, Martin and Foy, 2008). 32% of Kuwaiti mathematics teachers either specialized in or received advanced preparation and training for mathematics training, as compared to an international average of 25%. However, Kuwaiti teachers did not receive as much in-service and professional development support in mathematics subject areas, only at 27% as compared to 42% (Mullis, Martin and Foy, 2008). Overall, however, pre-service teachers were very confident regarding their ability to teach TIMMS mathematics topics, with 79% reporting readiness to teach all topics as compared to a 72% national average (Mullis, Martin and Foy, 2008). Average class size also dropped from 32 to 25 (Mullis, Martin and Foy, 2008). Classroom participation by students was also very high. It is clear that the resources available and teaching capabilities of the Kuwaiti primary educational system have matured over the past decade, but what is not clear is why actual achievement in mathematics has not followed suit.

Previous Studies in Technology and Teaching in Kuwait

There have been relatively few studies that focused specifically on the use of technology in the Kuwaiti classroom. However, one study did examine teacher expectations of technology use in learning in Kuwait (Aldhafeeri and Almulla, 2006).

This study was prompted by the potential of modification of the Kuwaiti educational system in order to encourage the development of an e-learning curriculum component. It distributed a 36-question survey to 519 teachers that focused on the potential impact of e-learning on the school system as a whole (Aldhafeeri and Almulla, 2006). The study identified six ways that teachers believed that e-learning curriculum could impact the overall educational effectiveness of the Kuwaiti educational system. These included basic computer operations and concepts, awareness of human and ethics issues, development of productivity and research tool skills, problem solving and decision making skills, and communications (Aldhafeeri and Almulla, 2006). The authors discuss the use of e-learning as a means of significantly improving the outcomes of the Kuwaiti educational system in its entirety, not just in mathematics teaching. However, it can be seen that there are some components of improving, including productivity and research tools and problem solving and decision making skills, that would directly affect the educational outcomes in terms of mathematics teaching within Kuwait (Aldhafeeri and Almulla, 2006). However, the potential improvements to all areas of the curriculum should also be considered.

Potential teacher training improvements

There have been a few areas of improvement of teacher training identified within the research that apply to overall teacher training as well as specific considerations for these improvements. One area where Kuwaiti teacher training may require improvement is in the requirement for practice prior to service (Mullis, Martin and Gonzales, 1997). The Kuwaiti teacher training system is one of the few systems that were in place in 1997 where teachers did not require any practicum teaching experience in order to become certified or to gain their teaching degree; instead, the first teaching experience teachers gain is that in the workplace, which could potentially reduce the effectiveness of the training programme (Mullis, Martin and Gonzales, 1997). Currently, Kuwait also has a relatively young teaching force; as of 1997, 80% of more of mathematics students were taught by teachers in their 30s or younger, while half of students have teachers with less than 10 years of experience (Mullis, Martin and Gonzales, 1997). While this would clearly be a situation that had been rectified at this point with many of the teachers having gained increased experience in the intervening 12 years, it is uncertain how much gain would have been realized. This is due to teacher experience not being a consideration in the 2007 TIMSS study, and thus there being no information available in that regard, and due to teacher turnover and experience rates not being available from other sources. Thus, I believe it is not possible to state with certainty the degree of experience of the current Kuwaiti mathematics teaching population.

Spending and other issues

In one article, Nadeem Burney and Othman Mohammed (2002) look at the Kuwaiti education system in terms of its efficiency. The authors focus primarily on budget expenditures and whether or not this has any influence on the education and productivity of the Kuwaiti people. They argue that what the Ministry of Education spends per year on the school system in Kuwait is not out of line percentage wise in comparison to what other schools are spending on average on worldwide basis. Burney and Mohammed (2002) also explore the efficiency of the school system in terms of the high school dropout rate, and the student teacher ration. They argue that some of the causal factors for this are low graduation rates in the teacher training programmes offered from the

University of Kuwait as well as lack of access to computer aided instruction and adequate textbooks in some areas of the country. The condition of education in Kuwait is very similar to that of education in other Asian and Middle Eastern countries. Chapman and Adams (1998) looked at the quality of education in Asia. They found that, much like in Kuwait, the quality of education in many Asian countries varied widely. In some countries such as Japan and Hong Kong education was efficient, graduation rates were high and students were motivated to learn. In other areas of Asia students often had difficulty due to lack of instructional technology, textbooks and well trained teachers.

Problem Statement

The introduction outlined above spells out the problem that has been identified within this research. Kuwait is currently facing an urgent need to modify its educational system, in order to provide the country with more diverse and capable workers for the coming transition from an oil-based economy to an economy based on services and technologies following the peak in oil production. However, this educational reform has focused on the use of mathematics as a real-world problem-solving tool. While this is not necessarily a negative orientation toward mathematics, and is one that is in fact of great use in engineering and other practical disciplines, it has had the net result of reducing student achievement scores on the 2007 TIMSS study, which addresses the achievement levels of students across 36 different countries. This is marked by a peculiar symptom that is almost unique to Kuwaiti students among the studied population – Kuwaiti students scored low overall, but they scored higher in application domains than they scored in knowledge domains. This indicates that something has gone seriously wrong with the Kuwaiti mathematics teaching curriculum, in that it is not teaching students to understand mathematics at the same rate it is teaching them to apply it. A potential solution may be found in the application of computer-based adaptive mathematics activities to the classroom educational and curriculum system. However, the relative paucity of information regarding education in Kuwait, which has not been well studied in the formal academic sense, is a stumbling block to determining whether or not this is the case. Given this lack of information in the literature, a broad-ranging approach to examination is suggested, in which actual classroom experience is sought in order to provide insight into this area of study.

Purpose of the Research

The purpose of this research is to use a qualitative and quantitative mixed methods quasi-experimental approach to examine the effects of the introduction of computers to the mathematics curriculum in a Kuwaiti fourth-grade classroom. Specifically, classroom norms regarding mathematics, mathematical achievement, and the approach to mathematics by students in the classroom was examined. In this approach, I have chosen to work with the educators and administrators in the school as well as the students in the classroom, in order to provide a smooth transition and to attempt to provide students with the level of mathematics enrichment activities that they require. The analysis of these results was performed both qualitatively, using a descriptive and narrative approach that explored the introduction of computers into the classroom mathematics curriculum, and quantitatively, by comparing paired results of testing for students in order to determine whether the training made a significant difference in the knowledge domain while retaining the relatively higher application domain.

Research Questions

The research method that was chosen was a mixed methods quasi-experimental study, in which statistical evidence of children's performance was tested using an experimental approach that integrated teacher and classroom participation with researchers as well as involvement of the school administration, curriculum planners, and others in the school environment. The classroom participants were active participants in the research and helped to establish the direction of the research. Given this structure, a number of research questions were posed for consideration during this research process. The research structure was a nested approach, in which some questions were chosen for examination under a qualitative methodology, some under a quantitative methodology, and some under both methodologies.

1. What are the student achievement effects of the introduction of computer-based mathematics teaching methods in a classroom in Kuwait?
2. Are there differences in student achievement effects based on student demographic and socioeconomic variables?
3. What challenges are encountered during this introduction, and how can they be overcome?
4. What structural and institutional barriers may be found in the Kuwaiti educational system in the introduction of teaching methods based on computer classroom interaction?
5. Are the gains in mathematics teaching found in these environments compatible with teacher understandings of the role of mathematics in the classroom and the environment?

6. How do the changes in the classroom affect student mathematic perceptions and viewpoints? Is this a positive or negative change?

These research questions are discussed both individually and in the context of connections to each other. This approach was chosen because I feel these issues cannot truly be discussed individually. Instead, they must be examined in conjunction in order to provide a holistic view of the classroom experience and to clearly indicate the depth and scope of the experience that was sought.

Hypotheses

The main research questions posed for this study that can be examined quantitatively include question 1 (What are the student achievement effects of introduction of computer-based mathematics teaching methods in a classroom in Kuwait?) and question 2 (Are there differences in student achievement effects based on student demographic and socioeconomic variables?) The hypotheses that were posed for these research questions are as follows.

The first hypothesis is based on simple achievement levels and their direction of change following the introduction of computers into the classroom. This hypothesis is based on the outcomes of the 2007 TIMSS study, which found that the scores of students that had computers and internet connections available in the home were higher than those students that did not have these facilities available.

Hypothesis 1: The introduction of computer-based mathematics teaching to a classroom in Kuwait will be associated with positive improvements in student mathematics achievement.

Hypothesis 1_0; There will be no effect on student achievement in mathematics that can be associated with the introduction of computer-based mathematics teaching to a classroom in Kuwait.

The second hypothesis is based on findings in literature that support an increased level of mathematics achievement for students that have higher socioeconomic status than others (Becker, 2000). This so-called Digital Divide is based on access to technology and mathematics learning, as well as potential differences that include issues like different emphasis on learning, career expectations, individual differences, and other issues that may affect how the students learn and what role their family lives play in the learning process (Becker, 2000). Thus, despite the standardisation of in-school learning opportunities, children of lower socioeconomic status will have less success in the school learning environment due to fewer outside opportunities for learning. This hypothesis states,

Hypothesis 2: A higher level of socioeconomic status will be associated with a higher baseline level of student mathematics achievement and improved outcomes following tests.

Hypothesis 2_0; There will be no difference in baseline or post-experimental outcomes based on socioeconomic status.

Research Question	**Data Collection Method**	**Analysis Method**
1.What are the student achievement effects of introduction of computer-based mathematics teaching methods in	Student testing instrument.	Descriptive statistical testing and difference in means (independent t-test, ANOVA).

a classroom in Kuwait?		
2. Are there differences in student achievement effects based on student demographic and socioeconomic variables?	Student testing instrument.	Difference in means testing (independent t-test, ANOVA)
3. What challenges are encountered during this introduction, and how can they be overcome?	Field notes and interviews.	Qualitative analysis (thematic and narrative)
4. What structural and institutional barriers may be found in the Kuwaiti educational system in the introduction of teaching methods based on computer classroom interaction?	Primary policy data, regulations, and government reports	Qualitative analysis (thematic and narrative)
5. Are the gains in mathematics teaching found in these environments compatible with teacher understandings of the role of mathematics in the classroom and the environment?	Interviews and focus groups.	Qualitative analysis (thematic and narrative)
6. How do the changes in the classroom affect student mathematic	Student interviews.	Qualitative analysis (thematic and narrative)

perceptions and viewpoints? Is this a positive or negative change?		

Table 2 Research question matrix

There are some advantages and disadvantages to mixed methods research that should be considered. Mixed methods research can help provide both breadth and depth to a study, and can also provide information regarding both the causal relationships in a given research situation and why these causal relationships may exist (Creswell, 2003). It can also provide information needed to analyse a complex situation, and provide a great deal of contextual information (Creswell, 2003). This allows for a detailed analysis of complex conditions, particularly where there is a lot of context involved. The mixed methods approach is useful for examining educational situations, because it can analyse both the outcomes and the methods by which changes are made.

However, there are some disadvantages to mixed methods research s well. Mixed methods designs can be difficult to construct, and can involve complex challenges in integrating the research findings (Creswell, 2003). This can lead to a degree of vagueness regarding the qualitative research (Creswell, 2003). It can also result in difficulty introducing the amount of data produced in order to allow for an effective analysis (Creswell, 2003).

Importance of the Research

Kuwait has undertaken educational reform on the assumption that in the near term its reserves of oil and natural gas, which currently drives an economy that is highly focused on oil and gas production, will diminish (CIA, 2010). According to one estimate, the petroleum market accounts for almost all of Kuwait's GDP (Gross Domestic

Product), 95% of government income, and 5% of export revenues (CIA, 2010). The petroleum economy has awarded Kuwaiti citizens one of the highest standards of living in the world, with an average per-capita GDP of USD $54,000 in 2009 (CIA, 2010). Kuwait has also agreed to increase oil production by as much as 4 million barrels per day through 2020 (CIA, 2010). However, this is only likely to accelerate the depletion of Kuwait's known oil and gas reserves. The official estimates of proven reserves include 101.5 billion barrels, with an additional 1.794 trillion cubic meters of natural gas reserves (CIA, 2010). Kuwait cannot sustain its current level of petroleum production over the long term without depleting its reserves substantially. In fact, this situation may be more vital than is currently presumed, due to the potential overstatement of reserves from Kuwait Oil Company in its official documentation (Energy Intelligence Group, 2006). Given this, the Kuwaiti government has a compelling reason to begin training Kuwaiti students to take jobs for which their parents were not prepared, particularly in the service and technology industries. Without this transition, there is no way that the Kuwaiti economy can survive the depletion of its petroleum reserves. However, although the Kuwaiti government has implemented reforms intended to promote just this transitional stage, these have so far proved unsuccessful. In fact, the students entering the school system following the 2004 reforms (who were those tested during the 2007 round of TIMSS studies) performed *worse* than their elder siblings a decade ago; given that Kuwaiti performance was already near the bottom in terms of mathematics performance, this was a significant blow to the reform effort. This research will provide a clearer understanding for policy makers and curriculum designers in the Kuwaiti school structure regarding the use of computers in the classroom, which could provide evidence for redesign or repositioning of the curriculum development effort. It will also provide further information regarding the role of ideas about mathematics and how these can be refined in order to improve the understanding of the process.

The Study Environment

The study environment in which this study took place was a fourth-grade boys' classroom in a small school in Kuwait. The classroom was one of four in the school that was in the age group of interest (fourth grade). The school was a government school and all children were of Kuwaiti origin. This is necessitated because the Kuwaiti government schools are restricted to the use of Kuwaiti citizens; citizens of other nations attend private schools (some of which are subsidized by the state). This school was selected from three candidate schools based on the school headmaster's willingness to participate in the research and the interest of the teachers in participating. The school administrator, Mr. B, and the head teacher for the classroom, Mr. M, were both highly involved in the research and were invested in ensuring that it went well. Overall, this school was largely typical in demographic distribution and in structure and management styles to other Kuwaiti primary schools, although it was not entirely consistent in terms of the management and teaching staff. In particular, the management and teaching staff were more experienced and more willing to experiment with research designs than the teachers at the other schools that were considered for the study.

Ethics of the Research

Given that primary school students are a major focus of the research, there is a clear ethical responsibility to ensure that no harm is done to the subjects and, if possible, that their learning should be enhanced. There is also an even greater requirement for informed consent and provision of information to parents, as children cannot consent (either legally or ethically) to research on their own. These conditions required careful design of the research and record keeping, which was much higher than might have been used in an adult-centred study. The issue of study ethics is addressed in more detail in chapter three (methodology). However, I am aware of this issue and did take an approach that would allow for protection of the interests of the children in the classroom as well as, as much as possible, for the improvement of their educational outcomes.

Bias, Validity and Reliability

The issues of validity and reliability for this research are not entirely consistent with quantitative expectations, as the research is primarily qualitative, but mixed, in research design. Additionally, the research was a quasi-experimental project that was fundamentally subjective, although I attempted to infuse the research with as many different perspectives as possible. Given this, the issues of bias, validity, and reliability, cannot be determined as easily as for some other research designs. However, attempts to ensure validity and reliability and reduce potential bias in the research were a central goal of the research process. Validity and reliability were approached primarily as an exercise in qualitative validity and reliability, which involved the clear description of all activities and provision of substantial information for understanding the conclusions drawn (Creswell, 2003). I believe that this was overall effective, although there is always the possibility that there is remaining bias. The research process and outcomes have been described thoroughly, in order to allow readers and others a view into how conclusions were arrived at and what these conclusions were based on. This will *not* easily allow for direct replication of results, as would be the case in a quantitative survey or experiment.

However, it will allow for oversight of the research and detection of possible biases, as well as critical application of some portions of the research to the live classroom environment or to other experiments.

Researcher and Participant Bias

There is the potential for researcher and participant bias within this research, which could affect the outcomes. I did not have any prior experience in the school or with the students, but instead was introduced to the administrators by a professional contact. Thus, there is not likely to be significant bias from pre-existing personal relationships. The most likely source of such bias is the varying epistemologies held by the researcher, teachers, and students. Epistemology, or beliefs and philosophies about learning and knowledge formation, are a fundamental part of the learning process and affect how the individual will learn, what they will learn, and how they will regard learning (Hofer, 2004). In many cases, these epistemologies do not reflect a conscious bias toward or away from a specific type of learning; instead, they reflect an underlying or unconscious attitude toward learning (in general, or toward a given subject) that will affect the outcomes of the learning process (Hofer, 2004).

In this case, the most relevant epistemologies will be mathematical beliefs. Mathematical beliefs are the underlying characteristics of how an individual thinks about mathematics and the mathematics learning process (Shapiro, 2000). These three classifications of mathematical learning are based on the mathematical constructions developed by early mathematicians, including Russell and others (Quine, 2008). Many individuals consider mathematics through a lens of formalism – that is, they believe that mathematics is a formal system of rules that has no application to the real world, but where rules can be applied consistently and with consistent results (Shapiro, 2000). Formalism is grounded in the philosophical work of Hilbert (Quine, 2008). Others view mathematics as a form of logic that routinely leads to the same answer if applied correctly, or logicism; in this view, there is the potential for real-world application, but no consideration of creativity or modification of mathematical technique (Shapiro, 2000). Logicism is espoused within the early writings of Russell as well as other mathematical philosophers (Quine, 2008). The intuitionist approach to mathematics learning, on the other hand, views mathematics as a way of thinking, which can be modified to meet a specific situation (Shapiro, 2000). This model of mathematics was developed by early mathematical philosophers Poincare and Kronecker, as well as later philosophers Brouwer, Heyting, and Weyl (Quine, 2008). The intuitionism approach to mathematics is not supported by all philosophers, as there are objections regarding its mathematical rigor (Raven, Tijssen, and De Wolf, 1992). However, it is considered to be one of the potential modes for mathematical learning.

An individual that holds a formalist approach to mathematics may view mathematics as irrelevant or frustrating, while one that views mathematics through a logicist lens may see it as boring or irrelevant, or as simply a tool. Through an intuitivist lens, mathematics may be viewed as a tool, language, way of thinking, or even as fun. However, it is clear that these different views about mathematics would lead to different biases in researchers and respondents.

I determined, following critical reflection, that my own approach to mathematics is primarily intuitivist, although there is an element of logicism in my mathematical thinking. In particular, I believe that mathematics can become a language or a fluency from which individual thought patterns can be derived, and also that mathematics can be a highly useful tool for application to real world problems. Given that mathematical views begin to develop during the first part of schooling, and are dependent not only on individual inclination but also on the influence of teachers and the home environment, most of the students that the research involved already had a well developed epistemology regarding mathematics.

Personal Motivations

The reason these approaches were chosen was because I do not believe that the quality of the learning experience can simply be expressed based on the outcome of tests. Instead, the outcomes of the tests should be indicative of learning, but the learning process and the revision of ideas about mathematics is also important. In order to help revise conceptualizations about mathematics and to provide support for learning not only during the short period of time that I would be in the classroom, but throughout the learning lives of the students (and possibly those that would teach mathematics to in future), the goal of the research was a revision of attitudes toward mathematics. In brief, I wanted to determine if introducing the use of specific computer tools into the classroom could make mathematics a challenging, rewarding, and fun naturalistic activity for children, rather than a frustrating academic or logical exercise. If possible, I also wanted to promote this change in the views of mathematics in the teachers with whom I interacted.

It was also important to me that the research should integrate the views of classroom teachers and other actors in the school as well. I felt that this type of integration was important because the classroom experience is a group experience, rather than a solitary experience, and there is considerable variation in the classroom environment based on individual factors. Teachers and administrators understood the classroom dynamic and environment that was in place in this classroom better than I could. The children in the classroom, who had mostly been in the same class since beginning school, had established relationships, hierarchal structures, and norms, rituals, and expectations that had developed over a period of several years. In order to be most effective, it was necessary to fit the additional mathematics instruction into this existing framework as carefully as possible, and this was not possible without the cooperation of the teacher. Additionally, although I assisted in the classroom several times a week and was highly involved in the management of the programme, this experiment ultimately meant more work for classroom teachers and aides, as it was an additional 45 minutes per week of intensive instruction and management per child. This was a significant burden on the teacher and classroom manager, and without their cooperation it would not have been possible to effectively manage the experiment or to engage with the classroom as well as I did.

I would like to take the opportunity to thank the classroom teacher Mr. M, the classroom aide Mr. Y, and the school administrator Mr. B for their extensive assistance with this research. This was truly a co-researching experience, and without the assistance of these individuals it would not have had any chance to be successful.

Overview of the Thesis

The thesis is arranged in six chapters. The first chapter (the current chapter) provides an overview of the intended research, including an in-depth discussion of the study context and the research that is to be conducted. The second chapter provides a literature review that focuses on the theoretical frameworks that was used in this study and examines the empirical literature that has so far emerged from the field. This chapter provides insight into what work has already been done in Kuwait (which is limited), as well as providing information from other study contexts that may be applicable to the case of Kuwait. Chapter three presents the quasi-experimental methodology that was used in the study, including the theoretical grounding and philosophical approach that drove the selection of this methodology as well as specific methods of data collection that were used within the study. Chapter four presents the results of the study, while chapter five provides an analysis of the study in the context of the existing literature, highlighting not only the findings of the study but also how these findings either concurred or did not concur with the findings of the study. Finally, chapter six presents the conclusions to the study, including a series of recommendations for educators that would seek out the use of the methods that were highlighted in this study in terms of how they can be best applied within the classroom.

Summary

The introductory chapter has presented the background and problem statement and discussed the ways in which the study was researched. The goal of this research is to provide insight into the specific nature of introducing computer-based mathematics learning into the primary classroom in Kuwait. As such, it has used a quasi-experimental methodology that integrated student experience and attitudes, teacher experience and attitudes, and researcher experience and attitudes into a single research focus that broadened the range of the inquiry from a single viewpoint to several viewpoints. The next chapter, the literature review, addresses issues of theoretical framework and empirical information that can be derived from the current study environment in order to frame and focus the current research.

Chapter 2 Literature and Context Review

The impact of computer use in the classroom has been studied from many different viewpoints and in different classrooms. This means that there is a good depth of information available on the use of computers in the classroom that can provide insight into the effectiveness of their use. Issues that have been studied include varied aspects such as integration with the curriculum of the school, teacher training and willingness to use computers and comparisons of effectiveness of their use in the classroom. This literature review addresses the theoretical and empirical bases for the formation of this study, specifically examining the issues of computer use that have been identified as well as other relevant areas of the subject matter. It was used to support the empirical work as discussed later in Chapters 5 and 6 well as to form the framework under which the study has been constructed. However, this literature and context review should be considered carefully, as most of the research in this area has not been done within the Kuwaiti context. Instead, most available research on classroom use of computers and computing technologies has taken place in the United States and the United Kingdom, which have very different cultural factors than Kuwaiti schools and very different school systems. Thus, each study included in this literature review must be considered carefully and critically examined in order to determine what applicability, if any, the research will have to the current study context.

Part 1 Teaching Theory and Technology Integration Factors

The first issue in the construction of this discussion of computer-based mathematics teaching is the use of teaching theory and technology integration features, which will be addressed within this study. This section examines the theoretical constructs and other issues involved in the use of computer technology in the classroom.

A Theoretical Overview of Computer Use in the Classroom

Computer technology was recognised as an important tool in the classroom as early as 1969, when Suppes (1969) discussed the future of computers in education and identified them as vitally important for the education of children. This view of the classroom positioned computers in a direct teaching rather than a facilitative role. That is, acting as the teacher rather than helping the teacher. However, its conception of the benefits of the computer for mathematics teaching in particular demonstrate that the conception of the computer as a mathematics teaching tool, including audiovisual components and interactivity, has not developed dramatically since this time (Suppes 1969). Individualised curriculum design and implementation was seen as one of the major benefits of the computer in the classroom. However, the development of a theoretical basis for the use of computers within the classroom was relatively slow to develop.

Constructivism and Constructionism

The use of computer programmes and models has come to be an integral part of constructivist teaching practices (Nickson, 2004). Constructivist teaching, which emphasises higher-order cognition and construction of knowledge and problem solving skills rather than rote memorisation, has had a growing presence in the classroom since the 1980s (Hickey, Moore and Pellegrino, 2001). It has become enshrined in the common literature of mathematics teaching (Bahr, Bahr, and Degarcia, 2008; Nickson, 2004). This focus also makes it a strong complement to the use of computers as teaching aids. One of the characteristics of the constructivist teaching method is the use of all available technologies to supplement and extend teaching practices within all areas of the classroom (Vannatta and Fordham, 2004). This use of technology has been shown to have dramatic effects on student epistemologies, with informal understandings of concepts being translated to formal understanding of knowledge and ideas at a much greater rate using a constructivist model and use of technology than a traditional, non-constructivist method of teaching (Windschitl and Andre, 1998). Widschitl and Andre's study, which focused on the transformation of informal anatomical knowledge of college students to formal knowledge, underscored this construction process to formal knowledge in a way that makes it clear that construction of knowledge and use of computer technology are integral. These findings have also been replicated in other knowledge domains, particularly mathematics and science domains (Hsu, Wu, and Hwang, 2008; Su, 2008). Studies on individual training materials have also upheld the effectiveness of the constructivist methodology; however, there have been no emergent models of specific learning practices that are claimed to increase the knowledge or learning practices of the classroom as a whole.

There has been other research on this issue as well. Another examination of constructivist learning was a case study of a computer literacy programme that was integrated into the primary mathematics and science teacher educational programme at a United States university (Halpin, 1999). Halpin's (1999) study assessed the effectiveness of this training programme using a questionnaire that addressed current levels of computer literacy at the beginning and end of the programme, in between which a constructivist methodology was used to build an understanding of computers into the cognitive map of the novice teachers enrolled in the educational programme (Halpin, 1999). This programme used three objectives for computer literacy that the authors remarked could be adapted to fit *any* level of computer literacy and learning, including at the primary level; these three objectives include: "fit the computer to the curriculum rather than the curriculum to the computer… Use the computer as a personal and professional tool… Use the computer in the learning of subject matter (Halpin, 1999, p. 129)." These three objectives were intended not only to enhance the novice teacher's integration of the subject material itself, but also to improve their understanding of the effective use of computers within the classroom, moving from a view of isolated computer lessons to a view in which the computer is viewed as an integral tool. The constructivist method of teaching computer literacy proved to be effective in improving the view of computers as an integral tool in this classroom. The researchers concluded that this method of teacher training, which fits into the constructivist teaching method, would also be useful if adapted to other levels of learning. This provides early evidence that the constructivist teaching theory can be applied not only at the primary level, but also at the meta-learning level of teaching the teachers of these classrooms. This research has been supported by multiple other research studies since this time (Alimisis, Frangou, and Papanikolau, 2009; Gibjels, Coertjens, Vanthournout, Struyl, and Van Petegem, 2009; Liljedahl, *et al*., 2009; Schaal, 2000). These examples of constructivist teaching in the classroom should not be considered to be the only situations in which this evidence exists; rather, these are representative examples of conditions that can occur.

Because mathematics teaching and science teaching are tied closely together, they are often considered in the same research models. An issue that has emerged in the case of science teaching, which can be extended to mathematics teaching, is the effective development of programmes for the integration of science teaching within the curriculum (Thomas, 2001). Thomas's study identified four concerns that were present in creating an effective environment for the teaching of sciences using computers. These concerns included the theoretical orientation of the computer work within the curriculum; the focus on models and examples in the use of computers; development of cognition and metacognition in student activities and thinking processes; and recognition of teacher and student epistemologies regarding the impact and use of computers and, where necessary, adaptation to these epistemologies (Thomas, 2001). These concerns can be extended through to the development of mathematics teaching methods that integrate computers and technology with mathematical learning models.

Constructionism

A useful subset of the constructivist view is the constructionist view, which was developed directly within the context of development of computer mathematics. The constructionist teaching model was developed by MIT computer scientist Seymour Papert (1991), who developed a number of direct methods of teaching technologies to school children, including the Logo programming language (Weiss, Nolan and Hunsinger, 2006). This model was focused on the teaching model of computer as tutee, with the development of a means to encourage children to develop an understanding of objective programming concepts through the use of computers. According to Papert,

> Constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Papert, 1991, p. 1)

Thus, constructionism adds to the concept of constructivism that it is not only activity-based learning that ties the development of activities to the formation of knowledge, but of self-creation of knowledge and theory. The addition of constructionism to the research framework improves the overall outcomes by adding the impetus of creative theories to the understanding of mathematics. The use of constructionism may be particularly useful within the model of the computer as tutee, or the use of computers as a passive or listening teaching device, acting in the role of the student rather than the teacher within the classroom, as it allows for students to determine new ways to teach the computer or other students different concepts. This is one of the key differences in approach within this research that will improve the outcomes of the research.

Structural Factors

Important factors can be divided into structural factors (those involved in the structure of the classroom or resources available) and non-structural factors (those involving the teachers, students, school culture and climate and other issues), These issues will be examined separately, but it should be recalled that the structural and non-structural factors in this case are not truly separate; for example, structural factors such as time resources available for mathematics teaching may be impacted by non-structural factors like the importance placed on mathematics in school culture, and vice versa. Thus, while these topics are divided for discussion purposes they should not be considered to be distinct characteristics of a school system.

There have been a number of structural characteristics identified within the literature that affect the use of computers in the classroom. These structural characteristics are directly related to the concerns addressed by Thomas (2001). The simplest structural issue is that teachers, curriculum designers, school leaders and educators must be aware of how to use computers as well as be able to assess and effectively implement computer training programmes in the classroom (McNamara, 1994). This speaks to Thomas's (2001) concerns regarding the epistemologies of teachers in the classroom. One study identified planning, leadership, curriculum alignment with technology, and professional development geared to technology use as simply requiring the use of computers in the classroom as structural factors in the use of technology in the classroom (Baylor and Ritchie, 2002). One of the basic characteristics of the structural requirements for integration of computer based teaching is provision of computers for this use. However, research has demonstrated that simple provision of technology equipment is insufficient to encourage effective use of technology within the classroom (Angrist and Lavy, 2002; . One study in Israeli classrooms following the introduction of computers in primary and middle school classrooms in the 1990s underscored this point (Angrist and Lavy, 2002). Angrist and Lavy (2002) did find that the introduction of computers resulted in an increased use of computer aided instruction within the classroom, as well as increased use of the computers for administrative purposes such as grade keeping and tracking of student progress. This finding was supported by research that found that there is still a wide range of computer use in the classroom, largely supported by teacher epistemologies regarding computer use and goals for computer use (Tondeur, Van Braak, and Valcke, 2007a; Tondeur, Van Braak, and Valcke, 2007b; Tondeur, Hermans, Braak, and Valcke, 2008; Wozney, Venkatesh, and Abrami, 2006).

Although it should not be the case that standardised testing drives all learning in the classroom, a pragmatic acknowledgment of the structural realities of many schools (including requirements for time use and regulatory requirements for achievement levels, as described by Cuban, Kirkpatrick and Peck (2001) does require an acknowledgment that use of computer aided instruction must be designed to positively impact the school's requirements for student achievement rather than have no or negative impact. There may also be spatial structural considerations of Internet access in the classroom, which is generally fairly low; for example Becker found that up to the early 2000s use of the Internet by teachers was very limited due to restricted access; even following an increase in access, the main use of the Internet in most classrooms remains the construction of lesson plans and use by the students for research, with communication, collaboration, publishing, and Web-based enrichment or pedagogical activities being far rarer activities (Becker, 2000). However, Web-based activities have become far more common in the educational environment since this time, particularly the use of Web Quests and similar educational approaches that use the Web as a teaching tool (Glazer, 2005; Orme and Monroe, 2005; Salsovic, 2009); thus, this part of the findings must be considered to be outdated. Unlike in many cases, age and gender of the teachers is not a factor in this use of the Internet, indicating that this may be a true structural limitation on the use of computers within the classroom rather than an artefact of computer training practices.

A further examination of the structural issues involved in adoption of computer technology in the school focused on the cultural issues and subject-cultural issues surrounding this adoption (Goodson and Mangan, 1995). The authors determined that while computers were likely to be regarded as a positive innovation by teachers in all areas, they were more likely to be integrated in some subjects (such as mathematics, science and technology, and language and writing) than in other subjects. This was due to the integration of the subjects and computer technology, available support from the curriculum development community, and other factors that influenced the ability of specific areas to integrate with this technology. As this study took place in a differentiated high school environment it may not be as applicable within the undifferentiated classrooms of the primary school environment. However, the cultural aspect of the difficulty in technology instruction may still be found among the different structural cultures of the primary classroom (Baek, Jung, and Kim, 2008; Teo, 2009; Wozney, Venkatesh, and Abrami, 2006). This is one of the potential factors that may influence the outcomes of the current research and as such should be considered during the construction of the research process.

Another structural factor that has been identified in the use of the computer within the classroom is overall integration into the curriculum program. It is not enough to simply use the computer in the classroom for specific tasks; instead research has indicated that it is essential that it should be integrated across the curriculum (Roschelle, Pea and Hoadley, 2000). This curricular integration involves not only the integration of computer use into several areas of the curriculum, but full-school structural involvement including teacher training and curriculum design, organisational change management, and involvement at all levels of the school in order to be effective in this integration. Integration of computers into the classroom mathematics curriculum has been found to vary widely depending on teacher characteristics including comfort with computers, teaching experience, belief in use of computers as a good instructional tool, and overall teaching efficacy of the teacher (Mueller, Wood, Willoughby, Ross, and Specht, 2008). The integration of computers into the mathematics curriculum has been considered to be a matter of primary importance within this literature review, and as such has been discussed in a separate section below.

Non-structural Factors

Non-structural factors that are discussed within this literature review include teacher factors and student factors; however, many of these factors are in fact similar or essentially identical factors – the mathematical self-efficacy, conception, and other factors involved in the discussion are often similar through the student period and into pre-service and in-service teachers, and thus the teacher and student factors should be considered to be a continuum of response and belief, rather than a distinct difference between the populations of students and teachers.

Computer Practice Framework (CPF)

The computer practice framework (CPF) is one theoretical framework that addresses the use of computers in the classroom. It has been identified as one of the simplest to use theoretical frameworks for the description of computer-facilitated teaching The CPF was also specifically designed for use in primary schools, which provides an advantage for this research over other available frameworks for computer use (Twining, 2002). This empirically derived framework provides a means of conceptualising the return on investment in computer technology in the classroom (Twining, 2002). This model was developed in response to existing models, which according to Twining was “value laden in terms of both its chosen focus and the underlying model of ‘good practice’ that the researchers have adopted” (Twining, 2002, 97). In other words, these models were constructed from an ideological viewpoint regarding the utility of computer-based teaching rather than being objective. Other problems with existing models included imprecise definitions of computer use and lack of clarity involved in the construction of the framework (Twining, 2002. The goal of the CPF was to overcome these challenges by providing a framework that addresses specific contexts in limited dimensions, compares practice across contexts, is simple to use, is not ideologically biased, is not based in a specific technology platform, and "provides a rich picture of computer use" (Twining, 2002, 100). The CPF consists of three dimensions, including Quantity (quantity of computer use as a percentage of available learning time), Focus ("objectives supported by the computer use"), and Mode ("the impact of computer use on the curriculum") (Twining, 2002, p. 11). The Quality dimension refers specifically to learning time (not including lunch or other break times) spent in using a computer either individually or in groups (Twining, 2002). The Focus dimension includes the focus of the learning on information technology skills; as a learning tool, which can include use of technology to support curriculum, mathematic or learning strategies, and affective learning or confidence and self-esteem; and other uses of computers (Twining, 2002). The third dimension is the Mode dimension, which includes the effect of the content and processes used; specific ways in which the Mode can be expressed include Support, Extend, and Transform (Twining, 2002). The figure below represents the connections and interrelationships between the three dimensions of the CPF. This model is a useful framework for identifying the appropriate amount of time to be used within the classroom; however, it can be difficult to measure, making it difficult to enact in practice (Twining, 2002).

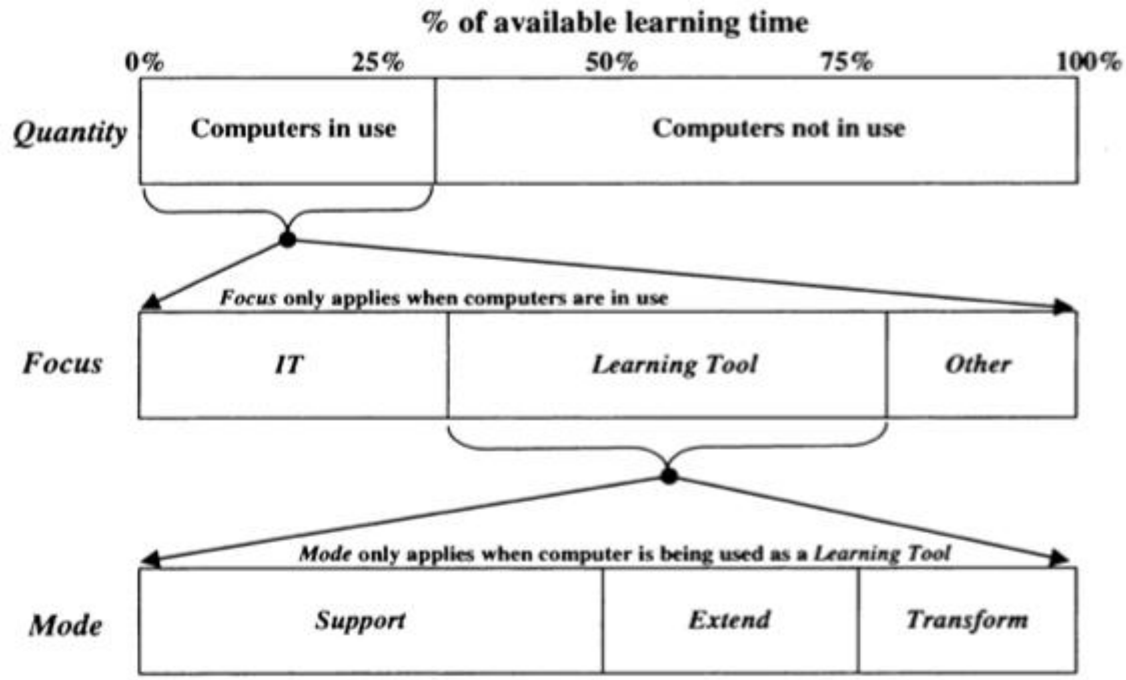

Figure 1 Computer Practice Framework (CPF) (Twining, 2002)

In this model, there are three possible focuses. The focus on computers as IT focuses on the role of the computer for networking, classroom management, or productivity tools, while the focus of computer as learning tool is based on the perception of the computer as a means of teaching (Twining, 2002). The *Other* category refers to the use of the computer for games or for other amusements or rewards (Twining, 2002).

The Use and Non-use of Computers in the Classroom

One paradox within the educational environment is the relative slowness with which computers have become integrated into the classroom. Historically, even though in many cases there were computers available in every classroom (and often even more than 1 computer per classroom) as well as other computer facilities, the frequency of use with these computers was often very low (Rosen and Weil, 1995). Rosen and Weil studied the issue of frequency of use and found that *technophobia* or fear of the computers on the part of the teachers was a determining factor in the relative frequency of computer use;

this was marked by concern over operation of the hardware aspect of the computer rather than concern over the effective use of the computer in the classroom (Rosen and Weil, 1995). Although Rosen and Weil examined this issue in 1995, it has not been reflected as a change in intervening years, indicating that this is still an issue in the classroom (Cuban, Kirkpatrick and Peck). One study noted that between 1986 and 2001, there was not much movement in the use of computers within the classroom despite a growing support of this use from policy makers and administrators (Cuban, Kirkpatrick and Peck, 2001). In 1986, 1 in 4 teachers were occasional users of the computers in their classroom and 1 in 10 were serious users, while in the 2000 study, 4 in 10 continued to be occasional users and 2 in 10 were serious users. While there was some progress especially in primary schools, they continued to be relatively underused in the classroom. However, the Cuban, Kirkpatrick and Peck (2001) study occurred in the American high school context, which means that this study may not be directly applicable to the Kuwaiti educational context. More recent research indicates that elementary use of computers is still relatively rare, although students use computers in the classroom more frequently as they progress through the school system (Franklin, 2007). This was found to be highly dependent on teacher characteristics as well as curriculum (Tondeur, Hermans, Braak, and Valcke, 2008).

Cuban, Kirkpatrick and Peck (2001) examined the same issue of low use of computers despite their consistent presence in 2001 in two schools in the United States. They found that despite high provision of technology within these schools, student and teacher use of the technology was still low, with use of technology mainly supporting existing methods of teaching rather than allowing for innovation in this use (Borko and

Livingston, 1989). The most common uses of technology in schools included word processing, grade keeping, email and Internet searching (Cuban, Kirkpatrick and Peck, 2001). The study also found that where computers were used they were most often used to supplement existing teaching practices rather than innovate; for example, a teacher may use a Power Point presentation rather than an overhead projector or slide projector, but with no additional improvement of the teaching method or practice (Cuban, Kirkpatrick and Peck, 2001). The authors offered a number of reasons for this seeming paradox of high availability of technology coupled with low levels of actual use. One strand of explanation centred on the idea of the "slow revolution", in which a gradual increase in the number of teachers using technology effectively will shift the use of technology gradually to he forefront (Cuban, Kirkpatrick and Peck, 2001). The other strand of explanation offered by the authors was the structural view, in which the physical space and context of the school and the structure of time usage and curricular demands reduces the use of technology despite its provision; in effect, the schools have not yet evolved to effectively integrate the use of technology despite its presence. The authors also highlighted the challenges of using the technologies, including difficulty of use, frequent requirements for support, and inappropriate configuration for the needs of teachers as one of the limiting factors in the use of technology (Cuban, Kirkpatrick and Peck, 2001). For example, some of the computers were found to have inappropriate software or to not allow students and teachers to log into them, making them difficult to use in the classroom.

Despite Cuban *et al*.'s (2001) optimism regarding the integration of computers into the classroom, a United States study in 2003 demonstrated that computers in the classroom were still having little to no impact on the effectiveness of curriculum (Norris, Sullivan and Poirot, 2003). This study found that 14% of teachers within the study did not use the computers provided to them at all, and 45% used computers with students for under 15 minutes per week (Norris, Sullivan and Poirot, 2003). The authors found that despite large amounts of funding spent on technology in the classroom in the United States, one in six classrooms did not contain any computers, while two-thirds had only one computer to be shared among all students; most teachers relied instead on computer lab access, which the authors felt tended to marginalise computer use and prevent its integration into the curriculum (Norris, Sullivan and Poirot, 2003). In other words, the assumptions of access that are inherent in the two studies above have been demonstrated by this study to be false; despite the large amount of money spent on integration of technology into schools, many schools simply have insufficient access to these technologies to allow for the full integration of computers into the curriculum. There is still recent evidence that there are too few computers in the classroom to support the number of students (Hew and Brush, 2007).

Effective use of computers in the classroom

There has been considerable research regarding the effective use of computers in education, driven by both empirical research and theory building practices. This research has focused on issues including the development of computer tools and the direction that this development has taken. This section examines the research regarding the effective use of classroom computer tools in order to understand how these tools can best be used.

There are a number of issues regarding research in the effective use of computers – simply, it is not as simple as it might otherwise be, and the development of classroom computer tools is often incomplete and difficult to fully describe. One issue is differentiation – in particular, children may be highly effective in mathematics with a lower effectiveness in computer use, or vice versa (Williams and Easingwood, 2004). According to Williams and Easingwood, prior research has shown that a given primary class can have as much to seven years difference in these two areas. That is, children may range in a given classroom, nominally at the same level of mathematics achievement, from three to four years below grade level to three to four years below grade level. Another issue is that of assessment of its effectiveness; researchers and teachers must be careful to assess mathematics learning issues, rather than computer use, when considering the issues of learning and practice (Williams and Easingwood, 2004). That is, in some cases assessments may not be measuring mathematics skill, but computer skill – strong mathematics students with weak computer skills may be hampered by the test, while students with weak mathematical skills and strong computational skills may be advantaged. However, while the development of computer skills in the classroom is not the primary goal of the development of computer integration of mathematics and computer technology, there must be consideration given to the development of computer skills in order to allow students to become comfortable with the computer and develop effectiveness in this regard (Leask and Meadows, 2000). However, this may be becoming less of a problem as computers are increasingly integrated into everyday life (Zevenbergen, Dole and Wright, 2004). As children increasingly become familiar with computer technology at an early age it will become less challenging to ensure that the computer curriculum will begin with developing familiarity with computers. However, attention must still be paid to the issue of the digital divide, or the gap between rich and poor in terms of computer access and facility with computers (Settlage and Southerland, 2007). Simply put, children with greater familial economic resources will have a better level of access to computers and information technologies that will increase their level of computer capabilities. These statistics are not available for Kuwait, making it difficult to compare the precise impact of this issue.

The ways in which computers are used differ with the type of tools, the focus of the tools, and the goal of use within the classroom. There are a number of models that can be determined that describe this phenomenon. These roles include computer as tool, computer as teaching aid, and computer as tutee (Gates, 2002). Gates (2002) described the *computer as tool* model as the use of computers by teachers for classroom management practices, such as word processing, tracking grades, and other assistive technologies. In this model, mastery of the use of the computer is viewed as the goal of the exercise of involvement rather than experiential learning (Gates, 2002). Computer as teaching aid is the perspective that most computer-based mathematics teaching aids are created under, with computers used to develop skills outside of basic computer skills. However, the computer as tutee model is radically different from the other two, with a focus on providing active feedback to learners that can dramatically improve the outcomes of the learning process; however, the computer as tutee role can be exceptionally uncomfortable for the teacher and the student, and as such is not used as often as the other two models (Gates, 2002). This is due to the perception that the computer is co-opting the teacher's role within the classroom, and simultaneously humans, rather than assistive technologies more appropriately engage in that teaching. These models should be considered in examination of processes involved in development of computer integration in the classroom. However, this variation in roles is the main characteristic that distinguishes the computer from previous technological classroom tools such as the video player, as was determined very early in formal research into technology in the classroom (Cornelius, 1982). Cornelius predicted in 1982 that the use of computers in the classroom was more likely to be effective as a teaching aid rather than a tool, which is in line with Gates' (2002) models of class-room based technology. However, there is considerable concern remaining within this model regarding the depth to which the use of technology is being implemented within the classroom; the development of classroom tools has in many cases been superficial and has not focused on true development of effective teaching aids, but rather has remained at the teaching tool level, reducing the efficacy of classroom involvement of computers (Tinsley and Johnson, 1998). It should be noted that this model was developed within the American teaching context, and thus may not be applicable across all areas because of cultural differences and differences in the educational system. Additionally, this research is relatively old and so may have moved on from this period.

Teacher Factors

One of the driving factors that has been identified in the use of computers in the classroom is individual teacher characteristics, which will influence how often the teacher chooses to use available technology when this use is potentially optional or when other teaching methods are available. The identified teacher characteristics are discussed below. However, it should be remembered that these teacher factors themselves are subject to cultural influences as well; as Brown and McNamara (2005) noted, issues such as "conceptions of professionalism, broader conceptions of teaching and mathematics, the affective response to the subject, the need to comply with accreditation demands, the way it is conducted between teachers and children and the way it is assessed as having been achieved or not" (Brown and McNamara, 2005, p. 105), are all culturally influenced issues that play a role in the construction of teacher identity and effectiveness, and as such the cultural issue should be considered carefully. These individual characteristics are not distinct from those experienced by students, but are instead continuations of issues that teachers experienced themselves as students, such as self-efficacy, comfort with technology, and conception of mathematics (Brown and McNamara, 2005). These three issues have been seen in multiple research studies (Teo, 2009; Tondeur, Van Braak, and Valcke, 2007b; Wozney, Venkatesh, and Abrami, 2006). In many cases, explicit research links the perception of mathematics as a student to the perception of mathematics of the teacher, as discussed in the literature below.

Self-efficacy

As with students, computer self-efficacy has been shown to be an important factor in the effectiveness of teacher's use of computers within the classroom (Vannatta and Fordham, 2003). Vannatta and Fordham established computer self-efficacy as one of the primary driving factors in the integration of computers and teaching, and many other studies have continued to enforce the idea that this is important for their use. This issue may also be tied to computer knowledge and comfort with computers, as discussed above, but it is in some respects independent from the issue of knowledge of computers and is instead dependent on the conception of skill rather than the actual skills involved in the process of learning; a highly skilled individual that does not show self-efficacy in use of computers in the classroom, while a person with a mediocre skill level and higher self-efficacy will be more effective in integrating computer skills into the classroom (Vannatta and Fordham, 2003). Self-efficacy is discussed below, and this information is also largely applicable to the self-efficacy of teachers as well. There are a number of instruments to study the issue of self-efficacy. One that has been designed specifically to examine issues of teacher self-efficacy is the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI), which consists of two subscales, a 13-item Personal Mathematics Teaching Efficacy (PMTE) subscale and an 8-item Mathematics Teaching Outcome Expectancy (MTOE) subscale (Enochs, Smith and Huinker, 2000). This instrument has been tested extensively in order to examine issues of construct validity, and has been shown that the two scales are independent, indicating a high level of construct validity (Enochs Smith and Huinker, 2000). However, this scale is intended for use at the pre-service teaching level rather than for teachers that are already engaged in teaching, indicating that there is some potential for improvement in this area. However, this instrument may prove to be an effective means of assessing in-service teacher’s effectiveness as well, which should be determined through examination of the instrument and further research.

Conflict Between Beliefs and Methods

One issue that has frequently been observed in the literature is some degree of conflict between beliefs regarding mathematics and the methods that teachers use to teach mathematics (Tondeur, Van Braak, and Valcke, 2007b; Wozney, Venkatesh, and Abrami, 2006). Mathematics teaching beliefs tend to range from very traditional beliefs to very non-traditional beliefs, of which there are a number of ways of categorising (Tondeur, Van Braak, and Valcke, 2007b). Shapiro (2000) characterised these beliefs as logicism (the belief that mathematics is a system of logic or a highly structured set of rules that will routinely lead to the correct answer), formalism (the belief that mathematics is a series of rules or algorithms that can be applied consistently but do not require attention to real-world situations) and intuitionism (which holds that mathematics is a flexible and intuitive means of understanding the world) (Shapiro, 2000). This grouping is not accepted by all understandings of mathematics but can be applied to many other systems in order to promote understanding as well; for example, this schematic approach can be readily mapped to Raymond's (1997) continuum of traditional and non-traditional mathematics (Shapiro, 2000). These mathematics beliefs are also shared by parents, many of whom may hold the same formalised beliefs that are held by teachers, which further enforces the paradigm of formalised mathematics beliefs and does not allow children the outlet of different learning styles in the home (Smith and Pourchot, 1998). However, as Smith and Pourchot noted, there has not been a significant amount of research performed on the structure of parental beliefs on children's mathematics learning, and as such this will not be a major focus of the literature review. The conflict between logicism and intuitionism is an important issue within the teaching and study of mathematics, as my own biases in this regard are almost certain to influence the outcomes of the study as well as the focus of the research. Thus, this is an important debate and one that should be considered carefully when constructing materials and study approaches.

Although the issue of conflict between belief and practice in mathematics teaching has not been explored in large-scale studies, it has been explored in small-scale qualitative studies. One study used a case study of a single observational subject in order to explore this conflict. The beginning mathematics teacher demonstrated some inconsistency in her stated beliefs regarding mathematics teaching and the practices that she actually used for teaching (Raymond, 1997). (The single case was part of a larger observational study, and was used as a representative case rather than the full study). The author drew a distinction between a teacher's beliefs regarding the nature of mathematics itself and beliefs regarding the teaching and learning of mathematics, drawing distinctions between traditional and non-traditional beliefs in each of these areas (Raymond 1997). The author also categorised the observed teaching practice of the subject in the same manner. She found that, in common with most of the participants in the study, the subject's beliefs on mathematics teaching were less traditional than her actual teaching practice (Raymond, 1997). However, the author observed that the subject also had considerably more traditional beliefs regarding the nature of mathematics itself than she had about the teaching of mathematics, which was unique within the subject pool (Raymond, 1997). In this case, categorisation regarding the nature of mathematics ranged from highly traditional (including a perception of mathematics as "an unrelated collection of facts, rules and skills" and a nature that is "fixed, predictable, absolute, certain, and applicable (Raymond, 1997, p. 556)," to entirely non-traditional, which included a perception of mathematics as "dynamic, problem driven and continually expanding… surprising, relative, doubtful and aesthetic (Raymond, 1997, p. 557)." In this case, Raymond traced the conflict between the subject's beliefs regarding mathematics and the nature of mathematics to her own experience in mathematics, which had emphasised and reinforced the traditional view described above (Raymond 1997). This example demonstrates that it is possible, even in cases where there is no enforcement of traditional norms of teaching mathematics or the nature of mathematics, that the teacher trainees and teachers will carry these previous experiences with them in developing mathematical ideas. This conflict is important because as Raymond (1997) noted, the approach toward computer-based teaching is highly influenced by the teacher's approach to mathematics teaching; thus, this is an important alignment of the study.

Technology in teacher preparation

One of the more past difficult issues involved in development of classroom technologies was the relatively low rate of appropriate use of technology use in the teacher training programme (Garafalo, Drier and Harper, 2001). One study in the United States pointed out that the issue was not only training of the trainee teachers in technology, but also training in those responsible for this training (Garafalo, Drier and Harper, 2001). It is not enough to simply assume that teachers will develop teaching technology skills through use of technology either in their previous use or through the training program; thus, it is important to "train the trainers" as well as the teacher trainees themselves in order to improve the use of technology in the classroom (Garafalo, Drier and Harper, 2001). Only through this second-order teacher training and development programme can trainee teachers receive the appropriate support needed to implement teacher training in the classroom. Guidelines offered by the researchers for appropriate development of teacher trainee technology capabilities include teaching them to "introduce technology in context… address worthwhile mathematics with appropriate pedagogy… take advantage of technology… connect mathematics topics… [and] incorporate multiple representations (Garafalo, Drier and Harper, 2001, 67)." These skills-based guidelines can be used for the development of not only teacher trainees, but also for their teachers. However, once again this study has been restricted to the United

States and thus the study must be considered in terms of its cultural impact and changes that may occur within the Kuwaiti cultural context. However, this has largely been addressed in other areas, and the role of computer technology in the teacher training classroom has been well established in more recent teacher training, and by the mid-2000s there was growing concern that the use of technology in the classroom had become too commonplace (Adams, 2006; Vallance and Towndrow, 2007).

Comfort or Discomfort with Technology

It is reasonable to hypothesise that teachers that are less knowledgeable about technology will be less likely to use it, and the existing research supports this. One study examined teacher attitudes toward technology using an instrument called the Teaching with Technology Instrument (TTI) in order to examine the use of technology in the (Adams, 2006) classroom and what factors the teachers related this to (Atkins and Vasu, 2002). Atkins and Vasu (2002) found that characteristics that were associated with use of technology in the classroom included computer confidence, access to computers and technology in the home and school, and hours of technology training. These findings demonstrate that simple knowledge and comfort with the use of computers in other aspects is likely to influence the use of computers within the classroom environment. Knowledge of technology and technology training has also been identified as an important personal characteristic by other studies, which included both personal training and knowledge and training undertaken as part of teacher training processes (Vannatta and Fordham, 2004). Atkins and Vasu (2002) suggested using the TTI instrument to specifically assess the technological capability of a given school's overall technological capability and identifying training requirements. Teacher competency and technological capability were also identified by Baylor and Ritchie (2002) as determining factors in successful technological integration. However, it should be considered that the ongoing education and increasing comfort with computer and technology skills would reduce this influence on the effectiveness of classroom computer instruction. However, this study begs the question of how this comfort level may be accomplished, as well as what level of comfort is required in order to support the effective use of computers in the classroom.

Flexibility and Improvisation

Improvisational techniques are often required for the successful integration of technology into the classroom and the conflict with these required improvisational techniques with the strict format of many student curricula (Borko and Livingston, 1989). One early study examined the differences in mathematics instruction by expert and novice teachers in order to explore the different techniques used by these groups (Borko and Livingston, 1989). This study directly connected the mathematics teaching methods in use by the novice teachers to their cognitive schemata of the teaching process. The authors noted that the planning process for novice teachers was more complete and less efficient, and allowed less room for improvisation in their teaching processes (Borko and Livingston, 1989). This lack of efficient planning allowed for less time within the lesson to explore emergent issues and change tactics if the methods in use proved to be ineffective within the teaching process. The study observed that teachers displayed considerable uncertainty when forced to deviate from their lesson plans by student incomprehension or other unanticipated difficulties, and also displayed less ability to predict or perceive when students were having difficulty with their lessons (Borko and Livingston, 1989). This indicates that the novice teachers, who in other studies have been shown to be more knowledgeable and comfortable with the use of computer integration in the classroom, may actually be at a disadvantage for *effective* use of computer technologies as compared to more advanced teachers, who have a better understanding of the teaching process as a whole. This is another paradox that remains unresolved in determining the relative effectiveness of teachers within the classroom. This study also does not provide room for examination of the teachers in terms of other aspects of their teaching ability, and does not contextualise the importance of the use of computers in the classroom in comparison to other aspects of good teaching.

The problem of encouraging student teachers and beginning teachers, as well as more experienced teachers, to use computers in the classroom, has been addressed by a number of organisations and authors. There are approaches that have been used to improve teacher effectiveness in the classroom in regard to computer usage. Teachernet was pioneered in the UK in 1994 in order to encourage student teachers to use Internet based resources and develop curricula based on these resources (Casey, 1994). This project was taken up in other English-speaking countries as well. For example, oz-Teachernet was focused on the Australian educational environment, and this community is still ongoing (Nykvist & Masters, 2007). These communities serve not only as sources of curriculum material, but also as a means of creating a community of practice around the Internet-based platforms that host them (Nykvist & Masters, 2007). The groups have also integrated new technologies such as Web 2.0 collaborative learning tools, which can be used to create deeper and more intensive interactions within the community (Nykvist & Masters, 2007). A similar group is the NAACE, the National Association of Advisors for Computers in Education, which provides support for curriculum development particularly at the primary level (Kakabadse & Kakabadse, 2010). The NAACE is active in research into the area of computers in the classroom, as well as encouragement of student teachers and others to use them (Kakabadse & Kakabadse, 2010). There are also a growing number of guidebooks for using computers in the elementary classroom. Elston (2007) has provided a clear guideline for teachers, describing the effective use of computers in the classroom as well as providing specific guides for information and activities that can be used. An older work by Richard Ager (2003) focuses not only on computers themselves, but also on other computer technologies such as digital still and video cameras as a means of promoting creativity and integration of constructive approaches in the classroom. Haylock and Thangata (2007) specifically address the issue of computer use in the mathematics classroom in their guide to primary mathematics learning and teaching. Mooney *et al*. (2009) also address the use of computers in the teaching of primary mathematics in the classroom in their trainee teacher course book for teaching mathematics (Mooney, Briggs, Fletcher, Mccullough, & Hansen, 2009). Thus, there are multiple resources available and many of these resources can be, and are designed to be, integrated into the student teaching curriculum in order to improve comfort with the use of computers.

Perception of Benefits of Computer Use

Another factor identified in the use of technology within the classroom is the teacher's perception of the benefits of this technology. For example, one study that specifically explored the issue of computer-mediated communication (such as through email, message boards or other methods) found that the use of this communication method was strongly influenced by the teacher's willingness to use technological innovation, but also by the perception of the benefits this communication method would have (van Braak, 2001). Thus, teachers in communications specialty areas (such as language, writing, and literature) were more likely to use computer-mediated communications than teachers in other disciplines. This research has been supported by later research in the area of teacher computer use in the classroom (Tondeur, Van Braak, and Valcke, 2007). This observation demonstrates that the perception of the benefits of the use of this tool was a factor in deciding to use it. This is important because without an understanding of the benefits of the use of the tool it would be difficult to convince teachers to use it in the classroom. It does seem clear that teachers that do not see the value of the introduction of computers into the classroom will not fully integrate computers into the classroom. However, in some cases teachers do not have significant influence over how they work, and can only control their action by using technology poorly. Thus, this outcome should be considered carefully in this discussion.

Engagement

While some issues are clearly structural or non-structural, some issues could be said to be semi-structural, or falling between the structural and non-structural aspects of the school system. One semi-structural characteristic that has been identified in use of technology within the school is teacher engagement, defined as "a teacher taking effort to affect the teaching that occurs in classrooms other than his or her own (Becker and Riel, 2000, p. 1)." This could be described as a between-teachers effect that influences the whole school from the individual teacher level, and as such is a point of interaction between the structural and individual teacher level. Another characteristic of engagement that has been identified is teacher willingness to spend time outside the classroom on specific tasks and activities related to technology, such as training, planning, and self-learning (Vannatta and Fordham 2004).

Becker and Reil (2001) found that teachers that were more engaged tended to support a more constructivist method of teaching and more intensive use of computers in classroom instruction than teachers that considered teaching to be either a primarily private activity or one that is imposed by specific standards bodies. This concept was viewed in practice in a case study in which an attempt to improve technology integration within a subject school was undertaken (Windschitl and Sahl, 2002). In this case study, teachers were given laptop computers for use in the classroom, both for direct teaching purposes and for administrative purposes, and were given leeway regarding their use of the computers. The use of the computers was tracked and causal factors for changes in their use were identified. The researchers found that the integration of this new technology and constructivist teaching methods were not driven only by the introduction of the technology; instead, the teachers studied displayed different motivations, some of which spoke to teacher engagement (Windschitl and Sahl, 2002). The teacher that displayed the highest level of engagement and the most dissatisfaction with current teaching methods in the school achieved the highest level of integration and constructivist teachings, while teachers that displayed lower levels of dissatisfaction achieved lower (although non-zero) levels of technology integration; the teachers that did not display this level of engagement did not achieve constructivist teaching practices (Windschitl and Sahl, 2002). This indicates that the issue of teacher engagement could be a specific issue in the highly constructed atmosphere of the Saudi Arabian primary school, as teaching may be considered to be primarily driven by outside regulators rather than subject to influence from the teachers. This is an important area for consideration in the current research.

Training and Development

In order to use computers effectively within the classroom it is necessary for teachers to have prior knowledge and experience in this use of computers or to gain this knowledge through formal training and development. Whether an individual teacher learns this information through training or through personal use is likely to depend on the individual's personal and demographic characteristics, such as computer self-efficacy or personal involvement in the use of computers. However, it is vital for teachers to be involved in this development for it to be effective. As one study astutely noted, "the potential benefits of [technology investment in the classrooms] cannot be realised unless teachers are prepared to use computers for instructional purposes" (Russell, Bebell and O'Dwyer, 2003, p. 307). . The teacher pre-service training period is an obvious place in which new teachers can gain the specific knowledge and experience in the use of computers that is required for effective use of technology in the classroom (Russell, Bebell and O'Dwyer, 2003). The study found that new teachers had considerably higher levels of comfort and knowledge regarding computers than did teachers that had been teaching for longer periods, but that beliefs regarding the usefulness of computers in learning did not vary depending on the time in service of teachers; this could indicate that while new teacher's computer skills have come from prior experience rather than direct training, their views on computers in the classroom are influenced by their training. And as can be deducted, the provision of training during the pre-service period for new teachers does not address the need to train existing teachers, which is potentially much greater due to lower levels of comfort with technology.

Knowledge assessment and training needs development is also important for understanding how teachers' use of technology can be improved. One means of assessment that has been identified is the use of the TTI instrument (Atkins and Vasu, 2002). More complex methods involving regression analysis of survey responses and follow-up interviews have been used by other researchers (Dusick and Yildirim, 2000). A number of training methods have been identified for use in training teachers to use computers in the classroom. Workshops, conferences, simple availability and informal learning through facilitator or mentor relationships with more experienced computer users were identified by Dusick and Yildirim (2000) as effective methods of training for teachers that were already within the classroom. However, it is not simply a matter of placing teachers in workshops – one study of pre-service teachers indicated that there was a significant gap between the training provided in this environment and the expectations of teachers once they entered the teaching environment (Pope, Hare and Howard, 2002). This gap indicates that it is essential, both in pre-service teacher training and in the construction of training for teachers that are already in service, to consider the needs of the teacher and the needs of the environment as well as current achievements in order to appropriately match the training to the environmental needs. The issue of training gaps between needs and training provided has been examined in other studies in the United States as well; Schrum (1999) examined the issue of technology integration, concluding that while technical training in computers that would overcome Ertmer's (1999) first-order challenges to technology integration was improving at the time, second-order issues such as perception of technology had remained unaddressed at this time. However, the increasingly common use of computers in everyday life may have reduced these training gaps, due to teachers having pre-existing skills on entry into teacher training; research has shown that existing computer skills are an important determinant in later teaching efficacy (Fleming, Motamedi, and May, 2007). This has not been established in the Kuwaiti context, but given global technology trends it is likely to be consistent.

Student Factors

Many of the same characteristics that have been observed in the development of student efficacy in the use of computer tools in the classroom as in the case of teacher efficacy; however, there are also some issues that have been identified within the literature of child effectiveness that are unique in this case. Childhood use of computers has been shown to be important in the development of emotional and cognitive development (Subrahmanyam, Greenfield and Kraut, 2001). Development of increased visual attention, spatial cognitive skills, and iconic recognition has been identified as major positive benefits of computer skills, as well as improvement of academic performance (Subrahmanyam, Greenfield and Kraut, 2001). In the United States, early computer use has been found to improve the school readiness of children in the Head Start programme (intended to provide pre-primary educational support for students of lower socioeconomic status) (Xiaoming, Atkins, and Stanton, 2006). Childhood computer use has also been shown to be important in early formation of three-dimensional visualisation skills (Sorby, 1999). There is even an argument that children of this generation can be considered digital natives, or those that have grown up with computer technology and Internet, and are more comfortable than adults in a digital world (Bennett, Maton, and Kervin, 2008). (Given that this concept has been developed in a Western context, it is not certain that this could also be said of Kuwaiti children, who may have different levels of access to the Internet and computers.)

However, there are significant differences in these developmental factors in relation to a wide range of student-specific characteristics and factors. It is reasonable to assume that student characteristics, as well as teacher characteristics, will impact the effectiveness of computers in the classroom, and the existing bulk of the literature bears out this assumption. A number of student characteristics and attitudes that impact computer use in the classroom have been identified within the literature that may prove to be relevant to the current research process. These are described below.

Socioeconomic status

The socioeconomic status of students cannot help but impact the development of effective computer skills either within or outside the classroom. One aspect of learning using computers that has been examined extensively is that of the Digital Divide, or the difference in learning between children that have access to home computers and those that do not (Becker, 2000). The Digital Divide has been studied and factors that are found to be indicative include per capita income, urbanisation rates, illiteracy, educational levels, infrastructure and regulatory quality (Chinn and Fairlie, 2006).

Becker's study of children in the United States revealed that while 91% of the students whose family incomes was over $75,000 had access to a home computer, only 22% of those whose family incomes were under $20,000 did. This issue is not simply one of degree of access; as Becker noted, most of the children in the study that did not have access to a computer at home did have school access to computers and teachers in lower income schools reported higher weekly use of these computers than did those in higher income schools (Becker, 2000). This research has been reconfirmed by further research in the UK, demonstrating that children have different levels of access to the Internet and computers based on their socioeconomic status (Livingston and Helsper, 2007).

The problem of the Digital Divide is not only one of quality of use, but also quantity of use (Goldfarb and Prince, 2008). While students at home have the opportunity for using computers in a freeform and creative way that sustains their interest, as discussed below, students that only use computers in school most often only use these computers for repetitive or routine tasks that do not develop skills beyond basic mechanical operation (Becker, 2000). For example, the student with a computer at home may develop an understanding of computers through game play and other interactive tasks, the student using a computer only at school may view the computer only as a way of performing tasks such as word processing, which are the main focus of school-based computer use. This results in a lack of interest in computers on the whole as well as a lack of the higher-order benefits of computer use such as development of spatial cognition skills. There are significant differences in quality and quantity of computer use observed even in cases where the nominal access to computers is identical (Goldfarb and Prince, 2008). Thus, whether or not a student has access to a home computer represents a significant factor in the effectiveness of computer-based learning for a specific student. However, the stakes of the Digital Divide are larger than simple educational issues, and continue to grow – as political participation and knowledge, job skills, and basic knowledge access are increasingly Web-based and computer-based rather than the other bases, the early acquisition of computer skills and comfort with computers is increasingly important for effective participation in adult social life (Shields and Behrman, 2000). This means that for children that do not have access to computers at home, the effective use of computers in the classroom, as well as access to Internet based resources and learning research skills, will become increasingly important for today's students to gain not only academic skills, but also basic skills that will be required for their adult lives. Unfortunately, these statistics are not available for the Kuwaiti context, making it difficult to determine what type of effect will be seen in the classrooms under study. Thus, an identification of computer use in the home will be established for the children within the proposed study rather than relying on external statistics.

One of the factors in whether students will be willing to use computers in the classroom is their experience and enjoyment of computers outside the classroom atmosphere. One study that examined third and fifth year primary students found that there were significant gaps between student usage of computers at home and at school, with computer usage at home being perceived as fun and computer usage at school being seen as boring (Mumtaz, 2001). Specific findings included that more students used computers every day at home than at school and that while home use included Internet use and game playing, school use was primarily transcription of notes and word processing, which was described as boring and frustrating (Mumtaz, 2001). Another study echoed these findings, indicating that children's use of computers at home primarily revolved around game usage and, in comparison to the use of computers in the school was largely unstructured and unsupervised (Kerawalla and Crook, 2002). Although parents that participated in the study believed that the primary use of computers within the home should be educational and encouraged this by educational purchases of software, most children actually used the computers to play games or explore other enjoyable activities (Kerewalla and Crook, 2002). Of course, these games are not without cognitive development advantages, as has been determined by other studies – video games offer significant benefits in developing spatial cognition, iconic recognition, hand-eye coordination and increased visual attention (Subrahmanyam, Greenfield and Kraut, 2001). However, it cannot be denied that the structured primarily academic focus of the school environment's use of computers may make the use of computers in school as appealing to children as the unstructured and interest-led use of computers in the home. More recent research has once again shown that beliefs regarding computer use, particularly in regard to the fun involved in the process (which may be higher in the home environment) is a factor in willing use in school (Vekiri and Chronaki, 2008).

Gender

One of the most significant findings in the literature on the attitudes of students toward computer use is the impact of gender on these attitudes. Gender is not a significant issue within the development of the Kuwaiti school system, as there is gender equality in school enrolment and provision of education, but it continues to be a problem as in most school educational systems across the world. (Of course, there may still be issues with non-systematic gender-based bias in the schools). A number of studies have examined gender and computer use within the classroom. However, there is some evidence that gender attitudes towards computers are likely to shift over time. One study conducted in the 1990s in the United States found that there were no significant gender differences in the actual degree of computer use between boys and girls in a high school classroom (Sacks, Bellisimo and Mergendoller, 1993). However this study did demonstrate that while the attitudes of boys toward the use of computers did not tend to shift over the course of the study, the attitudes of girls shifted as they became more familiar with the computers and knowledgeable about them (Sacks, Bellisimo and Mergendoller, 1993). As the authors noted, the subject matter may make more of a difference in the construction of student attitudes toward computers, with programming, mathematics and science posing a more difficult challenge than non-scientific and mathematical tasks like games or word processing (256 256-7). Another study found that home use of computers was also differentiated by gender, with girls preferring social activities such as interacting with their friends through email or social networking while boys preferred game playing (Mumtaz. 2001). This study also found that there were significant differences between boys and girls in confidence in computer use (Mumtaz. 2001). Li's (2002) study found that there were specific differences between boys and girls in the use of computers for mathematics and science learning as well. This small-scale study of 22 students found several specific differences in the use of computer mediated communication. These differences included differences in communication patterns and communications materials. The study found that boys are more likely to offer opinions and explanations, while girls were more likely to ask questions or ask for specific information (Li, 2002). Additionally, girls were more likely to begin discussions, while boys were more likely to enter discussions at later stages and continue discussions for longer. Although care should be taken in applying these findings across the cultural context from the United States to Saudi Arabia due to differences in cultural aspects of gender expression and communication styles as a whole, this is suggestive that there may be communications differences based on gender that should be examined. A study of gender issues in computing in the schools offers some basis that there may not be full gender equity in many cultures in use of computers within the schools (Reinen and Plomp, 1993). This study examined gender-differentiated use of computers in schools across seven countries; it found that across all counties, boys received more computer time on school computers than girls, and female teachers and female students were not regarded as being as effective in computer use as male teachers and students, even in cases where they had received the same training, received the same assessment grades, and otherwise had similar profiles of knowledge (Reinen and Plomp, 1993). Although Reinen and Plomp's (1993) research was conducted during the 1990s and it can be expected that this situation has been somewhat corrected today, there must be an awareness of gender differences in computer use in schools in order to fully understand student and teacher issues in this regard. More recent research has shown that there were still significant differences in Greek students based on gender in the experience with and enjoyment of the use of computers in school (Vekiri and Chronaki, 2008). This is an issue that will be considered and re-analyzed in the current research.

Experience and Enjoyment

Some researchers have acknowledged that this gap between the structured and unstructured experience can mean that some school-based computer experiences are more effective than others (Becker, 1999). Becker's study of student engagement in specific tasks and uses of computers (as measured by student's use of computers to work on class material outside of class) identified a number of characteristics of computer tasks that could be described as successful from this viewpoint. In order to perform this study, I examined the teacher's objectives for computer use, the estimated time spent by students outside class, and the relative frequency of use of certain types of software such as games, simulations or explorations, encyclopaedias, word processing, and other uses (Becker, 2000). The study found that pedagogical motivations that included “helping students present information to an audience (Becker, 2000, p. 6)” experienced the highest level of student engagement, followed by “expressing oneself in writing” and “communicating electronically (Becker, 2000, p. 7).” The software programmes found to be most associated with student engagement included email, presentation software, multimedia authoring programs, graphics programs, Web browsers, and reference software (Becker, 2000). While Becker drew a connection between the use of this software and student engagement, it should be noted that many of these programmes would be used by a student with access to computers outside the school anyway, and as such may not represent a significant change due to pedagogical concerns. The issue of learning and enjoyment is one area of research that has been focused on the student, rather than the teacher, but in this case this issue may well apply to both cases. As such, this would be one area for study or for future research. However, while the ideas will be integrated into the current research it will not be studied further explicitly in this research.

Learning Styles

Learning styles of individual students have also been identified as contributing factors in the effective use of computers in the classroom. For example, some students may be more or less interested in learning or engaging with patterns at the elementary level, which could reduce the overall effectiveness of a computer-driven mathematics curriculum (Orton, 2005). These individual learning styles make a considerable difference in the overall flexibility of the curriculum and its applicability to given children. One study that focused on the multicultural classroom and different epistemologies in use within multicultural student learning teams found that the friction caused by these teams resulted in different outcomes for students depending on these learning styles (DeVoogd, 1998). The main outcome of DeVoogd's (1998) study was the emphasis on creating a learning environment that integrates technology in such a way that is sensitive to and encourages the use of culturally based teaching styles (for example, the use of small group versus large group interactions, teacher-led versus student-led activities, and other specific issues that may be impacted by cultural learning styles). The study also described situations in which the interaction with technology actually changed the learning style of the students, indicating that this may be a way in which students from different cultural backgrounds can be integrated into the classroom. However, the study on which this writing was based was a small scale case study involving only four classrooms in the United States; as such, it is necessary that these findings be further explored before applying them uncritically to the classroom environment. More recent research has also explored the issue of e-learning styles. One study examining adult e-learning styles has found that communal e-learning styles are based on individual preferences, and that traditional approaches are integrated into the learning environment (Coole and Watts, 2009).

Computer Knowledge

Another factor in student use of computers is previously existing computer knowledge. This is a factor that can be found in common with the teacher research as demonstrated above. However, in this case a circular causal analysis has been shown that reflects the self-regulating and building nature of computer knowledge. One study found that while computer attitudes and computer confidence have a reciprocal regulating effect (in which attitudes toward computers affect computer confidence, which then affects computer attitudes again) and that the effect of these two together leads to perception of computer competence (Levine and Donitsa-Schmidt, 1998). This research was based on attitude-behaviour theory, which "[postulates] that beliefs about an object lead to attitudes toward it and that, in turn, attitudes lead to behavioural intentions regarding the object. Intentions for their part affect actual behaviours toward the object. Finally, there is a feedback loop in which behavioural experience serves to modify beliefs about the object (Levine and Donitsa-Schmidt, 1998, p.126)". Fishbein and Ajzen (1976) proposed this belief structure, illustrated below. It provides an understanding of how acceptance of computers can be built within the student understanding. It should be noted that although this specific study explored this interaction in students, the same interaction between behaviour, beliefs, attitudes, and behavioural intentions could be examined in teachers as well.

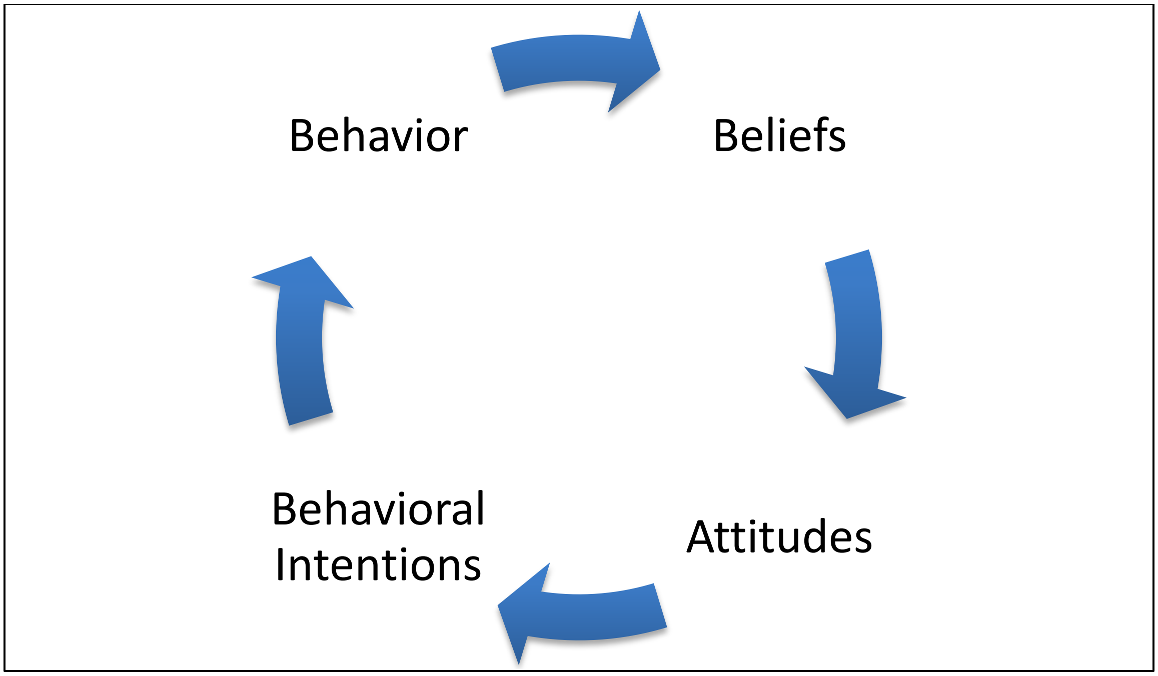

Figure 2 Attitude behaviour theory (Fishbein and Ajzen, 1975)

Kurz and Middleton (2006) stated that one of the most effective ways to get educators to use interactive software in their primary school mathematics classes is to encourage them to explore and evaluate software packages in their pre-service teaching days. In a study of two teachers they found that one pre-service teacher had professors and supervisors that encouraged her to develop an understanding of how to assess mathematics software packages. The other pre-service teacher was not exposed to evaluation techniques by her professors as ended up not being as comfortable as the other teacher in terms of evaluating computer software for her mathematics classes. Kurz and Middleton (2006) claim that it is not just what teachers receive in terms of instruction on evaluating mathematics software for the classroom, but their overall exposure and attitudes towards the use of classrooms in general. This research study indicates that even if instructional technology is part of primary schools mathematics curricula, that how it is implemented and how frequently it is used is often left up to the teacher who may or may not be influenced by pre-existing attitudes and perceptions about instructional technology.

Self-efficacy

Another factor in common between teacher and student effectiveness in this research is that of computer self-efficacy, or the individual's internal understanding of how well the individual fees he or she can use computers (Joo, Bong and Choi, 2000). Although related to the idea of computer knowledge, computer self-efficacy actually addresses how well students *believe* they are able to use computers, rather than their actual level of computer use skill (Joo, Bong and Choi, 2000). However, as Joo, Bong and Choi (2000) noted, academic self-efficacy in particular is strongly associated with actual performance at later stages; strengthened perceptions of self-efficacy and their association with stronger academic performance have often been observed by researchers (Joo, Bong and Choi, 2000). The authors examined whether self-efficacy beliefs had a positive impact on the outcome of computer based instruction programs. Using descriptive statistics, corerelational analysis, and path analysis, they found that overall Internet self-efficacy (identified as belief in skills involved using the Internet) related strongly positively to the outcomes of a Web-based test on a given subject matter; correspondingly, academic self-efficacy resulted in the same strong performance on a given subject matter, but did not impact the performance on the Web-based test (and vice versa) (Joo, Bong and Choi, 2000). This demonstrates that self-efficacy in one area cannot be directly translated to performance in another area, even though it is highly likely that there will be a performance gain from the specific area of concern; instead, each area of self-efficacy must be explicitly developed in order to gain the performance benefits. Thus, it will not always be the most academically confident students within a class or cohort that demonstrate the best computer performance, but instead will be those with the best feeling of understanding computers.

Mathematics Teaching and Technology Integration Into Mathematics

The main model for understanding the teaching of technology in integration with mathematics is the use of constructivist teaching practices, a common means of integration of these models. Constructivist teaching practices are a movement away from an older model of mathematics learning, in which mathematics is considered to be a transmission of formalised knowledge from teacher to student (Wood, Nelson and Warfield, 2001). Instead, constructivist teaching practices place the student at the centre of the learning process and allows for the development of teaching practices that emphasise practice and exploration based on student interests and activities (Wood, Nelson and Warfield, 2001). However, implementing constructivist teaching practices are not without their own challenges. One particular challenge in this case is the conflict between allowing students to pursue their own interests and abilities in a constructivist fashion and other demands and requirements, such as the teacher’s desire to provide the best possible outcomes for students or the curricular demands for specific teaching and learning practices (Greeno and Goldman, 1998). Thus, there are some concerns regarding how well the practice of constructivist teaching methods are actually put into place as compared to the theoretical basis. Although this will be considered as a theoretical basis it will not necessarily be a demand of the teaching practices that are involve in the research because of this reason.

Theoretical Frameworks of mathematics learning

One of the vital concepts in this structure is building understanding of mathematics. In other words, how do students learn mathematics? How do students and teachers *believe* they learn mathematics, and what difference does this make in the construction of mathematical knowledge? One useful conception of understanding is a division into relational understanding and instrumental understanding (Skemp, 1976). Skemp (1976) characterised this paired meaning as a *faux ami*, or “false friend”; or a pair of words that use the same phonemes to signify different meanings. Relational understanding is positioned by the author as the understanding achieved by knowing both how and why to use a given mathematical rule or process (Skemp, 1976). In contrast, instrumental understanding is the ability to use a given rule, but a lack of understanding of why the rule should be used (Skemp, 1976). This can be seen in practice in the TIMMS test score results of Kuwaiti students from both 1997 and 2007 as discussed above; in both tests (although this was measured in slightly different ways) students demonstrated a greater ability to apply a given mathematical rule or process than the ability to explain why they were applying this rule or process (Mullis, Martin and Gonzales, 1997; Mullis, Martin and Foy, 1997). Thus, the development of instrumental understanding and the neglect of relational understanding may be one factor in performance, as well as one area where improvements could potentially be made through the use of computers within the classroom. However, the problem may be deeper than simply development of student skills. As Skemp (1976) pointed out, if the teachers of mathematics are using an instrumental understanding of the mathematical rules and concepts they are conveying, then that removes the possibility that students will be able to achieve a relational understanding of the concept. In this case, the instrumental understanding of mathematics can be corresponded to the traditional understanding of mathematics described by Raymond (1997), while the relational view corresponds more closely to some degree of non-traditional understanding in the same system.

Learning Mathematics

An important characteristic of how mathematics can be taught is how mathematics is learned. One group of researchers based their examination of mathematical learning in three cognitive activities, including perception of the world, action upon this perception and reflection on the perception and action; rather than a straight line process, this was rather a cycle of thought and action patterns that resulted in the construction of mathematical knowledge piece by piece (Gray, Pinto and Pitta, 1992). Repetition and practice, use of language to build concepts, and compression of language to build mathematical concepts that can then be acted or operated upon are seen as the primitives or objects for building cognitive understanding of mathematics (Gray, Pinto and Pitta, 1992). The author's model is built upon Piaget's three forms of abstraction, which include empirical abstraction (focus upon the objects themselves), pseudo-empirical action (focus on the actions used to manipulate the objects), and reflective abstraction (which allows for construction of more advanced objects from the meta-observation of one's thoughts) (Gray, Pinto and Pitta, 1992). Gray *et al.* described two methods of using this cycle, one of which resulted in higher-level performance than the other, which they described as a divergence in performance. The point of this divergence identified by the authors was the point at which children chose to focus on empirical abstraction (focus on development of concepts themselves) and reflective abstraction (identification of means of improving on those concepts) or whether children chose to focus on the use of pseudo-empirical abstraction (focus on the methods used to manipulate the objects or concepts) (Gray, Pinto and Pitta, 1992). Their model of mathematical understanding development is shown in the figure below, illustrating how the difference in abstraction focus is associated with different levels of mathematical performance.

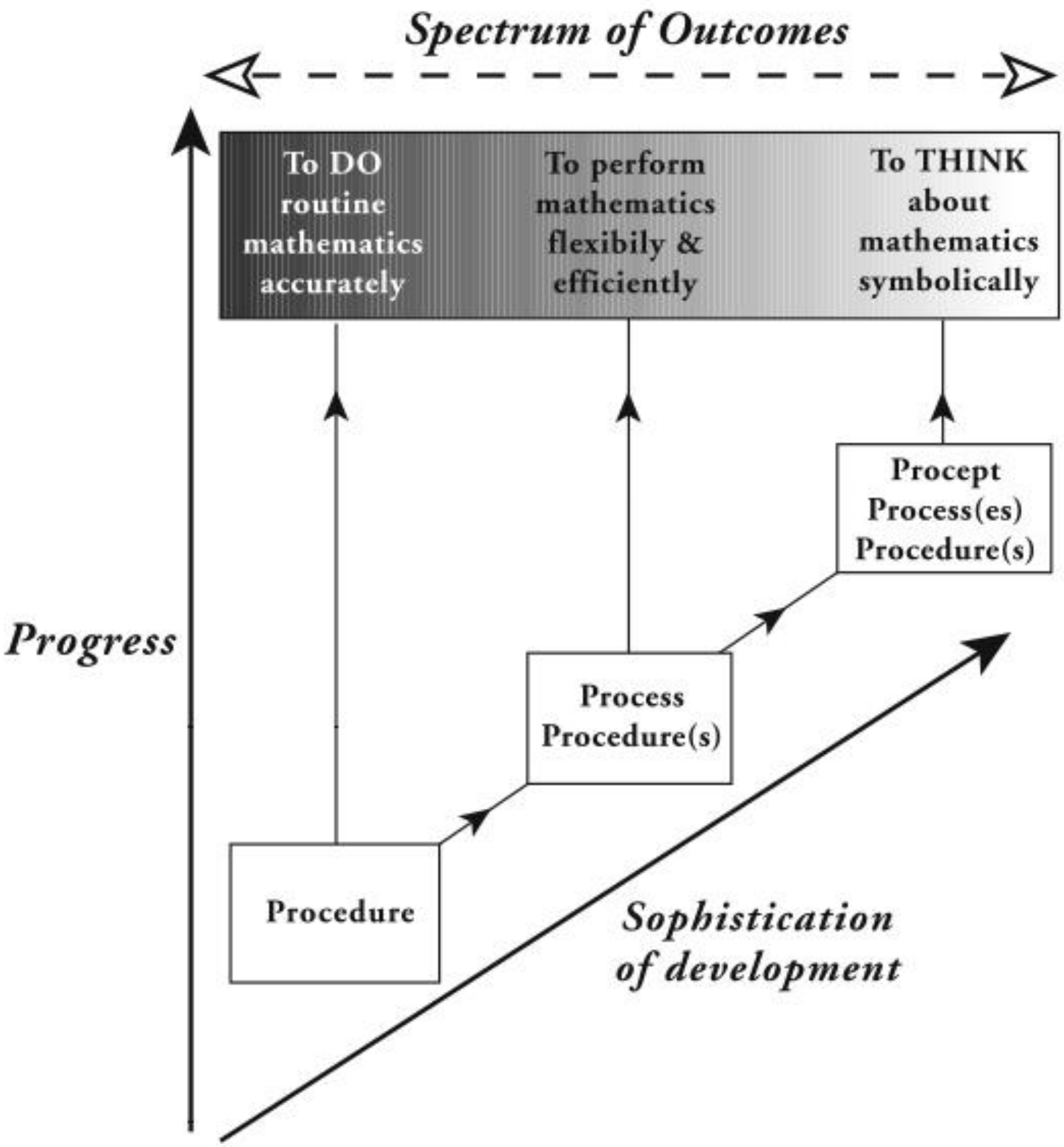

Figure 3 Modes of abstraction and sophistication of mathematical development (Gray, Pinto and Pitta, 1992)

Mathematics Teaching Standards and Variation

In many teaching contexts, there are specific standards that must be followed – whether these are enforced by a standard curriculum, classroom monitoring, standardised testing or some version of all three varies, but the goal of standardisation is to ensure that all children have access to the same level of knowledge development (Ross, McDougall and Hogaboam-Gray). However, Ross *et al.*'s (2003) study demonstrates that while this is an ideal outcome of standardisation, there is still some level of variation in the teaching of skills and specific focuses on areas of the curriculum even within teachers in the same school (Ross, McDougall and Hogaboam-Gray, 2003). Specifically, the study engaged in classroom observations in conjunction with a standardised testing example in grade 6 (12 years old), which revealed that even when using the same curriculum, materials and schedule teachers experienced variances in their teaching efficacy (as reflected by different test scores by their students). Some of this variation can likely be ascribed to differences in skill levels due to idiosyncratic factors of the students themselves, but some of it was ascribed by the authors to differences in teaching styles, methods, and focus of importance and perception of specific goals by the teachers themselves. This demonstrates one reason why standardisation of a curriculum may not work to standardise performance across students. The difference between curricular standards and constructionist or constructivist models may prove to strongly impact the overall effectiveness of the research, and thus the existing frameworks and knowledge should be considered in this case.

Constructivist Practice and evidence

One question is whether the use of a constructivist method of computer teaching would benefit students (i.e. would it be passed on to these students). How much evidence is there at constructivist practice actually works in the classroom? There has been a considerable amount of research on whether the principles of constructivist teaching that are commonly promoted in educational training actually are integrated into teaching practice. One study examined the use of constructivist practices by trainee teachers that had received this type of training for mathematics teaching (Klein, 1998). The specific issue studied by Klein (1998) is whether the use of constructivist practices in pre-service teaching methods increased or decreased overall performance in the classroom. Klein (1998) noted that the practices of collaboration, inquiry, and problem solving that are emphasised by the constructivist teaching method can lead to considerable differences in mathematics learning within the classroom that continue to reduce educational performance through gender and ethnic division of performance (Klein, 1998). Klein (1998) noted that this occurred through reinforcement of these norms within the teacher training programme, which enforced, rather than challenged, the views regarding mathematics that students entered the teacher training programme with. Thus, in order to change the basic nature of mathematical teaching and beliefs within the Kuwait school system the use of the constructivist method may not be the most effective choice due to the teaching methods in use in Kuwaiti teacher training.

There is considerable evidence within the existing body of the research for the use of a constructivist approach to mathematics teaching. According to Elisabeth Warren and Tom Cooper (2007), multiplicative thinking and the understanding of mathematical ratios are one of the most difficult tasks for students in the late elementary/primary grades. Understanding these concepts is thought to be conducive towards developing the skills that students need to make the transition from basic math to algebra and advanced mathematics. They hypothesised that teachers who encouraged classroom participation and interacted with students in terms of discussing concepts and ideas with the students rather than lecturing were more likely to be able to help students successfully navigate this transition from the basic skills that they are comfortable with too new skills that they will need to advance in their study. Warren and Cooper's (2007) secondary hypothesis was that repetitive pattern tasks would also assist students in grasping the concept of ratio in order to ease the transition from basic mathematics to algebra.

Warren and Cooper (2007) studied several Australian Primary schools during this study. The videotaped both teachers and students during a lesson on ratio. They recorded the number of interactions between teachers and students during the lesson. They found that repeating patterns made it simpler for students to grasp the concept of ration. They also found that how many times a teacher interacted with students and how they interacted with students determine how easily they grasped the new material. Finally, they found that teacher interactions had little impact on the ability of students to grasp repeating patterns.

Chung (2004) has studied constructivist approaches in teaching multiplication at the primary level. Chung (2004) hypothesises that because Constructivism is a more interactive hands on approach to learning and teaching, students make the connections between previously learned mathematical concepts much easier than they do when exposed to traditional methods of learning mathematics. In a study of four elementary school classrooms in St Louis Missouri, USA, Chung (2004) found that students in traditional mathematics classrooms were less likely to grasp key concepts and as a result they were less likely to do well on standardised tests that focused upon the theories behind the mathematics rather than the rote resolution of mathematics problems. In comparison, students in classrooms where the teacher approached the subject from a constructivist perspective were more likely to understand the theory behind the mathematics problems, not just the problems themselves (Chung, 2004). According to Lane the basis for the modern education systems in many nations are the constructivist concepts that focus upon the interactions between teachers and students and teaching students by having them participating in learning activities rather than using the lecture and repetition method that has been traditional worldwide in the historical sense. Lane hypothesised that teachers at the primary levels are generally more constructivist in their approach to teaching mathematics than are educators at the secondary and university levels. In a qualitative study in which Lane interviewed and observed three college professors and one graduate assistant, he found that the main reason behind this was because Professors who taught in the field of education, most specifically those that taught Mathematics Education tended to be much more constructivist in their approach than other professors. This increased the chance that new teachers would use the constructivist approach in teaching mathematics as well as in other subjects. Lane also argues that constructivism can be useful in teaching primary school students both familiar and novel concepts in mathematics. However; she argues that constructivist ideals should be blended with more traditional teaching approaches as ones teaching methods should be adjusted to meet the needs of the students and their learning styles.

The Constructivist Approach has also been critical when teaching science at the primary thru secondary school levels. Haney and Lumpe (2003) performed a study in which they focused upon the support that constructivist approaches to science learning receives from the community of parents and taxpayers and how this affects the likelihood that Constructivist Approaches will be used in the classroom in comparison to more traditional approaches. Hanye and Lumpe (2003) found that in School Districts where the taxpayers were these transitions into the idea that Constructivist approaches blend well with other types of methodology including Inquiry based teaching and learning. Chee-

Tan, Choo, Yeo and Ying-Lim (2005) state that one of the main challenges facing modern educators is teaching children how to become scientists rather than merely teaching them science. Chee *et al.* (2005) argue that the implementation of Inquiry Based Learning and Collaborative Learning techniques in the primary school years makes it more likely that students will become interested in and do well in science in secondary school. They also hypothesised that students at the secondary level who experienced Inquiry Based and Collaborative Teaching and Learning methods would also perform better in the sciences. In a study of 13 First Year Secondary students from a British Secondary School the authors found that students in Inquiry and Collaborative Based Learning classrooms performed better in terms of standardised testing and were more interested in science than their same age peers who were in a more traditional classroom setting.

Criticisms of constructivism

Although there is substantial evidence for the use of constructivism in the classroom, it cannot be denied that there is also a substantial body of criticism regarding the use of constructivism in teaching practice. Constructivism as a theory, however, has many faults. One of these faults is that the child must have the necessary resources to be able to actively participate in the learning and teaching experience. This is a condition that is not necessarily achievable in poorer areas of the world. Ismail (2009), in an analysis of the data from the International Association for the Evaluation of Educational Achievement found that Malaysian students who did well on national standardised tests did so whether or not the approach in their school was constructivist, or traditional. Students who did well tended to fall into specific social cultural and economic backgrounds in terms of mathematics performance in Malaysia. For instance, students who did well had access to books and computers in the home. They also tended to have parents who encouraged them in their studies, which improved their confidence in their mathematics skills. Students also tended to be from non-Malaysian families.

Another criticism of constructivism comes from the postmodern teaching philosophy (Walshaw, 2004). This criticism posits that constructivist teaching practices are based in discriminatory sociopolitical structures that do not allow for some individuals to move forward (Walshaw, 2004). These methods, along with other modern teaching methods, do not address concerns based in racial, class, and gender concerns, according to Walshaw. Furthermore, Walshaw (2004) noted that the traditional methods of mathematics often do not provide any *reason* to learn mathematics (this includes constructivist methods as well as other), which inhibits the learning of mathematics by many students.

Computer Teaching Programmes and Research

The effectiveness of specific computer-based mathematics teaching programmes have been explored within the literature, but the results are uncertain and often are dated even by the time they are published. One meta-analytic synthesis of 599 previous studies explored this issue in depth, focusing on improvement in mathematics achievement for low achieving students (Baker, Gersten and Lee, 2002). Computer-assisted instruction methodologies were included, but studies that explicitly taught computer skills (such as programming or logic) were not included in this analysis. However, this study found that much of the information that addressed specific instructional methods or technologies was too dated to use in the examination of current classroom effects of computer-assisted instruction technologies (Baker, Gersten and Lee, 2002). I have faced a similar problem, observing that the development of computer technologies to aid instruction has far outstripped the capability of the academic literature to study and assess these technologies in a timely manner. Thus, information regarding the effectiveness of any specific computer-aided instructional programme may be difficult to find depending on the speed with which researchers study it and whether it remains in use.

While there are difficulties involved in identifying specific programmes from prior research, general information regarding the effectiveness of methods used by these programmes may be found which can be applied to similar programs. For example, a study of one programme intended to teach students with learning and cognitive disabilities to remember multiplication tables using mnemonics (a peg- and keyword strategy) offers valuable insight into the use of computers in this situation even if the programme itself is no longer in use (Irish, 2002). This study demonstrated that for basic mathematical instruction, the use of computer-assisted instruction provided a valuable alternative to similar instruction provided by teachers or teaching assistants. This method could be used in a number of different contexts regardless of the specific programme in use. Another study examined the use of technology in the classroom and identified specific characteristics of computer learning programmes that must be present in order for the programme to be effective, including group participation, active engagement in the learning process, interaction and feedback mechanisms in order to allow students to understand their progress and build self-efficacy and efficacy attitudes, and connection to a real-world context that will allow the child to absorb the lesson more fully (Roschelle, Pea and Hoadley, 2000). These characteristics can be integrated into almost any computer-based mathematics learning programme effectively and do not depend on the use of specific technologies or frameworks in order to be effective, further increasing the overall effectiveness of the process.

Another method of computer-based learning that is not tied to a specific programme or methodology is the construction of a Virtual Web School (VWS), is designed to encourage participation and discourse between students (Lipponen, Rahikainen and Lallimo, 2001). In this method, a virtual space is constructed for formal or informal discussion of central topics, and students participate simultaneously. This method was shown to be effective in increasing the discussion density between students, but the discussions were not sustainable past the movement of the class beyond the topic (Lipponen, Rahikainen and Lallimo, 2001). Additionally, because the focus was on construction of knowledge and dialogue rather than the specific issues of the course it provided an increased level of dialogue within the class, but may not have resulted in the construction of long-term knowledge regarding the subject or interest beyond the assigned period for discussion of the subject. As such, the VWS has some modification and development to go before it becomes a truly useful method of knowledge construction, but remains one of the most promising recent techniques.

Another promising recent development is that of virtual manipulatives. Virtual manipulatives are simply "static and dynamic visual representations of concrete manipulatives (Moyer, Bolyard and Spikell, 2002, p. 372)." While static manipulatives offer the same level of representation of objects as pictorial manipulatives often do, the use of dynamic virtual manipulatives demonstrates advancement over the concept of static manipulatives. These dynamic manipulatives can be used in the same way as physical manipulatives in order to ease the formation of concepts and increase the learning process (Moyer, Bolyard and Spikell, 2002). The authors noted several important advantages of virtual manipulatives; they are available for free via the World Wide Web, allow for linkage of iconic and symbolic notations, and record specific users' record of use and capabilities, and are generally considered to be as engaging as physical manipulatives (Moyer, Bolyard and Spikell, 2002). The user can also alter the manipulatives in a variety of ways in order to increase the understanding of the manipulative and the underlying concept according to idiosyncratic learning needs. While the use of manipulatives involve an extension of current techniques rather than a transformation according to Twining's (2002) model, they do represent a solid extension that can be used very effectively and as such should be considered in the primary classroom.

A simple, yet persistent and effective, tool for teaching mathematical concepts at some level is the spreadsheet (Abramovich, Stanton and Baer, 2002). Abramovich, Stanton and Baer (2007) described a programme designed by novice teachers that allowed primary students to learn data analysis and probability techniques, as well as providing an incentive for use of the programme at the same time as allowing the teacher to track the student's progress (Abramovich, Stanton and Baer, 2002). The use of a tool such as a spreadsheet to teach these concepts has the attraction of familiarity and ease of use for both teacher and student and can be easily implemented in most classrooms regardless of structural or budgetary constraints. This type of tool, which is constructed from the materials at hand rather than relying on predesigned programmes and structures, does require considerable engagement from the teacher; however, in the case of a highly motivated teacher this is not likely to be out of the reach of the classroom – what is required, rather than a complex tool or strong technological skills, is an understanding of the cognitive and motivation issues at hand, which is often within the reach of both novice and experienced teachers.

Technology-mediated learning and teaching methods are extremely common teaching methods in post-compulsory mathematics, such as at the vocational or university level (Fitzsimmons, 2005). While the methods and precise materials of mathematics taught at this level would be inappropriate to apply to the primary teaching level, some of the criteria developed for its use including alignment with the intended goals and objectives of the learning process and contextualisation of the learning process with outside knowledge should be strongly considered (Fitzsimmons, 2006). This is particularly true given that Kuwaiti students undertaking the TIMMS examination have demonstrated an ability to apply knowledge, but lower capabilities when it comes to real-world context for this mathematical knowledge (Mullis, Martin and Foy, 2008). It is possible that this level of involvement in the research could be used to construct an understanding of how it could be applied to lower levels of education in terms of practice, if not in terms of material.

Teaching and Curriculum Reform in Mathematics

One of the main problems in this case is the current structure of mathematics teaching, which does not require or encourage creative or even effective use of computers in the classroom. The barriers to this reformation process exist not only in the structural elements of the school, such as curriculum requirements, but also in the beliefs of the teachers and students themselves (Schucl, 1999). Schuck's account described the process of attempting to reform mathematics teaching in her own classroom as "driving a mathematics reform with unwilling passengers (Schuck, 1999)." Although Schuck discusses her personal experience with the process of reform in the classroom, highlighting the need to identify and avoid the roadblocks that the students have due to their past training and experiences, she does not present a systematic method for identifying these roadblocks or for overcoming institutional and structural challenges in the process. One area that she does highlight is self-teaching on the part of the teacher (Schuck, 1999); however, as discussed above, the utility of self-teaching is highly dependent on issues such as training, self-efficacy, and teacher epistemological beliefs. As such, this cannot be relied upon as a valid method of driving reform. A more thorough examination of the issue is required; Although Schuck's view provides valuable anecdotal evidence for reform, it is insufficient to be relied upon in its entirety.

Computers, textbooks and other tools – their relative importance

In this article Kahveci and Imamoglu (2007) reviewed current literature on the use of interactive learning techniques in the primary school mathematics classroom. They discussed the pros and cons of each type of interactive learning ranging from pen and pencil games that teachers can use to teach mathematical concepts to more advanced uses of computer technology that allow students to more accurately visualise concepts in mathematics. Kahveci and Imamoglu (2007) argued that interactive techniques allow students to explore mathematical concepts in a more in depth manner. Specific examples of interactive tools have since been developed including interactive pens (Labahn, Lank, Marzouk, Bunt, McLean, and Tausky, 2008) However, there is some question as to whether full-scale interactivity is actually required, as in a question regarding whether interactive whiteboards are truly required in secondary mathematics teaching (Miller and Glover, 2010). Thus, the viewpoint of interactivity as the most important factor in mathematics teaching tools should not be accepted uncritically.

According to Abramovich and Ehrlich (2007), computer based mathematics programmes provide a more accurate method of depicting inequalities and equalities in advanced mathematics. Computer based mathematics programmes supplement what the teacher is focusing upon which helps those students that are visual as opposed to verbal learners. This can be helpful during the late primary years as students are trying to make the transition from basic to more advanced mathematics.

Computer programmes have also been used in successfully supplementing mathematics education through the college level. In this article Kennedy, Ellis, and Oien (2007) evaluated the effectiveness of a computer based pre-calculus programme at the University of Colorado. In an evaluation of this programme Kennedy *et al.* (2007) found that students rated the mathematics programme as more hands on and interactive than traditional classroom instruction. Students tended to perform better once they began taking Calculus classes and tended to have a better grasp of basic concepts. Another issue that it critical to the teaching of mathematics and science during the primary school years are the textbooks that are used in the classroom. A well written, well laid out textbook can make the difference between a successful mathematics class and one in which the students are un-motivated and bored with the subject. According to Mauch and McDermott (2007), many textbooks in the primary grades fail to meet the purpose of actually facilitating mathematics education. In analysis of many commonly used Third Grade mathematics texts the authors found that many books were poorly written and poorly laid out. Basic concepts were not covered in depth while concepts that were subordinate to basic ideas such as the relationship between adding and multiplication were given more coverage. Tables and graphs were not laid out properly so that students often had little idea of how illustrations related to what they were reading. These tables and groupings did not assist in the development of knowledge, much like many of the computer programmes examined.

Papanastisiou and Ferdig (2006) have performed a study in which they explored how using computer software as a supplement to mathematics programmes helps students develop skills in a wide variety of learning areas. In an evaluation of the Programme for International Student Assessment (PISA) they found that students who used the computer frequently and who used the computer to supplement more traditional education in mathematics demonstrated better grasp of mathematical concepts and theories as well as demonstrating a better grasp of the mechanics and rules of mathematics.

According to Fuchs *et al.* (2006) computer software can be helpful in teaching learning disabled children at the primary level number combination skills. Fuchs *et al.* (2006) hypothesised that Computer Aided Instruction (CAI) would facilitate children's skills in the area of number combination. In a study of 33 First Grade Special Needs Students that found that students who participated in CAI developed stronger number combinations skills in some areas such as addition however; these skills did not transfer to other mathematical concepts such as time, measurements, or subtraction.

Van Eck (2006) proposed that it is not the presence or lack of multimedia technology that impacts the ability of a student to do well in mathematics. Rather it is how the student perceives the advice and instruction they receive from the teachers, and their overall attitude towards mathematics in general. Van Eck (2006) studied 123 middle school students. Students were asked to participate in a computer simulation game involving mathematics problems, and different types of pedagogical instruction. Students who received positive instruction were more likely to do well in mathematics than students that did not receive positive instruction because students who were positively instructed were more likely to have a positive attitude about mathematics.

In this article Kalman (2005) discusses how computer aided instruction (CAI) can be used to give students a more hands on experience in mathematics and science. In this article, written from personal experience Kalman (2005) argues that teaching students to understand concepts such as gravity or number theory is very difficult for teachers because while the teachers themselves may understand the material as if it is second nature, students have not been exposed to the material yet and may not understand it if they cannot work things out and experience them for themselves. Kalman (2005) discussed a CAI programme that he developed for advanced studies in mathematics and science at the middle and secondary school levels and how it affected the understanding of the students in his classroom. This discussion centred on issues like the development of the programme, integration with curriculum and development of appropriate teaching aids, and focused on the development of individual achievement levels for these students.

Teacher involvement is highly important to the overall effectiveness of the student achievement level. Stippek, Given, Salmon and MacGuyvers argued that the attitudes a teacher has about what mathematics is about and whether understanding concepts or getting the answers right is a powerful influence on how well students do in primary level mathematics. They hypothesised that teachers who were focused upon the importance of understanding the theoretical and mechanical aspects of mathematics rather than on merely getting the answers right were more likely to have students that did well in mathematics. They surveyed 21 teachers who taught at the fourth through sixth grade levels and found that this hypothesis was supported. Teachers who rated understanding as being more important than grades and passing tests were more likely to have students who were motivated to learn and do well in mathematics. Teachers who focused more on grades, standardised test results and getting the answers right were more likely to have students who do poorly in mathematics.

Stavin and Lake argue that it is not whether or not a teacher uses the latest mathematics textbooks, or the latest computer aided instruction software in their classrooms. It is the quality of the teaching that occurs that makes the difference in motivating and encouraging students to do well in mathematics. In a review of the latest research on mathematics education they found that textbooks had little or no effect on whether or not a student was likely to do well in mathematics. Computer aided instruction (CAI) had a mediocre effect in that some students did well, other students did not do quite so well. Students exposed to high quality teaching however; were more likely to do well in mathematics class, and more likely to be motivated to learn than students who only received CAI or the latest textbooks.

Identified Success Factors in Integration

Ertmer (1999) identified barriers to successful integration of computers into the classroom as a combination of first-order challenges and second-order challenges, each of which would need to be addressed separately in order to be effectively overcome. First-order, or external, barriers include technological and knowledge and skill barriers – for example, placing computers in classroom or creating computer labs with sufficient access and training teachers to effectively use the computer provided (Ertmer, 1999). These challenges can be overcome relatively easily simply by application of sufficient funds and provision of training. However, second-order barriers, or internal barriers, which include barriers such as teacher self-efficacy, perception of the place of computers in the classroom, and pedagogical techniques that do not allow for ready adjustment of the curriculum, are much more difficult to overcome. A later study demonstrated that while teachers all experienced first-order barriers within the school environment, the way the chose to process these constraints depended strongly on second-order barriers such as perception of the importance of technology (Ertmer, Addison and Lane, 1999). For example, teachers that viewed computer use as a supplement to the curriculum did not consider the constriction of computer resources that first-order barriers imply to be a significant problem – in many cases these teachers only used the computer resources as a reward in the classroom, and did not address more than the mandatory parts of the curriculum with the computer (Ertmer, Addison and Lane, 1999). In contrast, teachers that used the computer resources available to support the existing curriculum or as an integrative part of an emerging curriculum tended to consider first-order barriers to be considerably more challenging and detrimental to the teaching process (Ertmer, Addison and Lane, 1999). This model assumes that first-order and second-order challenges, even though they are nominally separate, are in fact integrated into each other in a feedback mechanism that can result in increasing perception of the challenge involved in a first-order barrier. Ertmer (1999) provided a framework for overcoming second-order barriers that tied the effective addressing of these barriers to the first-order barriers that must be overcome first (for example, addressing perception of the place of computers within the classroom during the training session).

Specific skills for technology integration have been identified. One study that identified computer competencies for teachers identified two general groups of computer competencies required for teachers, as well as a grouping of discrete skills required for the integration of technology into the curriculum (Scheffler and Logan, 1999). Table 3 describes the most important of these three groupings (because the category of discrete computer skills had 34 skills ranked important or very important, this list has been truncated to only the five most important skills listed). However, the full list should be considered to be important skills. These skills will be used in assessing teacher skills and attitudes.

Basic understanding of computer operations	Evaluation and assembly of computer system for instructional use	Using software in instruction
Knowledge of impact of computers on society	Knowledge of impact of computers on society as relating to students	Using computer for instruction, as instructional medium, as problem solving tool
Operation and maintenance of computers at a home or business level	Development of plan for using computers in instruction	Using computer to individualise instruction and increase student learning
Development and execution of personal plan for computer competency	Implementation of plan to integrate computers into curriculum	Using computer technology to help students develop higher-order thinking skills
	Using computers in classroom management	Develop lesson plans using computers for instruction

Table 3 Skills for Technology Integration (Scheffler and Logan, 1999)

Another, simpler view of the use of computers in education identified eight keys to successful integration of computers into the curriculum. The eight areas of integration success focused on the teacher, rather than the structural level; they included overcoming fear of change, attaining training in computer basics, engaging in personal computer use, learning teaching models for computer use, maintaining a learning based focus, offering a climate of encouragement, and attaining motivation and support for the integration throughout the organisational structure (Bitner and Bitner, 2002). As can be seen, while Scheffler and Logan (1999) took a skills-based approach to the issue of construction of knowledge, Bitner and Bitner (2002) focused primarily on an attitude-based approach instead. Integration of the skills and attitudes approaches of these two authors would be more appropriate than either approach in isolation, as it would address both the first-order and second-order concerns as described by Ertmer (1999).

Integration of technology into the primary classroom

Along with focusing more upon Inquiry Based and Constructivist Approaches to teaching mathematics and science, many schools at the worldwide level seem to working to integrate technology into the classroom. According to Blubaugh (2009) this presents a challenge that is twofold. First, countries, districts and cities must educate their pre-service educators to understand new technology and to become familiar with using it in a classroom setting. The second challenge is that for economically unstable nations is coming up with the funding to afford the advanced technology that integrating technology into a primary school setting requires as this often includes upgrading schools for electrical power and internet service.

The use of technology however; is critical. Children will not only be able to access a wider variety of learning techniques in the fields of mathematics and science but, they will learn skills that will help them in the adult world. According to Schmidt, Kohler and Moldenauer (2009) a computer programme designed to help students learn algebra has been quite successful in German secondary schools. In a study of Grades 11 and 12 in 8 German Secondary Schools the authors found that students who used the algebra programme demonstrated better performance than students who were not supplementing their algebra class with the Computerized Algebra System (CAS) in 70% of the schools tested and were doing equally as well as other students in 30% of the classrooms tested. This indicates that the majority of students who supplement their traditional classroom instruction with the use of computer programs, and other media designed to supplement their curriculum tend to do better in class than students who merely attend the class and listen to the teachers.

How well technology is integrated into the classroom is dependent to some extent on how teachers and administrators attitudes about the uses of technology in the classroom. This is often determined during a teacher's pre-service teaching years while they are still attending University or Teachers Training Programs. According to Cheng Yao-Lin (2008) many teachers are not familiar with the uses of computer-based technology in learning and teaching science and mathematics because they themselves are not comfortable with computer technology. Yao-Lin hypothesised that teachers that were exposed to, and who became comfortable with computer based learning technology during their pre-service teaching years would be more likely to use it in the classroom. Yao-Lin (2008) studied 97 college undergraduates majoring in Education. Forty-seven students were exposed to web based programmes in mathematics and science. The other fifty students did not receive any exposure to the programmes whatsoever. In a survey of the student performed after the use of the web based learning programme Yao-Lin found that undergraduate education majors who were exposed to the web based programmes had more positive attitudes towards the use of computers in the classroom than did the pre-service teachers that were not exposed to the web based programs.

Another way in which use of computer technology in the classroom is important is because it makes learning fun for the students. When students enjoy a learning activity they are more likely to do well in it. According to Sedig (2008) the use of computer based mathematics games in the primary classroom encourages students to learn and teaches them to not be afraid of mathematics. In a study of 58 students in a Grade 6/7 middle school classroom in Canada Sedig (2008) found that students who were exposed to a computer based Tangram Game were more likely to enjoy mathematics (specifically geometry) and were more likely to do well in mathematics classes than students that were not exposed to the program. Much like with the implementation of new teaching strategies or hands on learning experience, the implementation of instructional technology is difficult for school in poorer areas of the world. According to Wycliffe and Muwange-Zake (2007), these economically disadvantaged school systems experience further difficulties when they finally do receive the funding for computers and other technology for school. This primarily results from the fact that neither the teachers nor the students have much exposure to computers, and that unfamiliarity with the technology may lead to educators being unwilling to use it in the classroom. In this paper the authors focus on developing an evaluation programme to help

Teacher training and practice

Examination of student teachers' use of information resources and the Internet in order to seek out computer-based solutions to mathematics teaching problems reveal that few students use these resources in order to improve their understanding of teaching and pedagogy problems (Betne and Castonguay, 2008). One study in a United States community education programme demonstrated that few students from the programme sought out information from the Internet or deliberately sought out computer-based solutions to teaching problems and challenges (Betne and Castonguay, 2008). Students also were not likely to use other resources, such as library resources, in order to find answers to their questions unless specifically directed to do so during the exercise from which the answers were derived. Of those that did use the Internet or other information resources, the majority used course-related resources or online textbooks rather than seeking out their own resources (Betne and Castonguay, 2008). This may be a problem for the teachers of students in the primary levels, but it may also be an issue for children being taught, who may not be inclined to seek out resources other than those given to them when allowed access to technologies in order to improve their learning experience. The authors recommended using student multimedia projects, online communications, and Web-based inquiry to drive assignments and create a more complete understanding of the use of computer and Web resources for development of mathematical skills (Betne and Castonguay, 2008). While this learning approach is intended for a more advanced level of student than the primary level being discussed here, it could be modified in order to allow for use within the age group when constructing an appropriate model of curriculum inclusion.

One of the dichotomies involved in mathematics teaching is the different perception of the teacher as the "sage on the stage", imparting specific wisdom and knowledge from a central and remote location in a teacher-centred format, or the "guide on the side", where teachers act as guides for the development of student performance and direction of interests (White-Clark, DiCarlo and Gilchriest, 2008). The first method of teaching is associated with the traditional understanding of mathematics as a fixed practice and the role of the teacher as passing on the formulae and processes that allow this mathematical knowledge to be passed to the students. The second is associated with the non-traditional approach, in which students are led to discover and understand the mathematical concepts they are being taught rather than simply taught by rote (White-Clark, DiCarlo and Gilchriest, 2008). As the authors pointed out, which path is taken depends largely on the experience of the teacher in learning mathematics in school, rather than in post-educational training or during the pre-service training process. Because of this, it is important that the development of views regarding mathematics should be considered to be a long-term process rather than an immediate process.

There are supplementary mathematics instruction methods that can be used to improve the performance of individual learners. One study examined the use of additional 15-minute periods of mathematical instructions for children with and without learning difficulties in a small-scale study (Tournaki, 2003). Pre-test and post-test methods were used to determine the effectiveness of two methods of supplemental instruction, including drill and practice and problem solving strategies (Tournaki, 2003). This study found that in the group with learning disabilities, the strategic problem solving method (a minimum addend strategy) proved to be effective in improving performance in one-digit addition exercises (Tournaki, 2003). The group without learning disabilities experienced improved performance outcomes when receiving both the drill and practice and problem solving strategy supplemental instruction (Tournaki, 2003). This could be useful in improving performance with computer-based use due to the ease of incorporating both methods of teaching into computer-based instructional methods.

Ongoing development activities

One specific issue that is involved in this study revolves around the professional development of teachers, which will be a significant component of the research (training to use the computers effectively, for example). One study focused on professional development practices and types (including immersion, examining practice, curriculum implementation, curriculum development, and collaborative work), the development of professional practice, and the impact on students' mathematical achievement that was observed through each of these methods (Huffman, Thomas and Lawrenz, 2003). The research, which focused on middle school science and mathematics teachers, examined the effects of these professional development programmes and instructional practices on the achievement of students on tests based in the same age level as the TIMSS 8^{th} grade tests (Huffman, Thomas and Lawrenz, 2003). The results of the study indicated that only curriculum development programmes actually had an effect on the student achievement outcomes that were seen. Curriculum development, which "involves having teachers help create new instructional materials to better meet the needs of students (Huffman, Thomas and Lawrenz 2003, p. 302)," will therefore be the main goal of the teacher development practices used within this study. However, there will also be secondary attention paid to curriculum implementation, which is "having teachers use and refining the use of instructional materials in the classroom (Huffman, Thomas and Lawrenz 2003, p. 302)," will also be used in order to build efficacy at implementing the computer programmes and supports used within the classroom. This will allow for the most complete implementation of the computer programme chosen for use within the classroom and will allow for the highest degree of development of the students' learning capabilities.

It is possible to work with teachers in order to change teaching practices and implement the practices identified as positive in the training of teachers into the classroom, as well as to shift practice into beliefs about mathematics teaching rather than preformed beliefs about mathematics itself (Brewer and Daane, 2002). For example, Brewer and Dane worked with a group of teachers that exhibited a strong awareness of constructivist methods and practices within their interviews, but were not using these methods visibly in the classroom. The researchers worked with the teachers through observation, co-teaching and other methods in order to identify opportunities for co-teaching and bring the teacher's teaching practices back into line with their beliefs about constructivist teaching methods (Brewer and Daane, 2002). Although this research was done specifically using constructivist teaching methods, there is no reason why it could not be applied to other teaching practices and methods as well. Thus, the attitudes of the teachers regarding computer use within the classroom will be assessed at the beginning of the research, and classroom support will then be used to encourage the realisation of these attitudes (assuming they are positive attitudes) in the development of practices that will be used to support this research.

Classroom enrichment activities

Enrichment activities have been positioned as one way to close achievement gaps between individuals with poorer performance in the classroom and those with better performance (Beecher and Sweeny, 2008). Beecher and Sweeny (2008) examined this issue from the perspective of a poor-performing United States school that had fallen behind in educational achievement requirements. The authors examined the use of differentiated curriculum, in which students are offered work tailored to their individual achievement levels, and enrichment exercises for all students, in order to improve achievement (Beecher and Sweeny, 2008). The authors noted that this method of curriculum improvement resulted in not only improved school-wide performance improvement, but also a narrowing of achievement gaps between groups of students, which improved the overall performance of the school as well as individual members (Beecher and Sweeny, 2008). The divisions that Beecher and Sweeny (2008) focused on were ethnic group differentiation and gaps between rich and poor students, which could be applied to Kuwaiti schools; gender gaps would also be appropriate focuses for the improvement of achievement of students in relative terms.

Standardised testing

Preparation for standardised testing is important, as noted below. This issue will also be important for this research due to its reliance on pre-testing and post-testing of students in order to determine how well the students have improved their achievement levels due to the introduction of the testing process. However, it is also important to balance preparation for this testing with appropriate levels of outside preparation that focuses on skills that are not directly related to test preparation (Volante, 2006). Volante identified three areas of concern regarding standardised test preparation, including the amount of time spent on test preparation, the content of the preparation instruction, and teaching test-taking skills to students. The author noted that the amount of time to spend on test preparation was often problematic for teachers, who may not have clear guidance regarding the relative amount of time to spend in each subject; although this may be determined through consensus practices in staff meetings, it still remains difficult to determine what the appropriate ratio of time spent on this preparation should be (Volante, 2006). Although the author stated, “Test preparation time should never come at the expense of non-tested subject matter, even when a significant number of students and parents approve of this instructional shift (Volante, 2006, p. 132),” realistically the use of this solution may not always be possible as it is also not possible to extend the school day in order to account for the time required to engage in standardised testing.

The issue of item-teaching or “teaching to the test” is also problematic when considering standardised instruction methods (Volante, 2006). In this teaching method, teachers use their knowledge and preparation for test materials in order to target specific knowledge areas (even specific questions), which will be included on the test, and focus on these areas of knowledge when teaching students (Volante, 2006). The research shows that while this may improve students’ performance on the tests, it weakens their domain-specific knowledge due to lack of understanding of the bigger picture in the subject, and reduces the potential that they can react to a novel situation (Volante, 2006). Thus, the author recommends that curricula should not be modified in order to account for the specific criteria of a given test; instead, the focus should remain on the set curriculum and test materials should be emphasised as a means of improving instructional goals rather than directly improving test scores. Finally, the author noted that most test-taking strategies had been rejected as illegitimate; for example, one strategy that trained children to scan multiple-choice questions for a reading question led to lack of understanding of material the children had read (Volante, 2006). However, some test-taking strategies, including reading and following directions and awareness of common test question structures (such as multiple choice and fill in the blank) do improve children's test taking success, and thus these are the issues that should be focused on for test preparation (Volante, 2006). Another issue that should be addressed is children's anxiety and fear of academic failure, which can dramatically decrease the overall effectiveness of the testing process. These recommendations are unlikely to be implemented into the larger standardised testing culture in the Kuwaiti school system at this time; however, on the small scale they can be implemented within the subject classrooms of this study in order to prevent not only excessive focus on the testing material, but also avoidance of prejudicing the results.

Instrumentation and Measurement

A number of instruments have been identified that can be used within this study to examine issues involved in teacher training and learning, student assessment, and other factors. Table 4 provides a brief synopsis of the identified instruments. However, it should be remembered that the use of these instruments must be considered carefully; due to the construction of testing instruments according to a specific cultural context, these instruments may not reflect the true performance, but instead may be skewed by the cultural differences (Bealer 2000).

Instrument	Brief Description	Target Subjects
Computing Concerns Questionnaire (CCQ)	Examines concerns regarding teaching with technology	Teachers and administrators

	(Atkins and Vasu, 2002)	
Teaching with Technology Inventory (TTI)	Determines factors involved in level of comfort with computer use (Atkins and Vasu, 2002)	Teachers
Mathematics Teaching Efficacy Beliefs Instrument (MTEBI)	Examines personal efficacy beliefs in mathematics teaching for pre-service teachers on two sub-scales, including the Personal Mathematics Teaching Efficacy (PMTE) sub-scale and the Mathematics Teaching Outcome Expectancy (MTOE) subscale (Enochs, Smith and Huinker, 2000)	Pre-service teachers
Mathematics Attitude Scales	Intended to examine differences in learning mathematics separated by gender (Fennema and Sherman, 1976)	Students (I believe this may be adapted for use with pre-service or in-service teachers as well)
The Attitudes Toward Mathematics Instrument	Examines student attitudes, anxiety and self-efficacy toward mathematics learning (Tapia, 1996)	Students
Conceptions of Mathematics Scales	(Crawford, Gordon and Nichola, 1998)	Students, teachers

Table 4 Instrumentation and Measurement Tools

Summary

This literature review has provided a clear introduction to the issues that will form the basis of this literature review, including the construction of a theoretical framework and considerations of critiques of this framework, the development of an understanding of the importance of computers in the classroom and development of an understanding of how these issues can be constructed into a classroom environment, a view into the challenges involved in integrating computers into the classroom, and an overview of potential development of instruments or other tools that could be used to determine the efficacy of both students and teachers in this discussion, all of which will be used to construct an understanding of the potential issues involved in the construction of the research process. This was also accompanied by an overview of the current Kuwaiti educational system, its performance and history, in order to understand the current educational structure and history of the research. This information will be used throughout the research in order to determine the direction and understanding of the current research project.

Chapter 3 Methodology

The methodology that was chosen for this research is a quasi-experimental methodology that was thought to be highly appropriate for resolving considerations of this research. It is a method that can be relied upon to not only provide consistent results within the classroom, but also to provide a rigorous understanding of the impacts of computer usage within the classroom in Kuwait and fulfil the requirements of the research effectively. This research methodology was positioned as a means of not only providing theoretical support for a given method of research, but also for creating an understanding of what potential challenges could be faced within this implementation. This chapter presents the methodology for this research as well as identifying challenges and issues surrounding the research that could have impeded the research outcomes. This research project was designed as a quasi-experimental project integrating qualitative and quantitative assessment and observation. This research was designed as a balanced mixed methods experiment intended to elicit information regarding the effects of the involvement of computer technology within the classroom.

Research Philosophy

My research philosophy is a grounding characteristic of the chosen research process and has been chosen in order to fully support the current research requirements and the requirements of the research question. Pring (2000) identified two separate research philosophy traditions within the existing literature. These included the traditional of empirical research, which is based in the conception of educational research as a social science, and the tradition of phenomenology, which focuses on the experience of research as a determining characteristic of its outcomes (Pring, 2000). I believe that the phenomenology approach certainly has value when resolving some educational questions, including building an understanding of the outcomes of the educational research in terms of emotional contexts and issues. However, the current focus of this research is on the observable outcomes of the introduction of computers within the classroom, and as such I believe that a phenomenological approach to this research would not be appropriate. Although the issue of researcher perspective must be acknowledged, because of this an empirical philosophical approach has been chosen that will address the issues involved in the research in a measurable and observable manner that could be duplicated if my work were to be examined by others. This empirical approach will include observation, experimentation, and interviewing, and will be based on measurable changes within the research groups. However, I do acknowledge the problem of the "false dichotomy (Pring, 2000, p. 46)", or the lack of understanding that regardless of the methodological approach chosen for research, my point of view will influence the outcomes of the study. This influence will stem from the impetus to even research the information chosen to the method chosen to research it to the interpretations of the outcomes, all of which will come from my own experiences, viewpoints and consideration of the importance of given issues and contexts. Because of this, it is not the case that I can truly separate myself from the research, but rather that this influence must be acknowledged and discussed in order to demonstrate the precise ways in which my point of view has influenced the research. This will be determined by critical reflection and will be included in the discussion of the research topics.

Research Design

The research design was constructed from the research questions established in order to examine all issues involved in the research subject. The research design included qualitative components (interviewing and classroom observation), quantitative components (pre-testing and post-testing of student achievement), and quasi-experimental components (design and implementation of a computer-based curriculum enhancement programme for use in the Kuwaiti schools). The research process was conducted over the course of a school year within the Kuwaiti school system, with analysis and adjustment of the quasi-experimental component ongoing over time.

Research Question	**Data Collection Method**	**Analysis Method**
1.What are the student achievement effects of introduction of computer-based mathematics teaching methods in a classroom in Kuwait?	Student testing instrument.	Descriptive statistical testing and difference in means (independent t-test, ANOVA).
2. Are there differences in student achievement effects based on student demographic and socioeconomic variables?	Student testing instrument.	Difference in means testing (independent t-test, ANOVA)
3. What challenges are encountered during this introduction, and how can they be	Field notes and interviews.	Qualitative analysis (thematic and narrative)

overcome?		
4. What structural and institutional barriers may be found in the Kuwaiti educational system in the introduction of teaching methods based on computer classroom interaction?	Primary policy data, regulations, and government reports	Qualitative analysis (thematic and narrative)
5. Are the gains in mathematics teaching found in these environments compatible with teacher understandings of the role of mathematics in the classroom and the environment?	Interviews and focus groups.	Qualitative analysis (thematic and narrative)
6. How do the changes in the classroom affect student mathematic perceptions and viewpoints? Is this a positive or negative change?	Student interviews.	Qualitative analysis (thematic and narrative)

Table 5 Research question matrix

Sample

I chose four primary school classrooms at the same level for this experiment. The current student/teacher ratio average within Kuwaiti schools is 21:1, and so I selected two classrooms with an average of 21 students per classroom. These schools were Kuwaiti state schools, and thus the students will be all Kuwaiti nationals. I identified classrooms with new teachers (with less than five years in-service experience) in order to reduce the barriers regarding the introduction of computers in the classroom. Although the goal was to perform an experimental approach (using a control and test classroom), there were not sufficient classrooms available where teachers were willing to participate, so I chose to use an observational approach with a single classroom instead.

These classrooms were selected using a convenience sampling method, which was based on my access to the classroom as well as school administrator (headmaster or headmistress) permission for the research and teacher willingness to participate. I attempted to ensure that all participants were actively willing to engage in the research project in order to maximise the successful outcomes. The control classroom if it was available should undergo the same pre-testing, teacher testing and interviews, and post-testing and demographics building that the experimental classrooms underwent, but not participate in the curriculum enhancement and support activities, in-service training or observational activities. However, teachers in the control group were asked to log when and how they used computers within the classroom (estimating the number of hours and the purpose of the use of the computer in the classroom) in order to determine a baseline of usual use of these computers within the classroom.

Arranging the Study

The process of arranging the study required contacting the school leadership and making arrangements for the study, identifying the resource needs of the school, making arrangements to have these resource needs met, and making initial contact with teachers in order to create a personal relationship with the teachers. This process took approximately one month following the initial identification of the potential schools.

Administrative Arrangement

Three potential schools were identified for the research study. I met with the leadership of all three schools in order to explore the potential for the research study to be conducted within these schools. One school administrator felt that the research would be disruptive for the school environment, and did not wish to have the research done within his school. The other two school administrators were receptive to the research study, and I discussed the potential for the study to be conducted within the school. Ultimately, the school that was selected was the one that had poorer mathematics performance in the lower grades. The school administrator, Mr. B., was very receptive to the research process and actively engaged in the coordination of the study, as well as in the training process for teachers. After final approval for the research study within the school, the research plan was finalised with Mr. B. and the teacher supervisors that would be involved in this research. This took a series of four meetings, during which the arrangements for timing as well as which classrooms would be available for the research. A particular concern in this area was the identification of classrooms that would be appropriate. The school had only three fourth grade classrooms that would be appropriate for the research, and one teacher was reluctant to engage in the research due to discomfort of the teacher with the co-teaching framework. I agreed that the comfort of the co-teacher was paramount to making sure the experiment worked, and so excluded that classroom from the potential choices of classrooms for research. Thus, the choice of two classrooms required the reduction of classrooms from the original research from four classrooms to two. Following a significant number of opt-outs from the study by parents in one classroom, the final classroom was chosen for the study, reducing the scope of the study from four classrooms to one classroom.

In the initial engagement with the classroom, I introduced myself to the students, and then explained the mathematics project that would be engaged in. The students were then each provided with a packet for parents, including the informed consent form and demographic survey, a discussion of the benefits expected for the children (including improved mathematics learning and computer self-efficacy), and a description of the work the students would be doing. Students were asked to return the packets within a week of the beginning of the term. All 24 students were granted permission to participate in the experimental project.

Instruments and pilot testing

The instrument that was used in this testing process was a custom-designed instrument designed to measure the mathematical capability of the students. This instrument is attached in the Appendix (A). This instrument was pre-tested using oversight from three fourth-grade teachers, who adjusted the level of testing and questions identified as appropriate for the students. It was then pilot tested using a group of five students.

> *The major issue in the pilot testing was the issue of test-retest reliability. The pilot testing approach was to split the questions randomly into two groups, and then to give the students each of the two randomly split tests (with a different split for each student, ensuring they each had all questions between one or the other tests. The questions were keyed and double-checked, and students were then given each of the tests two weeks apart. Scores were compared to ensure that they*

were statistically similar between both tests. There were found to be statistically insignificant differences in this test. This test showed that the instrument was appropriate for testing progress of the students over the test period.

Entry interviews, pre-testing and preliminary data gathering

The first stage in the research experiment was gathering data on the classrooms, teachers, and curriculum that will be involved. This included an interview of teachers, pre-testing of the students within the classrooms, preliminary data gathering in order to build a classroom profile, and assessment of curriculum and computer resources available for the students and, if necessary, providing extra resources to the test classrooms in order to allow for the curriculum design to take place.

The process began with open interviews with the teachers and administrators that would be participating, building familiarity and gaining an understanding of the teaching environment within the school and the educational experiences of the teachers. This was then followed by a guided interview used to collect specific information. The teachers were resistant to standard instrument-based testing, and instead data regarding computer and mathematics attitudes and self-efficacy was collected using interviews. Students were then pre-tested in the classroom during a normal mathematics-testing period. Preliminary data collection was performed using counts and observation of students in the classroom, as was assessment of curriculum and provision of further resources. This process is described in detail in the following chapters.

Curriculum and resource assessment

I attained a copy of the standard curriculum for the chosen primary year in order to assess what the learning expectations and expected grade level achievement of the children within that year are. I also ensured that the classroom is equipped with Internet access and at least one computer per five students in order to ensure that the classrooms have the required resources available for success. I determined that if these resources are not available, I would either choose another school or negotiate with school leadership in order to attain these resources for the classroom for the duration of a year. However, this was not necessary, as the first choice primary school did have the available resources.

Teacher interviews and testing

The first stage in the assessment was the interview and assessment of the teachers involved in the experiment. This process was designed to elicit attitudes toward technology, technology comfort, and levels of intended technology use in the classroom over the year. This also included assessment of attitudes toward mathematics (such as whether the teacher believes that mathematics is primarily a formalised logic system or whether it is an experimental or creative system), attitudes towards technology, and experience with technology. This was accomplished through the use of a guided interview process in which I explored a series of questions with the teacher. The questions were be designed using Trochim and Donnelly's (2008) guidelines for construction of interview questions which will help to ensure that the questions are focused, targeted, and do not use leading techniques or other responses in order to lead to pre-determined answers. The teacher interviews were a small-scale instrument, and so the validity and reliability of these instruments cannot be tested using a statistical approach. However, data reliability was safeguarded by maintaining transcripts of the interviews.

Data Preparation and Analysis

The interviews was recorded using a tape recorder and then transcribed by someone other than myself in order to ensure accuracy. The responses to the surveys was retained for comparison at the end of the research.

Student profile

In addition to the teacher profile above, a student profile consisting of basic demographic information was created from a take-home survey that asks up to ten basic questions regarding the student's family life and demographics, including factors such as income level, computers in the home, family attitudes toward mathematics and external mathematics support (such as tutoring). This was intended to identify any issues with socioeconomic differences or the Digital Divide. This was also accompanied by an informed consent form for parents in order to let them know what the purpose of the research is and to ensure that their permission is gained from this research. Any students whose parents did not sign these permission slips would not be excluded from classroom instruction or activities involved in the research (in order to avoid stigmatising the children) but their results will not be observed or recorded, nor would they take the pre-test and post-test assessments. Because parental consent may be required by law and is certainly required by ethical standards of research, this is considered to be an integral part of the research process (Johnson & Christensen, 2010). Johnson and Christensen (2010) have provided a template for a parental permission form that was used in this case. However, in actuality none of the students were excluded from the study.

Data presentation and analysis

Following the attainment of permission the students will then be assigned student numbers (in order to allow for paired-samples t-testing and other means of examination of improvement) and would have their results and demographic information entered into an SPSS data file. The permission slips and information sheets will be tagged with the same number and will then be filed for further reference. Descriptive statistical techniques were used to build an overall profile of students, a profile of students in each class, and an active versus control group profile.

Student Pre-testing

An appropriate instrument was identified to test the students at the grade level to which they are currently achieving (or should be achieving). The test that was chosen must be appropriate for children in terms of age group, expected outcomes, cultural background, and language; as such, it was expected that I may need to modify a test for the classroom in some way (such as translation or adjustment of cultural cues). This was the case, and modifications was applied prior to the pilot testing process. The instrument was also put through pre-testing through expert oversight, where subject matter experts reviewed the instrument and identified potential issues with its structure, suggested improvements, and approved the final instrument for testing.

These tests was administered within the first few weeks of a new term, and was accompanied by any prior preparation or planning for the students in order to ensure that their true level of current capabilities, rather than a test preparation programme, were reflected (Mertler 31). Mertler’s other guidelines for administering and scoring standardised testing will also be followed.

Data preparation and analysis

Following scoring of the standardised test according to instructions I recorded record the outcomes for each student within the student SPSS database and then used this information to build a classroom score profile and across all respondents.

Identification of appropriate computer based tools

In preparation for the in-service training, I identified between ten and twenty appropriate computer-based tools for the age and abilities of the students that can act as curriculum aids or teaching tools for the teachers. These tools included both Internet based tools and programmatic tools that can be loaded onto the computers, and which address the curriculum material in a useful manner. However, the use of free tools was encouraged in order to prevent any further barriers to research. An ideal type of tool that was identified were the N-Rich tools provided by the Millennium Mathematics Project of Cambridge University. These tools were used extensively in the materials.

In-service training #1

The first experimental process was an in-service training with the experimental group teachers. The full in-service training was recorded for later contextual and content analysi. The first half of this training will consist of discussing the use of computers in the classroom, the benefits and drawbacks, and other information as noted above. This discussion was a round-table discussion, where I provided materials including formal materials on the models in use and other information available. This discussion is expected to take one to two hours. I provided information and facilitate the discussion, but the primary goal of this portion of the research was to determine what the teachers currently think and know about the use of computers within the classroom.

The second half of the training session was determining via a consensus process what the goals of the computer training was and how it was accomplished. I encouraged that a small-group, computer as teaching aid approach was used in order to encourage the appropriate development of the curriculum. Specific areas the teachers wish to focus on should also be explored. The teaching and observation process was scheduled and the teachers were encouraged to maintain a set schedule for this teaching process (both to maintain consistency and in order to ensure that I was able to observe the outcomes routinely). Teachers were provided with logbooks in order to log the activities performed for each child, their relative performance (for example, scores, number right, or "leveling up", and other information such as signs of discouragement or difficulty with interfaces).

Observation Cycle #1

The first observation cycle took place over the period of one term. My goal was to observe each classroom for an hour every two weeks during a computer lesson.

The process of observation in the active classroom was as follows. The observation times was identified through coordination with the teacher of each classroom in question, by determining when these teachers was engaging in classroom instruction and computer use of the type desired to observe by the researchers. These observations was accompanied by note taking by myself, and may involve interaction with the children as well in order to observe what they are learning. Following each observation the notes were transcribed and I reflected on the overall progress being seen in each classroom. If necessary, consultations with the classroom teachers were held in order to identify and correct any sources of potential difficulty within the classroom. During these observations, I recorded the number of children who worked on the computer, what types of activities they were doing, how these were related to the curriculum, and any signs of frustration or other challenges that may occur during these activities. I also informally questioned children regarding their experiences and feelings about the computers and whether they feel the use of the computers helps their mathematics capabilities. I also copied each teacher's logbook during this period.

In-service training #2

The second in-service training served as a means of discussing, critiquing, and refining the tools used in the first observation cycle and in identifying any gaps or ways in which the experience could be made better. I examined the notes from the first process and highlighted any particular difficulties, including teacher difficulties and student difficulties, and the teachers brought up any potential difficulties they encountered during this process as well. Following this session, the teachers and researcher brainstormed ways to overcome these difficulties and assessed how well the chosen tools are working and whether they could be better targeted to the students. The teachers and I then resolved an action plan to move forward into the second stage of implementation for the computer enrichment. As with the first in-service training session, I recorded and then transcribed the session in order to provide support for my later analysis. Teachers were provided with second term log books and encouraged to continue taking notes on the use of computers within the classroom.

Observation Cycle #2

The second observation cycle was conducted in the same fashion as the first observation cycle, with me visiting the classroom and observing and participating in computer-based activities, consulting with teachers and students, and assisting in computer based training activities if this is called for. I continued to gather logbook output and update information for each student such as total time spent, score improvement, and other characteristics.

Post-testing and exit interviews

The final stage in conducting the research was post-testing of the students in order to examine improvements as well as conducting exit interviews and perception instruments for the teachers. These processes were conducted in much the same way as the pre-testing and entry interviews, using the same standardised tests and instruments that were used in the pre-testing stage in order to maintain consistency between the processes. Results for post-tests for the children were logged into the children SPSS database, while the teacher results were entered into the appropriate database. Students were at this point be provided with a release slip for their parents that discussed the ending of the study and gathered contact information for any parents that wish to see the results of the study. There was also a final in-service session that allowed for a final discussion of the outcomes of the implementation, identifies any difficulties or high points the teachers had, and gathers their suggestions for improvement of the experience. This data was prepared in the same way that the information above was prepared.

Final analysis and presentation of results

There were two goals to the research process. The first was to identify the difference in mathematics achievement between the control group and the experimental group. The second goal of the research process was to identify particular challenges and difficulties involved in implementing the integration of computers in the classroom.

These two objectives were addressed separately through the analysis and presentation process.

Difference in mathematics achievement

The difference in mathematics achievement between the two groups (the control student group and the experimental student group) was the primary focus of the quantitative analysis and was the determining factor in how successful the integration was. The data for this analysis was identified by the pre-test and post-test factors, and integrate moderating factors such as computer use in the home and external mathematics support. The statistical analysis that was used is a paired-samples t-test, which determined the overall change in the same students over the course of the year. That determined how many of the children in the control group as compared to children in the experimental group experienced a statistically significant score improvement over the course of the experiment. Between-groups tests were used to determine whether the aggregate change in students as dependent on the control or experimental groupings was statistically significant. These results were presented in a standard fashion including tables demonstrating the changes identified, p-value, f-value and interpretation of these results, as well as a final clarification of whether the outcomes are statistically significant or not.

The experience of implementation

The second stage in this research was examining the experience of implementation on the whole, and included examining issues such as teacher involvement and attitudes, the underlying structural and cultural difficulties the experimenter and teachers faced in their examination of the issues involved, the outcomes of the observations and in-services, and what the teachers thought about the process of the implementation and how this affected their views on computer teaching. This process used a narrative approach to outlining issues and challenges, spotlighting particular successes, and discussing the context and changes that took place due to the quasi-experimental methods used by the researcher. The goal of this portion of the research presentation was to highlight how the increased implementation of computers in the Kuwaiti classroom happened in actuality, and what effects and benefits this had on the student population as well as the teachers. As such, a timeline was constructed and features from each of the points along this timeline were examined. This section also used quantitative examination of teacher attitudes and experiences in order to determine whether these changed over time (which was analyzed using paired samples t-tests as noted above). However, it should be noted that the teacher population was so small that even though differences between results could be detected, these results were unlikely to be statistically significant. As such, the results of this analysis were primarily intended for analysis and discussion rather than for true generalised statistical outputs.

Researcher involvement

Presentation of the results included a debriefing on my involvement in the study and an examination of the ways in which I detected any potential biases or difficulties that may have influenced the results. These results were determined through critical reflection on the process (which was conducted throughout the research analysis process through the use of my reflection journal) and were summarised and deconstructed at the end of the results section.

Problems and Challenges to the Research Methodology

There have been a number of potential difficulties with the research that have either been directly outlined or alluded to within this research. In summary, I expected the following difficulties to arise, and had anticipated potential mitigation or removal strategies for these difficulties.

1. I expected it could be difficult to gain access to appropriate resources such as Internet and computer resources. In order to overcome this difficulty I would seek out community, business and government resources in order to provide the required technologies in case the school cannot (or doesn't want to) provide them.
2. I expected that it may be difficult to gain access to the required level of schools for the period of time required. In order to mitigate this difficulty I would use personal and educational connections to overcome the difficulty involved in gaining access to the school. Although I acknowledge a slight loss of full randomness in choice, pragmatically the use of random sampling of students is only rarely possible in educational research and as such this is not considered to be a significant issue in the design of the research.
3. I could have experienced a high degree of resistance from parents in allowing their children to participate in the study. In order to mitigate this possibility I carefully crafted a disclosure and permission form that outlines the importance and goals, emphasises that no personal information regarding their children was kept, and otherwise encourages parents to participate. I will also seek out support from school administrators to overcome challenges to participation. In the worst case scenario, if classroom participation drops below 75%, I would choose a

different classroom for the experiment. In reality this was not necessary as there was no resistance from parents.

Summary

This chapter has given an overview of how the primary research for this dissertation was conducted. This research is based in an understanding that educational research should be shown to be effective in the classroom before it is positioned as an appropriate response to a given research problem. The research design integrates a rigorous pre-test and post-test design with active classroom and teacher training involvement in order to attempt to control the overall structure of the research. The following chapter discusses the findings of the research.

Chapter 4 Results

The process of this research has a complex structure, and because of this, describing the results of the study is also a complex process. The results of the study are focused on several areas: the classroom and in-service experience, the processes that were used for the study, the amount of time spent on the computers by the children, the experiences of the teachers, and the simple statistics of improvement over a period of time. This provides a complex environment to determine what results would be found within the research and how it should be organised. In order to overcome this, the results of the study have been organised chronically, from the beginning process of making contact with the school through the process of implementation of the project.

Identification of Technology Needs

The second step in the coordination process was the process of identifying the resource needs for the school. The school that was chosen had only limited computer resources for classrooms. In common with many of the schools in the region, the school had a central computer lab that was used for classroom computer practice, but did not have individual computers in the classrooms for student use. Although the laboratory was available to classes in theory, it was rarely made use of in practice. Students received less than one hour a month of computer laboratory time in most classes, with some classes rarely if ever using the computer laboratory. Teachers were the primary users of the computer lab machines, and teachers primarily used the computers for classroom management activities (such as grade keeping and lesson plan preparation). These machines were also significantly out of date, which made accessing the Internet at the speeds required to use the Internet-based resources that were identified for the study. There were no computer or Internet facilities located in the classroom.

In order to provide the appropriate technology needs, the classroom that was chosen for the study would need to be outfitted with appropriate technologies, including sufficient software and Internet connections. The administrator and researcher determined that in-class computers would be more effective for the computer-based educational program. The computers that were required were acquired under the school's educational training budget, with the assumption that the computers would be repurposed following completion of the study. I arranged for a donation to cover the cost of Internet connection for the classroom for the time period of the study, in order to ensure that the students could access the Internet for the resources identified.

Meeting with teachers

The final stage in the preparation of the study was meeting informally with the teachers that would participate in the study, describing the context of the study and what the intended goals of the study included, and gaining teacher buy-in to the research project. Although only two teachers (the classroom teacher and junior co-teacher) would be directly involved in the research project, Mr. B and I made the decision to involve the full lower-school teaching cohort in an initial meeting for the research project, in order to introduce me to the school as a whole and to allay any curiosity regarding the research project. This informal meeting took place following the all-teacher meeting at the school, which occurred on a weekly basis. I presented the purpose of the research (being open and up-front about the research and its focus on technology), and offered teachers a prepared handout that discussed the theory and focus of the research. I then answered any questions that came up during the question and answer session that followed. Because my intended goal was to make sure that everyone had full information and buy-in to the research, there was no attempt made to hide the purpose of the research, its scope, or anything else about it.

This first informal meeting was then followed by meetings with the teacher and co-teacher of the classroom, as well as the classroom aides that regularly interacted with students in the classroom. These meetings were not part of the initial research design. However, the teachers that would be interacting with me showed some degree of reluctance to engage in the research, and because of this, I thought it would be a good idea to make their acquaintance more carefully and build trust between the teachers and the researcher. The social interaction did serve to build trust within the school environment and to increase my understanding regarding the school environment. Thus, this was a helpful part of the research process, even though it was not included in the initial research design.

Teacher In-Service #1

Although only one classroom participated in the mathematics learning experiment, the teacher in-service was offered for any of the teachers that chose to participate in the school. Thus was considered as a mean of improving the benefit to the school, as teachers that were not participating in the testing process could use the testing and informational tips as well as the teachers that were participating in the site. A total of seven teachers chose to participate in the in-service training session, which was held in the school computer laboratory. The first stage of the in-service process began with the administration of the teacher survey; this was timed so that their responses to the survey were not influenced by information that would be provided within the survey. The survey administration took approximately 20 minutes.

I then presented approximately 20 minutes of information regarding the use of computers in the classroom and their effects on mathematics learning. This presentation consisted of a consolidation of the information provided within the literature review. Handouts were prepared that summarised this overview and provided a bibliography including the most important or relevant studies that I identified. This was intended to provide all teachers that participated with a background understanding of the importance of computers in the mathematics classroom.

During the next stage of the session (approximately two hours), the teachers and I worked together in order to learn to find age-appropriate mathematics resources and modify them for use in the classroom. I provided a starter list of sites and programmes that provided effective support for elementary level mathematics learning, and also helped teacher use search tools and centralised repositories of links in order to find their own preferred programs. In addition to simply finding the resources, the participants (teachers and researchers) began to use the sites and to analyze how the site content fit with the curriculum in use and the needs and learning level of the classrooms they were responsible for. This process allowed teachers not only to gain a specific list of resources they could use in the classroom, but also to begin to develop self-efficacy in Internet use and computer use in terms of this specific process.

The main problem involved in the use of many mathematics programmes freely available on the Web was language. Although the teachers spoke English fluently, the pupils in the classroom were in many cases only just beginning to learn English, and so the use of written English materials was considered to be difficult for building understanding. However, many of the sites were located in this case. Two approaches were used in this case. The first was using Google Translate in order to translate the contents of the pages from English to Standard Arabic, which was moderately successful. (Although this approach did yield many of the errors associated with machine translation, the elementary level English used on the sites intended for English-speaking children made the translation process earlier). In other instances, teachers developed a translation for the material itself that could be provided for children. Editing Web pages to include the mathematics learning material and the translation was considered, but it was discarded as an approach that would not be effective due to lack of support within the organisation. Only one of the teachers expressed confidence in Web development or design, and she had not learned to work with Java, which made the translation of many of the pages very difficult.

The final stage of the internship, which lasted approximately one hour, twenty minutes, involved in-depth discussion between the teachers and researcher regarding the experience, any thoughts or feelings regarding the intended process, and the difficulties that they foresaw, as well as any technical issues they felt would be important in constructing an understanding of the research. Many of the teachers expressed continued reluctance in using computers in the classroom. Specific concerns that they addressed were the potential that this would be disruptive, that it would not provide appropriate support, and that they did not know enough about computers themselves in order to provide the appropriate level of support to their students. However, most expressed a desire to continue to seek out computer resources for mathematics learning, and a few of the teachers were very enthusiastic about integrating computer-based mathematics training into their classroom teaching. One teacher at a higher level expressed a desire to consider the use of an integrated learning process through having his students access the English-language sites rather than translated sites, allowing them to simultaneously develop English and mathematics skills in this way. Some of the major questions revolved around the validity of teaching methods proposed by the sites. Many of the teachers expressed scepticism regarding the claimed effectiveness of many of the commercial learning sites that were found during the search process, and asked how the quality of the materials and their effectiveness could be independently evaluated. There was no simple answer for this – the materials that were found varied so widely that it was difficult to immediately identify a way to determine the efficacy of a given model. This question was noted for the second teacher in-service, which would take place halfway through the experimental learning process.

The teacher in-service did make one flaw in the research design apparent – the problem of language and translation. Although resources were sought out that addressed the same material in a more accessible language base for the children involved in the study, these resources were not able to be located. As a result, the experiment would have been substantially hampered. In order to overcome this difficulty, I manually translated the materials on the identified resources on a regular basis and stored local copies of the translated versions on the school's internal Web server. These translations maintained the format and applets involved in the learning process, graphics, and other materials, but translated the text to Standard Arabic in order to allow children to concentrate on a single cognitive task, rather than being required to both engage in language and mathematics learning. I did contact site owners and programme owners prior to this modification for use, and received permission for this use of materials in all cases where materials were modified. The issue of correctness of translation was an issue. In order to deal with this issue, I asked two other bilingual speakers of English and Standard Arabic to oversee the translation and point out any errors that may have been made during the translation process.

Teacher Surveys

Although only one teacher participated in the teacher survey, the seven teachers that participated in the in-service all took part in the survey prior to its beginning. This was a useful approach to identifying the attitudes toward technology and computers that were present in the classroom. The seven teachers that took the survey all were teaching at the elementary level, with participants between the first and fifth grades. Table 6 below provides a descriptive analysis of the outcomes of the teacher survey.

Question #	Question	Answer Summary
1	Do you have a computer in the home?	One teacher indicated they did not have a computer in the home. Six indicated they did have a computer in the home.
2	How many years have you had a computer in the home?	Mean number of years was 5.5, with the minimum being 1 and the maximum being 13. The mode number of years of having a computer in the home was 5 years.
3	How much do you know about computers?	The mean score in this question was 3, with a mode of 3. This indicates that teachers do not consider themselves to be ignorant about computers, but do not feel they know a lot either
4	How confident are you with computer use?	The mean score in this question was 3.5, with a mode of 3. Teachers indicated a slightly higher confidence of computer use than they did in their knowledge about computers.
5	What roles are appropriate for use of computers in the classroom?	Marking and grading: 7 Making worksheets and materials: 7 Internet and research: 5 Use by students: 3

		- Word processing 3 - Games 1 - Use as reward 0 - Mathematics practice drills 2 - Mathematics skill building 2 - Literacy teaching 3 - Multimedia 6
6	Which roles for computers in the classroom have you received training for?	Marking and grading: 7 Making worksheets and materials: 7 Internet and research: 7 Use by students: 1 Multimedia 0
7	How much technical support is available for computers in the classroom?	The mean for this question was 1.5, with a mode of 1.
8	Do you have access to computers in any of the following places? For how many hours per week?	- In the classroom: 0% (N=0) 0 computers in this school environment] - Shared lab or resource room 7 - Mean reported use time was 2.5 hours per week - Library or media room 0 [Computers within this school environment are centralised in a central media laboratory]
9	How much do school administrators support the use of computers in the school?	Mean response to this question was 2.3, with a mode of 2. This indicates only a moderate support for use of computers in the school.
10	Which of these attitudes best describes your beliefs about mathematics?	- I believe that mathematics is a formal system of logic: 4 - I believe that mathematics is primarily a practical tool that can be applied to real-world situations: 3 - I believe that mathematics is a flexible way of thinking: 0
11	What type of formal training did you receive in use of computers in the classroom?	5 respondents indicated they received no formal training in the use of computers within the classroom. 2 respondents indicated they had received a small number of seminar sessions during teacher training devoted to questions of computer use in the classroom. On further informal questioning by the researcher, it was indicated that these teachers were some of the newest within the school, having been trained within the past five years.
12	Have you ever used computers for mathematics teaching in the classroom?	No: 6 Yes: 1 This respondent indicated that this experience occurred at a different school. There was no formal training offered on the programme, it was simply provided to teachers as a tool for use in the classroom. He reported that only a few students had significant luck in using the programme effectively.
13	Do you currently use	No teachers reported the use of computers in the

	computers in the classroom for any purpose?	classroom for use with students. However, 5 reported record and grade keeping, communication, and other classroom management tasks, and 3 reported the use of computers for library research.

Table 6 Summary of teacher survey results

The results of this teacher survey indicated that the use of computers in the classroom within this school was nearly non-existent, with no teachers reporting the current use of computers with students (although many did use it for classroom management tasks). The results of this survey also indicated that teachers within the school received very little in the way of technical or administrative support or training with computers, either generally or in terms of specific use of computers in the classroom. Most indicated they did have home computers, and seemed to be moderately confident in their ability to use computers in general. However, there is little indication that teachers in this school are generally confident in the use of computers in the classroom, or that they have been provided the tools and support necessary to do so successfully.

A further potential roadblock that was identified within this survey was the conceptualisation of mathematics within the teacher set. The majority of teachers indicated that their conceptualisation of mathematics was focused on the formal approach, in which mathematics represents a series of logical rules and sequences that should be learned. This is potentially problematic in that the representation of mathematics as a logical system is associated with a conceptualisation of mathematics a difficult or frustrating to learn (Shapiro, 2000). This model of mathematics, known as logicism, could pose a problem for learners of mathematics from the teachers that hold it, because of the idea that mathematics is inconsistent and has no application to the real world. The remainder of teachers conceptualised mathematics using a formalist approach, in which mathematics is seen as a tool for solving real-world problems. This approach holds that mathematics is a logical and consistent system, but that it does not necessarily have any real-world applicability or consistency (Shapiro, 2000). However, none of the respondents indicated an attitude of intuitism, in which mathematics is held to be a flexible and intuitive tool for understanding (Shapiro, 2000). Under another model of analysis, all teachers taking the survey represented a traditional approach to mathematics, while none (including the teacher that would be the main participant in the study) represented a fully non-traditional approach (Raymond, 1997). Because beliefs regarding mathematics primarily stem from the mathematical education that teachers themselves receive, this was somewhat expected given that the main approach to mathematics teaching in Kuwait has been a formalist or traditionalist style for some period of time. However, this also offered the potential for difficulty in conducting the research, as I considered the research to be more effective if the teacher involved was willing to view mathematics as a flexible and intuitive approach. Thus, this was noted one of the things that would need to be addressed within the context of the research study.

The Classroom

The experiment was conducted in a single classroom, due to unavailability of the number of classrooms required within the initial research project. The classroom was a class of 24 fourth-grade boys. This classroom was slightly larger than the average class size in Kuwaiti classrooms, which is a student teacher ratio of 21 to 1. However, this was deemed to be acceptable in the research due to the relative closeness.

The classroom was led by Mr. M., a teacher with four years experience in the primary classroom. Despite the teacher’s recent training, he had not received any significant training in the use of computers, other than a small number of seminars and the integration of computers into the training process. He did not make significant use of computers in terms of interaction with students, but he used computers extensively for classroom management and research, and has used computers in mathematics treatment in his previous employment. The school currently employs him on the second year of a three-year contract. This contract was renewed pending the successful completion of his renewal review.

Mr. M. is assisted in the classroom by a small number of classroom aides, who address specific issues such as working with students with learning disabilities and specialty teaching (music, arts, and language primarily). The school has also allocated an additional aide for mathematics teaching assistance during the period, in order to ensure that the students was able to have individual interaction with teachers and appropriate levels of support. The temporary aide, Mr. Y, will provide classroom supervision services during periods when students are working one on one or in small groups with Mr. M, as well as providing additional support for the small group sessions.

Demographic characteristics for the students were collected during the research process, a part of the informed consent process in which I gained consent for participation form the parents of the students. This included questions regarding economic status of families, age, citizenship, parent’s marital status, and whether or not the students had access to a computer in the home. The 24 students in the classroom shared significant similarities in terms of socioeconomic and other positioning. As primary classrooms in Kuwait are gender-differentiated, all the students within Mr. M.’s classroom are boys, and all are between the ages of nine and ten. The students are also all

Kuwaiti nationals (only Kuwaiti citizens are allowed to attend Kuwaiti state schools, as discussed in Chapter 2). The students were primarily of middle class origins, as they were all from a single neighbourhood that shared a consistent socioeconomic background. Of the students, the majority (83%, N=20) had married parents, while the remainder had parents that were divorced or widowed. Three students in the classroom were receiving additional support for mild mathematics learning disabilities, while five students were receiving additional support for dyslexia or other verbal or language learning disabilities. (One of these students was receiving support for both mathematics and language related learning disabilities, indicating that seven students in total were receiving additional support for learning disabilities). There were no students in the classroom that were receiving support for more extensive language or learning based disabilities. No students in the classroom had significant physical disabilities.

The students in general had a relatively high level of computer access. Of the students, 71% (N=17) had unrestricted access to a computer in the home, while a further 21% (N=5) had restricted home access to a computer in the home or had access to a computer in other contexts (such as at a relative's house or in a public area). The remaining two students did not have access to a computer at home or in the school. The majority of students (N=19, or 79%) used computers at home primarily or entirely under supervision. Of the students that reported access to computers at home or in other contexts (either restricted access or unrestricted access), 59% (13 of 22) had access to educational software or educational Web sites. The types of educational software available varied widely, including typing training software, language and literacy, mathematics, and test preparation software. However, the specific types of software were not discussed. The use of educational software in most cases was not monitored or required by parents, and the parents did not report in most cases how frequently or for how man hours the children used the software.

Student Pre-Testing

The student pre-testing process took place one week after the return of the permission slips. The standard testing instrument consisted of a total of 30 testing questions, each of which was identified as being at the fourth-grade primary mathematics level, although the difficulty level of the questions varied. This variation was deliberate, and was intended to provide for a range of abilities as well as to allow for the same instrument to be used for the process. The pre-testing process took place over a two-hour period, with short breaks taking place in the middle of the session. Tests included materials in randomised order, in order to reduce the potential for cheating on the tests. (Although it was made clear that the test was not going to be reflected in the achievement or their grades, this continued to be a concern because some students indicated they thought that it would reflect on their evaluations.)

Pilot testing and instrument adjustment

The testing instrument questions consist of aggregate items in most cases, and included almost one hundred questions in the full test. Students were not presented with all these items, but were instead presented with only the first half. This would allow for use of the other half of the test during the post-testing process. (The parallel validity of the test was determined during the pilot testing process, which indicated that the two halves of the test were approximately equal). It was also done in response to the pilot testing of the test instrument, which was performed using a sample of five students;

during this process, I noted that children began to lose interest in the test halfway through, and that the responses during the first half of the study were more correct than in the latter; from this evidence, I determined that the test as initially described was too long. The split tests are attached in the testing appendix. In order to ensure that the questions remained consistent in difficulty, a second pilot test was performed, with students taking both tests on different days. The results of questions for both tests were then compared in order to determine whether there were statistically significant differences in correct or incorrect answers on the test using an independent samples t-test. No significant differences in the results were found. (Results are shown in Appendix C) Thus, the pre-test and post-test instruments were considered to be functionally equivalent in difficulty.

Coding Guide and Internal Validity

The pre-test and post-test instruments had a coding guide constructed for each test. The coding guide below identifies the area and SPSS variable that was used for each test item.

Category	Question #	Variable (SPSS Data Set)
Graphical representation	1	graph_1
	2	graph_2
	3	graph_3
	Average graphic score	graph_avg
	Total graphic score	graph_tot
Basic statistics	4	stat_1
	5	stat_2
	6	stat_3
	7	stat_4
	8	stat_5
	9	stat_6
	10	stat_7

	11	stat_8
	Average statistical score	stat_avg
	Total statistical score	stat_tot
Place value	12	place_1
	13	place_2
	14	place_3
	Average place value score	place_avg
	Total place value score	place_tot
Pattern completion	15	pattern
Number order	16	order_1
	17	order_2
	18	order_3
	Average number order score	order_avg
	Total number order score	order_tot
Time definitions	19 (5 categories)	time_1 time_2 time_3 time_4 time_5
	20 (2 questions)	time_6 time_7
	Average time definition score	time_avg
	Total time definition score	time_tot
Addition and subtraction	21 (3 questions)	add_1 add_2 add_3
	22 (3 questions)	sub_1 sub_2 sub_3
	23 (3 questions)	addsub_1 addsub_2 addsub_3
	24 (3 questions)	add_4 add_5 add_6
	25	add_7
	Average addition and subtraction score	add_sub_avg
	Total addition and subtraction score	add_sub_tot
Multiplication and division	26 (6 questions)	mult_1 mult_2 mult_3 mult_4 mult_5 mult_6
	27 (6 questions)	div_1 div_2 div_3 div_4 div_5 div_6

	Average multiplication and division score	mult_div_avg
	Total multiplication and division score	mult_div_tot
Total Score	Addition of all items (each scored 1 for correct and 0 for incorrect)	total_score

Table 7 Coding Guide for Pre-test and Post-test instruments

The marking of the tests involved assignment of 1 point for each correct answer and 0 points for each incorrect answer. Partially correct answers, missing answers, and ambiguous answers were assigned as incorrect. I marked each test using the correction chart, and was then verified by the teacher. The answers were then entered into the SPSS data set and double-checked using a 100% sampling double check. Because there was not a high degree of variability in the demographic and socioeconomic makeup of the class, these factors were not considered during the analysis process.

The final portion of preparation was the identification of internal validity for the test, using Cronbach's alpha and including each of the individual questions within the analysis. Cronbach's alpha represents the degree of internal reliability (representation of the constructs) that can be seen within the model. In this measurement, an alpha coefficient indicates total lack of relationship, while a coefficient of 1 indicates absolute relationship. (Relationships can be positive or negative). Generally, a Cronbach's alpha of .60 represents a figure that is sufficient for exploratory research, while .80 or above is good for confirmatory research. The Cronbach's alpha calculation in this data set indicated an alpha coefficient of .70 for the full data set. This is considered to be sufficient for exploratory or interpretive analysis, and as such this was accepted as a good (although not outstanding) representation of the selected models. A higher Cronbach's alpha would have indicated a higher inter-item correlation and internal validity for the test, making it appropriate for confirmatory research.

The internal validity test also examined the individual constructs or subject areas in order to determine what type of internal validity could be seen within the individual scales. The individual scales that were considered corresponded to the question groups above. Table 8 summarises the Cronbach's alpha for each of these individual subscales, which shows that they have varied levels of reliability based on the outcomes of the pre-test. (Figures would be re-examined following the post-test as well in order to ensure that they remained consistent through the model).

Subscale	Cronbach's Alpha
Graphical representation	.323 (3 items)
Basic statistics	.333 (8 items)
Place value	.398 (3 items)
Pattern completion	(1 item only, Cronbach's alpha not calculated)
Number order	-.349 (3 items)
Time definitions	.079 (8 items)
Addition and subtraction	.419 (13 items)
Multiplication and division	.633 (12 items)

Table 8 Internal validity of constructs for basic mathematics learning

As can be seen, there was not a very strong correlation in intra-scale items; however, given the consistency of the items, this may be due to inconsistency in test taking practice or procedure between students, and the relative lack of practice (as students had returned to the classroom following a break only two weeks prior to the model). Another issue is the relationship between logicity and the correlations, as items that could be addressed using algorithmic or rote memorisation practices were significantly more consistent than those that could not be, or that required interpretation. Full results of inter-item correlation for the individual sub-scales are seen in the statistical appendix (Appendix C, section A). This also includes inter-item correlation for the subscales, including both average and total scores. (Unsurprisingly, the results of both these items were consistent).

Descriptive Results

Each of the items was subjected to descriptive analysis, including mean, median, mode, and quartiles. A summary of these variables (including the average and total variables) is included in the table below. Full descriptive statistics for each of the individual items is included in the statistical appendix (Appendix C, Section B).

Variable (Category)	Mean	Median	Mode	Std. Deviation	Min	Max
Graphing and Representation Average (graph_avg)	0.5139	0.6667	0.67	0.3257	0	1
Statistics Average (stat_avg)	0.5208	0.5	NA	0.21388	.12	1
Places average (place_avg)	0.7222	0.6667	1	0.30561	.33	1
Order average (order_avg)	0.7222	0.6667	0.67	0.23399	.38	1
Time average (time_avg)	0.7396	0.8125	0.88	0.1645	.23	1
Addition and Subtraction Average (add_sub_avg)	0.6218	0.6154	NA	0.17263	.17	.92
Multiplication and Division Average (mult_div_avg)	0.6667	0.75	0.75	0.21423	0	3
Graphic and Representation Total (graph_tot) (Max score for this item: 3)	1.5417	2	2	0.97709	1	3
Places Total (place_tot) (Max score for this item: 3)	2.1667	2	3	0.91683	0	3
Ordering Total (order_tot) (Max score for this item: 3)	2.1667	2	2	0.70196	1	3
Time Total (time_tot) (Max score for this item: 7)	5.9167	6.5	7	1.31601	3	8
Addition and Subtraction Total (add_sub_tot) (Max score for this item: 13)	8.0833	8	NA	2.24416	2	11
Multiplication and Division Total (mult_div_tot) (Max score for this item: 12)	8	9	9	2.57074	3	13
Total Score (total_score) (Max score for this item: 51)	32.7917	32	31	6.10758	16	45
Total Percent	0.643	0.6275	0.61	0.11976	.31	.88

(tot_pct)						

Table 9 Descriptive statistics for aggregated results (Pre-test), including average and total scores and percent scores

As can be seen, the average score on the test was around 64%, with the lowest score being 31% and the highest score being 88%. This indicates a wide spread of ability and variation within the results of the study. The histogram below shows the distribution of responses according to percentage correct.

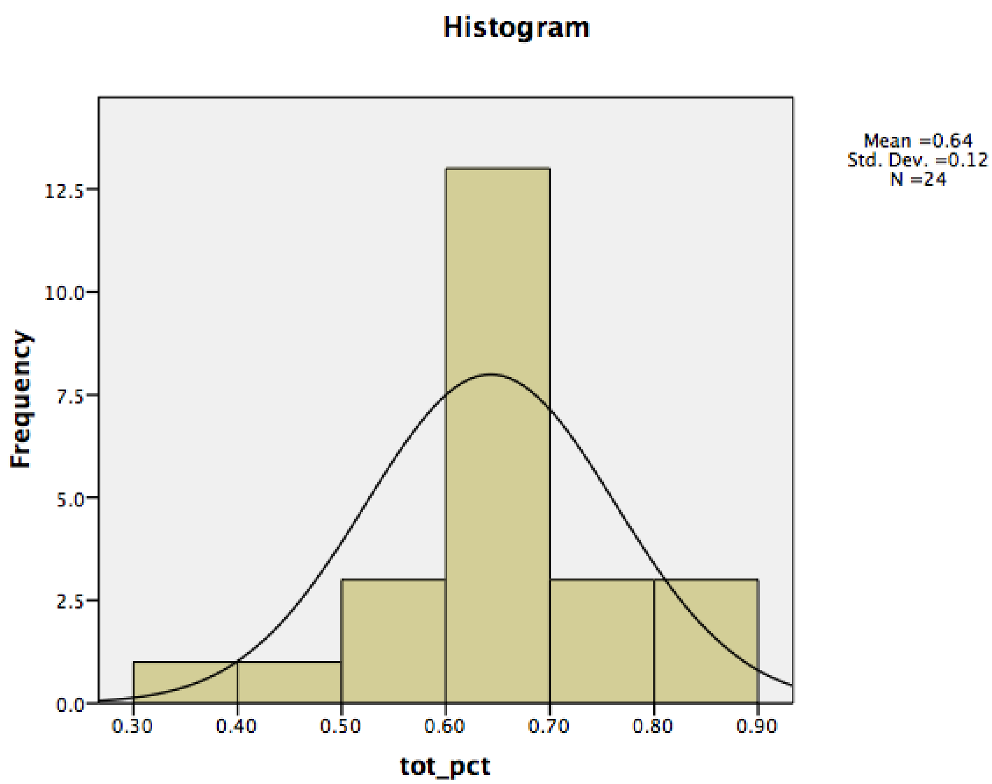

Figure 4 Distribution of percentage achievement on pre-test (Tot_pct represents the total percent correct on each test)

As can be seen, the majority of students scored between 60% and 70% on the test, with a small number of students scoring below 50% and a somewhat larger number of students scoring above 70%. The figure does not represent a perfect normal distribution. However, given the small size of the sample, the central limit theorem cannot be expected to apply;

that is, it is unlikely that the distribution of the sample provides any significant information regarding the distribution of the full population.

Summary

On completion of the pre-test results and descriptive analysis, the process of the observation cycle began. During this six-week period, the researcher, teacher, and supplied aide worked in conjunction with each other in the classroom in order to integrate specific identified computer-based tools for mathematics learning. The process that was undertaken during the observation cycle is described in detail below.

Observation Cycle

The observation and classroom involvement cycle lasted through the middle portion of the term, for a total of around six weeks. An observation schedule was not used because the classroom schedule was somewhat unsettled, and observations were scheduled on a weekly basis. During this time, the classroom would ordinarily have continued with the prescribed mathematics curriculum, which included approximately one half-hour per day of mathematics practice, including formal teaching by Mr. M, the use of worksheets, practice sheets, and quizzes, and the use of homework papers in order to determine the overall level of achievement and to keep the participants on track for the required materials. This process did not vary significantly from the process that was used in the three other classes in the same age period. However, the experiment replaced this process with approximately two to three hours per week of experimental mathematics practice using computer-based software and Internet-based resources. The number of hours varied depending on the student and the resources available, and in some weeks was shortened slightly due to the need to perform other tasks (required by the school). On average, the students undertook 15 hours of additional mathematics instruction over this six-week period. The process of resourcing materials and providing appropriate levels of mathematics instruction was dependent on the student mathematical skill level. Students continued to do paper worksheets one time per week in order to maintain the curricular requirements of the school, and the material that was covered during this six-week period was similar in nature to the material that would have been covered during the traditional non-computer oriented structure of mathematics teaching during this period. This allowed the research to isolate the effects of the computer-led mathematics teaching in a single subject group. Although this is a quasi-experimental method, it was considered to be more effective than attempting to isolate students into computer and non-computer groups within the same classroom. (Although I proposed this approach during the experimental discussion period, Mr. M. rejected the idea, indicating that it was likely to cause difficulty between students, who tend to perceive the use of computer time as a reward for good behaviour. He felt that this could increase or create tensions within the classrooms between students who did not perceive any differences in the behaviour of those that were and were not allowed to use the computers.

Technology resources

The technology resources used in the practice included both visualisation and logical expansion tools and practice drill tools. The use of these two types of tools varied depending on the skill level and confidence of the student, as well as where they showed difficulty in the curriculum-based mathematics learning process.

All students used computers for baseline skills building through the use of practice drills and involvement. The baseline skill drills that were used were provided by a mathematics practice drill programme acquired by the school in preparation for this practice. This mathematics practice drill programme allowed the teacher to set a base level of practice, and then drilled students in an iterative fashion from that level. The programme was adaptive, meaning that as students answered questions correctly, they were given increasingly more difficult questions. Children were rewarded with different levels, like a video game, and were ranked and scored in a competitive fashion. (Different levels of achievement offered the ability for individuals to compete effectively even in cases where they were working at a lower level, because the programme scored depending on the individual level rather than against each other directly). This programme allowed students to focus on specific areas they were working on in class, or to build development in other areas in some cases. This approach was chosen based on an adaptive, non-traditional approach to skills building, but was essentially focused on a drill-based learning approach to the problem and did not focus on the development of mathematics as an intuitive understanding. In other words, this programme was focused on the development of formalist mathematics skills and application of the skills being taught to real-world situations.

The second set of tools that were used were intuitive mathematics structure building tools, which were intended to promote the use of an intuitive approach to mathematics learning. The main tools that were used in this case were practice puzzles and logic approaches derived from the Cambridge N-RICH mathematics Web site. These puzzles were translated from the English version and stored on the school server for student access. Students were allowed to access puzzles at will, and these puzzles were not selected for the students as the skill drill levels were. Instead, students were allowed to try puzzles at any level from the group selected for the inclusion. A selection of these puzzles is included in the Research Tools Appendix B (these were not the only such puzzles that were used in the classroom, but they were some of the most popular puzzles that were selected by the children). These puzzles were not scored competitively, and children were allowed to work in cooperative groups in order to solve puzzles. For each puzzle that was successfully solved by the class as a whole, one point was given; on the achievement of each 100 points for the class, the children received a small reward. This process was intended not to improve the skills that were being directly worked on, but instead to improve the use of collaboration, intuition, and a sense of enjoyment in the use of mathematics. In many cases, these activities also included the use of other tools, such as paper, scissors, counters, and other manipulative tools, in order to provide the full benefit of the interaction. Students were encouraged to select these activities depending on their own interests and their own self-efficacy levels.

Classroom Practice and Management

The division for most students between skill drills and intuition building exercises was approximately even, although this depended on the skill level of the student. Students that were further behind in the development of skills, or who worked at the skills building exercises slower, did have less time for the intuition building exercises. In other cases, students completed their drill work very rapidly, and were not required to spend extensive amounts of time involved in this process. This did allow for different levels of involvement in each of these areas for students. Standardising the amount of time in each activity was considered, but the teachers and I thought that this would lead to either boredom on the part of more advanced students or frustration on the part of less advanced students, and so was thought to be inappropriate to the goal of improving individual mathematics performance over baseline levels. However the, teacher, the classroom aide, and I did make sure that no student had less than an hour of the intuition building exercises, and that each student had at least half an hour of skill drills. Average time for each student in drill-based work and intuition-building exercises was recorded on a weekly basis. The specific activities that were performed by each student was also recorded, in order to make sure students were making forward progress and in order to identify any challenges that students began to encounter.

Students were divided into groups of eight on a weekly basis, and were assigned three one-hour slots for computer time. Students were assigned to different groups each week in order to allow them to engage with different students during each weekly session. This resulted in a total of nine hours per week of classroom involvement for the researcher. During these involvement periods, the classroom aide maintained control of the main class, while the classroom teacher and I provided one on one involvement for students when needed. This involvement included going over concepts with students, providing guidance and support, and observing the student's progress and talking to them about the process of learning. The estimation of how much time each student would need to spend on skill drills was considered to be the primary scheduling concern in these sessions, as each student required his own computer in order to complete these drills. The teacher and I attempted to schedule students in order to ensure that they could complete the drills by the end of the second session, reserving the third session for group and individual intuitive work and games. This was intended to provide a sense of anticipation as well as to provide an organised time during which all the children within a study group could engage in the intuitive gaming sessions, many of which were cooperative games. This allowed individual students to cooperate in skill building as well as learn to work cooperatively, allowing students at different skill levels to work together.

Staff Meeting and Debriefing

The sessions concluded each week with a half-hour meeting the aide, teacher, and me. This meeting was intended to discuss the learning process in the classroom, resolve any difficulties with the learning process, and determine what changes would need to be made over the following week. This weekly meeting allowed for discussion of individual student needs as well, and the participants could identify the require changes in the classroom environment that would be needed to support each individual student. One particular reassessment that was made by the teachers and me was whether each student was working at the correct level. On a weekly basis, the level of achievement and observed frustration of each student in regard to the skill drills was assessed. If students were completing their skill drills rapidly and with a high rate of accuracy, the difficulty level on the skills was increased or new material was opened. In the case of a few students, the amount of time required for the skill drills was reduced, because the students reached the top level of the computer program. These students continued to receive the three hours additional mathematics instruction using computer sources, but were assigned an increase amount of time using the NRICH intuitive exercise models. In contrast, if students were showing signs of frustration, or if they were not achieving the majority of their skills questions, the skill drill level was lowered in order to allow students an increased level of achievement and to provide students to develop their skills at the more appropriate level. If students were struggling to complete their skill drill exercises during the week, the time they are assigned to complete these drills may also be increased. Other issues that were discussed in these meetings as well, including the selection of new intuitive mathematics problems, potential new sources for these problems, and difficulties that each of the participants was having during the process. Wherever possible, challenges and difficulties faced in the classroom were resolved either immediately or during the meeting, in order to keep the project on track and improve the outcomes on a regular basis.

Student Interviews

The most significant finding that came from this portion of the research, in addition to the practice of refinement as well as the use of specific models, was the feedback provided by informal student interviews during the weekly sessions with various students. I attempted to spend at least 20 minutes in aggregate discussing the experience of mathematics learning and their views of mathematics learning with each student. The focus of these interviews was on the experience of mathematics generally, but it also included the use of computers in the classroom and whether students felt that this experience enhanced their ability to learn mathematics. A selection of student comments has been identified, regarding specific issues of concern to them. These included computer self-efficacy, their understanding of mathematics and self-efficacy regarding mathematics, their views regarding the use of the skill drills and intuitive exercises, and the experience of the computers in the classroom.

Most students expressed a level of computer self-efficacy that was consistent with my expectations, given their level of access to computers. Most of the students indicated that they felt comfortable using the computer for tools such as game playing, email, and

Internet searches (although Internet self-efficacy was relatively low in this group, possibly due to the supervision of students while using the Internet. Students also indicated that their use of Internet was restricted at home in many cases, such as through the use of filtration software or other means (a fact that was not reflected in the parental surveys, due to the lack of specific questions regarding the use of filtration software). Students generally felt confident regarding the use of computers, and few indicated that they had any need for further training on software or computers. A selection of comments regarding the use of computers is provided below. (The children have not been identified, in accordance with the agreement that I provided to the parents. The names included are fictitious names assigned to each child for ease of identification.)

Child's Name	Age
Abdullah	9
Bahir	9
Esmaeel	9
Faisal	8
Fahim	9
Farid	9
Hakim	9
Husam	9
Halim	8
Mahir	0
Riyad	9
Samir	10
Salman	9
Tamir	9
Umar	9
Zaki	9

Table 10 Names and ages of children discussed in the interviews (Children that did not have feedback offered in the interviews are not included. All children in this classroom were male.)

- *Computers are not difficult, I use them all the time at home. (Abdullah)*
- *I use the computer at home for email and games. (Faisal)*

- *I have my own computer, and I can use it any time I like, but there are some things I can't do. I'm not allowed to use the Internet on my own. (Samir)*
- *I can usually figure out what I want to do on a computer, but I don't use it for much besides games. (Riyad)*

Most of the students had similar expressions of self-efficacy. Overall, students did not show any difficulties in using the computer or in navigating either the standalone programme or the other activities.

The second issue that was addressed in these interviews was mathematical self-efficacy of the children and their conceptualisation of mathematics. Children were asked questions regarding how confident they are in mathematics, as well as how they view mathematics. Like their teachers, children were about evenly split between a formalist and logicist view of mathematics. Most students expressed only a moderate level of mathematical self-efficacy, which did not reflect a great deal of either confidence of or enjoyment of mathematics. Only two students admitted to actually liking mathematics, while the remainder of students seemed to regard it as something that had to be done regardless. A selection of comments regarding this issue have been provided below.

- *I don't really feel like I understand mathematics. (Abdullah)*
- *My mother tells me that I will need to know maths as an adult, but I don't see why I would need to. Maths doesn't seem to be important to adults either. (Farid)*
- *Mathematics rules are confusing and I don't see how they are made. (Riyad)*
- *I am not good at mathematics. (Samir)* [Researcher note: The student that made this comment was actually in the top quartile of the class in terms of average

mathematics scoring, indicating a disconnect between perceived mathematics self-efficacy and achievement]

- *I like it when we use real problems in mathematics. (Hakim)*
- *I like geometry but not mathematics. (Tamir)*
- *I like mathematics and feel like I understand it. (Zaki)*
- *Maths is like, one of those things that grownups make you learn, but I don't feel like I use it. (Esmaeel)*
- *I don't really think anything about maths – only in school. (Salman)*
- *I really hate maths. It makes me angry, and I don't understand it. (Halim)*
- *I like math puzzles but I don't like the worksheets we do. (Faisal)*

These discussions indicate that students have a relatively low level of mathematical self-efficacy and do not have a strong liking for math. Although a few students expressed confidence for mathematics and enjoyment of it, most of the students had ambivalent or negative feelings regarding the mathematical process. Some of the students approached mathematics in a very negative way, which further increased the impression that they were not fully engaged in the mathematical process. None of the students expressed feelings or thoughts about mathematical learning that could be regarded as an intuitive orientation toward mathematics learning, although a few did express that they enjoyed mathematics games or puzzles, which could be indicative of the development of such an approach. However, as Shapiro (2000) notes, the orientation of their mathematical learning toward logicist and formalist approaches does mean that it is less likely that they will begin to engage in mathematics learning from an intuitive approach in many cases.

The third area of focus was the experience of the intuitive learning and skill drill additions to their mathematics curriculum. Overall, the children expressed more interest in the intuitive learning puzzles and games than in the skill drills (which is to be expected, given the cooperative nature and the “fun” orientation of the games). The overall perception of the skill drills seemed to be more “useful” than “fun”, while students saw the enrichment activities provided as more fun than the others. However, students did frequently report a sense of accomplishment related to the drills, particularly in regard to their structure in “levels” and the public nature of their achievements. A selection of their comments regarding the skill drills, the enrichment activities, and both of them in comparison are below.

- Skill drills:
    - *The drills help me learn the stuff that’s on the test. (Faisal)*
    - *The drills are useful, they help with my homework. (Halim)*
    - *I feel like the drills are testing me. (Riyad)*
    - *The drills are frustrating, they feel like they are too hard and I don’t understand them. I don’t do well (Zaki).* [Researcher note: This student was reassessed and his drill level was adjusted lower due to this expression of frustration, and he had a higher level of achievement during the remainder of the experience]
    - *Moving up a level in the drills is exciting, because everyone can see it. It makes me feel smart. (Umar)*
    - *The drills are just like homework – they’re boring. (Esmaeel)*
    - *I only do my drills so I can do the games too. (Hakim)*

- *I think the drills are helpful. (Abdullah)*
- *My father thinks the drills are helping me with my homework. He's buying me the software for home. (Farid)* [Researcher note: the student did not express whether this was a positive or negative outcome]

- Intuitive and cooperative exercises
    - *I like the puzzles and games, they are a lot of fun (Abdullah)*
    - *The games are good! I didn't think math would make good games. (Zaki)*
    - *I didn't know maths could be used like this. (Fahim)*
    - *The games are fun and getting our rewards is fun too. (Bahir)*
    - *I feel like the games help me learn better. (Esmaeel)*
    - *I taught my sister some of the games and she plays with me at home. (Umar)*
    - *We like to make up our own maths games sometimes.(Hakim)*
    - *We learn from each other. (Husam)*
    - *I don't always understand the games, so I give up easily and try an easier one. (Mahir)* [Researcher note: This was allowed within the scope of the research and was encouraged by the teacher and the researcher, because the goal was to become more comfortable with mathematics as a tool rather than as proof that they could solve difficult problems]
    - *Sometimes I let my teammates do the work in the games (Zaki)*
- Comparison of methods
    - *The drills help me do better on tests, but the games are more fun.(Mahir)*
    - *I wish we did more games and less drills. (Abdullah)*

- *The drills are useful and so are the games. (Husam)*
- *I feel like I have to do well on the drills, but the games are just messing around (Samir)*

Overall, students did see value in both methods, but appeared to consider the games to be more based on entertainment rather than focused on learning mathematics in a rigorous way. The drills were seen as more boring, but of more immediate use (a number of students indicated that they felt more capable on tests because of the computer-based practice drills). The intuitive exercises (which were described to the children participants as “maths games”) were seen as more entertainment, cooperation, or game playing by most of the participants rather than as a serious means of learning mathematics. This is not necessarily counter to the intended result of the study, as the introduction of the intuitive exercises was to engage the participants and help them to develop a more intuitive approach to mathematics rather than to directly teach mathematical logical processes.

The final area of interview focus for the students was the overall impression of the use of computers in the classroom. While this was overall positive, many of the students indicated that the student use of computers in the classroom during the school day was loud or disruptive, and that it was distracting to have the students in the classroom split between two different exercises. This was also a concern discussed during the teacher in-service (discussed below). However, the majority of students did not comment to a high degree on the amount of interaction between students or the affect on the classroom, and no students spontaneously expressed either a positive or negative opinion regarding this.

Teacher In-service #2

The second teacher in-service was performed mid-way through the six-week training session. During this in-service, a short presentation by the teachers involved and me presented the results as observed of the experiment that was in progress to interested teachers. A handout that included the type of information that was being used and the ways in which it was being used accompanied this. A short question and answer session was then used to provide additional information where desired to questioners.

The core of the second teacher in-service session, however, was a closed conference between the researcher, Mr. A (the school administrator), Mr. M (the teacher), Mr. Y (the classroom aide), and Ms. S (the school's curriculum consultant). This meeting was intended to address difficulties that were perceived in the classroom management and the process that was being used in the classroom in order to teach the computer skills and mathematical learning styles that were integral to improving achievement. This meeting lasted approximately two hours, and was built on the weekly debriefing meetings in terms of interaction and development of the program. Overall, the participants expressed satisfaction with the approaches that were chosen for mathematics learning, although there were some suggestions for simplification or improved translation of the N-RICH materials. This improved translation suggestion was not due to lack of consistency in language, but rather in the level of language used, which was sometimes beyond the understanding of some of the students. Thus, a simpler translation was suggested for some exercises.

The main issue of concern in this meeting was the classroom disruption caused by the mathematics lessons. Although all efforts were made to maintain classroom order during this process, it was acknowledged that the group work was noisier than expected and that it posed a problem for other students in the classroom in terms of maintaining a quiet and orderly atmosphere. However, it was determined that the classroom disruption was most noticeable during the final hour per week of classroom instruction for each group, in which the group focused primarily on the group enrichment activities. These activities were often dramatically more noisy and interactive than either the skill drills or the individual intuitive tasks, and there were frequent requests from the classroom monitor (most frequently the classroom aide) to reduce the noise level from these activities. Due to this level of noise, the approach that was taken to reduce the impact of the activities on the classroom was to move the final hour per week of each group's session out of the classroom and into the school media and computer lab. This did reduce the presence of computer use in the classroom, but at the same time, this portion of the activity was negatively affecting the other students, and as such the decision was taken to move the highly interactive group sessions to a separate classroom for one session per week. This reduced the level of noise in the main classroom significantly and allowed students in the remainder of the class to engage in their own activities while at the same time allowing the group work to move forward. Although this solution would not necessarily have been effective in a longer term experiment, as the research experiment was half over it was considered to be acceptable in terms of overall level of risk.

Other issues that were discussed during this session included the progress of the experiment, as well as whether the teachers and administrator felt that the methodology would be a useful permanent addition to the teaching methods in use at that school. However, no decisions were taken regarding this point during the teacher in-service.

Another issue that was discussed was that of the teacher's feelings of self-efficacy regarding the use of computer instruction in the classroom. The teacher, Mr. M., admitted that he felt that he was still not capable of using computers to their fullest capacity, and that this use of computers was actually only relying on student's native computer skills in order to promote classroom learning. As such, he did not think that he was using computers to the fullest extent. However, he was uncertain how to resolve this issue given the relative lack of training available and the need to remain focused on the school's central curriculum, which did not include extensive use of computers in the classroom. He discussed this with the school administrator that was also present at the conference, Mr. A., and explored whether further training would be appropriate. Although no conclusion was reached in this regard, I did provide Mr. M. with further information regarding teaching and computer self-efficacy, which may provide some degree of critical support for Mr. M.

Finally, my interaction as the researcher and the student and teacher participants was discussed. I did not feel he was fully engaging in the classroom and through a period of critical reflection had determined that it was necessary to understand why in order to improve this ability to engage. The administrator and teachers had some good resources and tips for the researcher, particularly relating to classroom management styles and skills, which could be enacted relatively easily. This included speaking to children on their level (rather than from above), and asking questions in more simple language in order to achieve better results. The teachers also provided some other advice in regard to classroom management (particularly, in the ways in which children would be seen to interact with the researcher). I noted the practices as ways to improve direct practice of classroom management.

Student Post-Testing

Following six weeks of my classroom involvement, in which students received an average of 15 additional hours of classroom instruction using computer based instruction, the students were retested using a similar, but not identical, test to that with which they had previously been tested. The test (included in the Appendix A) used the same types of questions as the pre-test, although the figures and situations were different. Testing once again took place over a one-hour period, with a break during the middle of the test. Students were once again informed that this test would not be counted in their grades and would not be assessed, in order to reduce pressure levels for students. However, the tests were once again rearranged into random order in order to reduce the potential for cheating. In short, the tests were given under as close a condition to the original tests as was possible given the classroom conditions. This section discusses the outcomes of the post-testing process, which included analysis of the test-retest validity of the underlying tests (which indicates the external reliability of the test or how well the results can be replicated); the descriptive outcomes of the test; and the means comparisons of the test outcomes.

Test-Retest Validity and Internal Validity

One important issue in this discussion was test-retest validity. This is a particularly difficult issue because the instruments had to be close enough to each other to allow for any changes in results to be seen as the influence of the increased mathematics instruction, while at the same time not allowing students to simply memorise the answers given in the first test. In order to help ensure test-retest validity, the pre-test and post-test instruments were divided, with each test using the same structure, wording, and format but using different actual problems for analysis. This provided students with the opportunity to maintain testing in a familiar environment, while at the same time allowing students to reflect the changes in their performance (if any have taken place). In order to determine this, the Spearman Brown coefficient was calculated. This is an appropriate measure of test-retest reliability due to the conceptualisation of test-retest reliability as a specific type of split-half reliability. (As students were literally given half the test during the pre-test and half during the post-test, this is an appropriate conceptualisation of the model.) (In order to perform this test the data set was manipulated in order to copy the post-test variables into a second set of variables, due to the restrictions of SPSS).

As with the Cronbach's alpha figure used in internal reliability testing, the Spearman Brown coefficient ranges from 0 to 1, with 0 indicating no between-tests correlation and 1 indicating perfect correlation. Cut-offs that are commonly used with this test are .60 for exploratory research, .80 for acceptable levels of reliability, and .90 for good levels of reliability. The full reliability statistics are included in the Appendix C. However, the test returned a between forms correlation of .912, with a Spearman-Brown equal length coefficient of .954 and a split-half coefficient of .890. This indicates that this model has adequate to good test-retest reliability, indicating that it was successful in replicating testing conditions and difficulty levels for students.

Internal Reliability Retest

One of the problems with the pre-test environment was the relatively small number of samples, which led to the indication of only a moderate level of internal reliability according to Cronbach's alpha calculations. This was recalculated in order to determine whether this figure was improved with the increased sample size. The retesting found the Cronbach's alpha to be somewhat improved at .683. Thus, while high internal scale reliability is likely to be out of the range of this test, there is an indication that the reliability was improved due to a higher number of samples.

Descriptive Statistics

As with the pre-test, the post-test figures were had a full set of descriptive statistics calculated, including mean, median, mode, and (where meaningful) minimum and maximum values as well as standard deviation. The summarised table below provides the descriptive statistics for the post-test average and total aggregate scores, as well as the total score and score percent. Per-item descriptive statistics are also included in the Appendix (Appendix C, Section D, Post-test Descriptive Statistics).

Variable	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Graphing and Representation Average (graph_avg)	0.1713	0.2222	0.22	0.10857	0	0.33
Statistics Average (stat_avg)	0.7344	0.75	0.62	0.14887	0.5	1
Places Average (place_avg)	0.7778	1	1	0.28937	0	1
Ordering Average (order_avg)	0.7361	0.6667	0.67	0.24035	0.33	1
Time Average (time_avg)	0.75	0.875	0.88	0.16485	0.38	1
Addition and Subtraction Average (add_sub_avg)	0.6987	0.7308	0.77	0.13782	0.46	1
Multiplication and Division Average	0.7222	0.75	0.92	0.20064	0.25	0.92

(mult_div_avg)						
Graphing and Representation Total (graph_tot) (3 items)	2.375	2	NA	0.6469	1	3
Statistics Total (stat_tot) (8 items)	5.875	6	5	1.191	4	8
Places Total (place_tot) (3 items)	2.3333	3	3	0.86811	0	3
Order Total (order_tot) (3 items)	2.2083	2	2	0.72106	1	3
Time Total (time_tot) (8 items)	6	7	7	1.31876	3	8
Addition and Subtraction Total (add_sub_tot) (13 items)	9.0833	9.5	10	1.79169	6	13
Multiplication and Division Total (mult_div_tot) (12 items)	8.6667	9	11	2.40772	3	11
Total Score (total_score) (51 items)	37.3333	37	NA	4.62194	25	45
Total Percent of Maximum Possible Score (tot_pct)	0.732	0.7255	NA	0.09063	0.49	0.88

Table 11 Descriptive statistics for aggregate variables (post-test scores only)

This indicates that there does appear to be some improvement, particularly in the lower range of achievement within this test. In particular, the minimum score percent has been raised from 31% to 49%, which was a substantial improvement. However, the maximum score was not raised. However, more detailed analysis was performed using the outcomes of the means difference.

Difference in Means

The descriptive statistics regarding the post-test did provide some promising information. However, there is no indication of whether there was actually a change in means between the two sample sets. Because this is the core of the research material, it is necessary to determine whether there was in fact this difference. In order to do so, a number of different methods have been used. These methods include the use of the means comparison, paired-samples t-tests, and ANOVA methods. Detailed statistical outputs for each of these variables is included in the Appendix (Appendix C, Section D. Means Differences). However, the statistical outputs for the aggregated (total, average, and percent) categories was discussed within this section.

The first test was a descriptive comparison between pre-test, post-test, and total means for each category. This provides a view into which of the resulting statistical categories have some higher degree of difference between them that can be seen with the naked eye. The highlighted rows below are those that show a difference of more than .05 between the pre-test and post-test means. (Although this is not conclusive evidence of statistically significant difference in means between these tests, it does provide some insight into which categories experienced some change in outcomes).

	pre-test		post-test		Total	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
graph_avg	0.5139	0.3257	0.1713	0.10857	0.1713	0.1074
stat_avg	0.526	0.21487	0.7344	0.14887	0.6302	0.211
place_avg	0.7361	0.31051	0.7778	0.28937	0.7569	0.29766
order_avg	0.7222	0.23399	0.7361	0.24035	0.7292	0.23476
time_avg	0.7396	0.1645	0.75	0.16485	0.7448	0.163
add_sub_avg	0.6218	0.17263	0.6987	0.13782	0.6603	0.15934
mult_div_avg	0.6701	0.2163	0.7222	0.20064	0.6962	0.20806
graph_tot	1.9583	0.80645	2.375	0.6469	2.1667	0.75324
stat_tot	4.2083	1.71893	5.875	1.191	5.0417	1.68798

place_tot	2.2083	0.93153	2.3333	0.86811	2.2708	0.89299
order_tot	2.1667	0.70196	2.2083	0.72106	2.1875	0.70428
time_tot	5.9167	1.31601	6	1.31876	5.9583	1.30398
add_sub_tot	8.0833	2.24416	9.0833	1.79169	8.5833	2.07142
mult_div_tot	8.0417	2.59563	8.6667	2.40772	8.3542	2.49672
total_score	33.3333	6.0553	37.3333	4.62194	35.3333	5.69932
tot_pct	0.6536	0.11873	0.732	0.09063	0.6928	0.11175

Table 12 Descriptive means and standard deviations differences between pre-test, post-test, and total figures

This shows that the biggest changes are likely to have taken place in the statistics, graphing, and addition and subtraction and multiplication and division categories. Encouragingly, none of the mean scores went down on average, although some did have changes that were not shown to be highly significant. The average total score percent climbed from 65% to 73%, which is a substantial improvement. However, full determination of which variables were significantly improved would need to be performed using another method, such as paired-samples t-tests. (The visual comparison of the means between groups is not indicative of whether these differences are statistically significant).

The paired-samples t-test helps to determine whether there is a difference in means in cases where the means of a given set of statistics cannot be said to be independent. This is the case in this research, because the samples were the result of testing the same children at different points in time on learned knowledge. The children would be expected to be able to answer many of the same types of questions at the same efficacy rate, and thus the samples were not independent. In order to analyze this problem, the secondary data set prepared for internal validation was used (due to the pairing of data samples). Each variable from the pre-test was paired with the variable from the post-test in order to identify statistically significant differences within these variables. The tests were calculated at a 95% confidence level. For individual items, statistically significant differences in means were found in the following variables: graph2, stat1, stat2, stat3, stat7, add2, add3, addsub_2. This demonstrates one of the particular peculiarities of this research – because of the primary units that was undertaken during this time focused on statistics, the statistics group was highly likely to improve over this time.

The table below shows the results of the dependent-samples test for the average and total variables, which represent the constructs that are represented in this test. It also includes the paired-samples correlations for these variables

		N	Correlation	Sig.
Pair 2	graph_tot and graphto2	24	.365	.080
Pair 3	stat_avg and statavg2	24	.396	.056
Pair 4	stat_tot and statto2	24	.396	.056
Pair 5	place_avg and placeav2	24	.824	.000
Pair 6	place_tot and placeto2	24	.824	.000
Pair 7	order_avg and orderav2	24	.873	.000
Pair 8	order_tot and orderto2	24	.873	.000
Pair 9	time_avg and timeav2	24	.952	.000
Pair 10	time_tot and timeto2	24	.952	.000
Pair 11	add_sub_avg and asavg2	24	.831	.000
Pair 12	add_sub_tot and astot2	24	.831	.000
Pair 13	mult_div_avg and mdavg2	24	.914	.000
Pair 14	mult_div_tot and mdtot2	24	.914	.000
Pair 15	total_score and total_score2	24	.880	.000
Pair 16	tot_pct and tot_pct2	24	.880	.000

Table 13 Paired-sample correlations, construct variables

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 2	graph_tot - graphto2	-.41667	.82970	.16936	-.76702	-.06631	-2.460	23	.022
Pair	stat_avg -	-.20833	.20743	.04234	-.29592	-.12075	-	23	.000

3	statavg2						4.920		
Pair 4	stat_tot - statto2	-1.66667	1.65940	.33872	-2.36737	-.96596	-4.920	23	.000
Pair 5	place_avg - placeav2	-.04167	.17890	.03652	-.11721	.03388	-1.141	23	.266
Pair 6	place_tot - placeto2	-.12500	.53670	.10955	-.35163	.10163	-1.141	23	.266
Pair 7	order_avg - orderav2	-.01389	.11955	.02440	-.06437	.03659	-.569	23	.575
Pair 8	order_tot - orderto2	-.04167	.35864	.07321	-.19311	.10977	-.569	23	.575
Pair 9	time_avg - timeav2	-.01042	.05103	.01042	-.03197	.01113	-1.000	23	.328
Pair 10	time_tot - timeto2	-.08333	.40825	.08333	-.25572	.08905	-1.000	23	.328
Pair 11	add_sub_avg - asavg2	-.07692	.09624	.01964	-.11756	-.03629	-3.916	23	.001
Pair 12	add_sub_tot - astot2	-1.00000	1.25109	.25538	-1.52829	-.47171	-3.916	23	.001
Pair 13	mult_div_avg - mdavg2	-.05208	.08796	.01795	-.08923	-.01494	-2.901	23	.008
Pair 14	mult_div_tot - mdtot2	-.62500	1.05552	.21546	-1.07071	-.17929	-2.901	23	.008
Pair 15	total_score - total_score2	-4.00000	2.96355	.60493	-5.25140	-2.74860	-6.612	23	.000
Pair 16	tot_pct - tot_pct2	-.07843	.05811	.01186	-.10297	-.05389	-6.612	23	.000

Table 14 Paired-samples t-tests for construct variables and totals

These results demonstrated that there were statistically significant differences in outcome within the mathematics program. In particularly, the areas of graphing, statistics, addition and subtraction, and multiplication and division showed a statistically significant difference in means between the pre-test and the post-test. Consulting the means calculation, it can be seen that the mean achievement in graphing went from .5139 to .1713, indicating a drop in overall achievement. For statistics, the mean average achievement score went from .526 to .7344, with an increase in the total statistical score of 4.2083/8 to 5.876/8. The variation in addition and subtraction went from an average of 0.6218 to 0.6987, with an increase in total score from 8.0833/13 to 9.0833/13. The multiplication and division average went from 0.6701 to 0.7222, with an increase in total multiplication and division score from 8.0417/12 to8.6667/12. This resulted in a statistically significant change in the total score from 33.333 to 37.333 (from a maximum of 51, or an increase in mean percentage achievement for the full test from 65.36% to 73.2%. Thus, this process can be said to have created a statistically significant change in the outcomes of the test, indicating that the mathematical teaching process that was used by the participants within this experimental process was effective.

Exit Interviews

The final stage of the research was a series of critical exit interviews in which the participants and I discussed ways in which the methods derived by the research could be improve, as well as ways in which they worked well. These interviews included a small number of interviews with the children involved in the research as well as the administrator (Mr. A), the teacher (Mr. M) and the classroom aide that also participated (Mr. Y). The interviews yielded considerable information for the study design efficacy, as well as discussion of how I could improve the outcomes of the testing process. Some of the particular lessons learned that were addressed within the exit interviews included:

- The need to maintain classroom cohesion, either through involvement of the full classroom in the computer-based activities at the same time or through the use of media room or slightly separated classrooms
- The need for a larger number of adult participants in order to ensure that children had access to necessary help. The teachers and I discussed the matter in detail, determining that any fewer than one adult per each four children participating in

the intensive practice drills was too few adults to provide the level of involvement required from adults.

- Children were found to have required more input than anticipated in this research, but not in the expected areas. In contrast to adult participants in the first teacher in-service, children required little or no assistance with the technology, and many expressed a high level of computer self-efficacy and even at times refused assistance with the computer programs, stating that they could figure it out themselves. However, in the intuitive and skill drills, they often were not confident, preferring or in some cases requiring that an adult should explain the required process or thought pattern that would help them solve the problem. The teachers and I agreed that this was due to a lack of mathematical self-efficacy that was expressed by the students repeatedly throughout the process.
- The programmes required more IT support than expected, despite the relatively straightforward programmes that were chosen for use. This was largely related to the need to store translations of the N-RICH intuitive activities in an accessible form by the students. This was considered to be one of the major issues found with the study project, and was not simple to negotiate, given the lack of IT support in general that was available within the school. The overall experience demonstrated that if the school were to continue to use the programme, there would need to be more advanced IT support for the programs, and the school may want to pursue more specific or skilled translations of the materials that were chosen for use in order to improve the program.

- Overall, the administrator and teachers felt that the programme had been mildly beneficial, and that it was a good experiment in using technology. The teachers felt that, despite classroom management problems that were experienced throughout the process, it was a positive experiment in integration in computing. However, the administrator ruled out using the system on a school-wide basis, indicating that there were not sufficient funds for the technology to be implemented in every classroom and that most teachers in the school were not as comfortable with the use of computers in the classroom as Mr. M. However, the school administrator did recognise the popularity and value of the intuitive problem sets on the learning experience and view of mathematics by the child participants, and agreed to leave these resources available in the computer labs and on the school servers for teachers and students that wanted to use them.

The results of these exit interviews were used to form recommendations for further implementation of the programme (presented in the next chapter) as well as to engage in a critical review of the research design. This was discussed in detail below.

Results Summary

In purely quantitative terms, this experiment can be shown to be successful, as six weeks of involvement in the teaching of mathematics to students represented a statistically significant shift in the mathematics test score from a mean percentage score of 65.36% to a mean percentage score of 73.2%. This indicates that students did learn from their experience and that this learning did produce measurable results within the test. However, there were also significant findings in terms of the mathematics beliefs and computational experience of teachers within the school, children's views of mathematics, and the pragmatic aspects of integration of computers into the classroom. Mathematical beliefs of teachers in the school setting were found to be evenly divided between logicist and formalist styles, with no significant influence of the intuitivist belief sets in the teaching environment. This was reflected in the mathematics beliefs of students, which were also informally examined and which can be described as primarily logicist or formalist. The use of computers within the classroom also yielded a number of interesting observations regarding their use, including issues in classroom management and the need to maintain a high level of adult supervision in order to provide assistance not with the computers (the majority of children demonstrated high levels of computer self-efficacy and skill), but with the mathematics portion of the material, which proved to be a struggle for many of the students. Another interesting observation was that the students did not seem to consider the intuitive exercises that were used to be mathematics practice, and instead viewed them as games or puzzles to be solved. The findings that are presented within this chapter are discussed in detail in the following chapter, which addresses the fit of the current research with existing studies as well as providing a critical review of the research design and recommendations for inclusion of computers in the school curriculum at this specific age and environment.

Chapter 5 Analysis

The results of the study above provide an understanding of the bare occurrences that were found within the study situation and the outcomes for students and teachers. However, it does not provide a direct view into how these findings can be situated when considering the existing research, or a critical examination of the potential for bias within this research. The analysis of the research focuses on two different areas. The first area is the critical examination of the research experience, focusing on the researcher's experiences and views as a participant observer in the research area. This also includes a reflection on how effective the quasi-experimental process was, what changes could have been made that may have led to a more effective process, and what worked well about the research process. This allowed for the consideration of the overall effectiveness of methods chosen, which could be used for clear identification of a method to use in other schools. The critical analysis of the study also discussed changes that were made during the study, why they were made, and what effects these changes may have had on the study's outcomes. This analysis was intended to identify what effects may have been different from the intended effects of the study, and whether these changes were detrimental, beneficial, or indifferent to the study's results.

The second area of focus is the outcomes of the study and their relationship to the existing literature. Especially given the pragmatically oriented focus of the quasi-experimental project, understanding the outcomes of the research means understanding how it meshes with the existing literature on the material. This section focuses on discussion of what differences and similarities were seen within this research and how it can be situated within the wider body of the research. In particular, situation of the research outcomes within the context of constructionist educational theory is focused on. The constructivist approach is the theoretical approach that was chosen as most appropriate for the literature, but the nature of quasi-experimental is such that the initial theoretical framework may be found to be inadequate to fully explain the results of the study. Because of this potential for a difference between theoretical findings and the outcomes of the study, there is a need to analyze the fit between the previously identified theoretical framework and the findings of the research.

Connection of Findings and Existing Research

This research can be considered under the theoretical framework adopted for this research as well as tying into the existing empirical research on the subject that has been presented. A detailed overview of the theoretical and empirical frameworks that have been chosen for this research is discussed in Chapter 2 (the literature review). This section provides a synthesis of this material provided in the literature review, as well as additional concepts that were used during construction of the research process.

One of the main requirements for the computer learning process that was used in the selection and design was to use the computer as a tool to advance the curriculum, rather than changing the curriculum to meet the needs of the computer (Halpin, 1999). This was enacted within the research by considering the current curriculum of the school and the level students were working at, and selecting tools that would allow students to continue working at this level through time. Selection of computer-based tools was intended to provide the support for the existing curriculum through selection of a skill drills based programme that emphasised the learning levels of the current classroom, with the main enhancement being the intuitive learning and reinforcement exercises and collaborative exercises provided by the N-RICH program. However, these were not chosen because they were computer tools, but because they met the objectives required by the research study to improve computer learning. Another area of the research that was used in constructing and conducting the research study was the need to recognise the student and teacher epistemologies regarding computers (Thomas, 2001). This epistemology identification was enacted through teacher surveys as well as more in-depth discussion and conversation with the teachers and students. It was not included in the assessment of outcomes, but was instead the focus of management of the lessons and the structure of the integration experiment. Epistemologies regarding mathematics were roughly classified using Shapiro's (2001) model of logicism, formalism, and intuitivism, with each individual being identified as holding a majority approach that reflected one or the other of these epistemologies. I feel that by taking these issues into account, the research was much stronger and more effective than if the issues had been ignored. Thus, this was considered to be a successful experiment in that regard.

The constructionist approach, which was proposed by Papert (1991) was also integrated into the experimental interactions in the classroom. IN particular, children were considered to be active participants in the creation of their own knowledge, and as such were presented with a selection of activities, including drills (some portion of which, but not all, were required) and intuitive activities that they could complete on their own or in a group. Teachers did not direct the children in which of the intuitive activities they should complete, but instead allowed them to follow their own interests through the activities and engage whichever of the activities they felt would be most useful to them. This allowed the students to formulate their own models of learning and expectation of learning, which is consistent with the constructionist approach to learning (Weiss, Nolan and Hunsinger, 2006). In some cases, this was more successful than others, as about half the children had to be encouraged to select their own activities or routinely did not want to select their own activities, instead asking for direction. This represents a general lack of experience with the constructionist approach to learning, however, as the majority of primary education in Kuwait (as in most cases elsewhere) is teacher-led rather than student-led. I believe that if the experimental project were performed for a longer period of time, this would eventually rectify itself as students gained a sense of self-efficacy in selection of activities and began to develop preferences and interests for specific activities.

As expected from the existing research, I encountered challenges both from structural and non-structural factors in the research. Consistent with the findings of other researchers, simple existence of computers for use in the classroom (or in this case readily available for classroom use) had not resulted in use of computers for students, and the computers that were available were rarely in use (Angrist and Levy, 2002; Baylor and Ritchie, 2002). This lack of use could in many cases be traced to attitudes of teachers regarding the use of computers by students; consistent with previous research, many of the students at the school did not consider computer use by students in the classroom to be appropriate, or viewed it as something that should be limited (Angrist and Levy, 2002; Becker, 2001). However, the introduction of computers as a means of improving school achievement was positively regarded by both teachers and administrators involved in the research, and allowed me access to the classrooms required; this was in accordance with findings by Cuban, Kirkpatrick and Peck (2001). Given that this did result in an improvement in student outcomes in the experimental model, it is hoped that the administrators and teachers will have received reinforcement of this potential for improvement. Conditions within the school were as predicted by Becker (2000), Cuban, Kirkpatrick and Peck (2001), and Rosen and Weil (1995), with computers being available within the school, but being primarily in use for classroom management tasks rather than for student learning activities.

The introduction of computers into the main classroom was generally upheld through the enthusiasm of the classroom teacher involved in the research, Mr. M. However, Goodson and Mangan's (1995) prediction of better acceptance of computers for mathematics learning than for other tasks was not upheld in other instances, as teachers were generally sceptical of the role of computers in the classroom for any student learning experience. In this limited research project, it was not possible to integrate the use of computers across the curriculum, as suggested by Roschelle, Pea, and Hadley (2000). This was due to the restrictions on the programme and the requirement that children maintain the same curriculum materials in other areas, as well as the limited resources and time available. However, in a more extensive application of this research this would be an effective approach to improving the computer self-efficacy of students and reducing the cognitive load associated with computer usage.

One of my initial concerns was the computer self-efficacy of the students as compared to their mathematics self-efficacy. William and Easingwood (2004) observed that students routinely varied in these two areas, and that there may be a wide variation of computer and mathematical self-efficacy within a given classroom. The digital divide (Settlage and Southerland, 2007) was not seen to be a significant issue in the classroom, however, as students came from a consistent socioeconomic background. Consistent with the observation of Zevenbergen, Dole and Wright (2004), the issue of computer self-efficacy was not significant; the majority of students had a moderate to high level of computer self-efficacy (in some cases demonstrably higher than that of their teachers), which was seen as a result of the common use of computers in the home, representing the integration predicted by the authors. However, variance in mathematical self-efficacy between students was marked and played a significant role in the design and execution of the study. Because this was expected, the teachers and I deliberately attempted to provide reach student with appropriate materials for his own level of mathematical self-efficacy, including specific skill drill levels and allowing for choice of intuitive exercises.

One area of the research that was not addressed during the initial review that proved to be useful was the concept of cognitive load theory. Cognitive load theory is a learning model that specifies that learners have only a specific amount of cognitive load that they can undertake in order to learn a given task or concept (Clark, Nguyen, and Sweller, 2006). This cognitive load is divided between three different areas, each of which contribute to the overall cognitive load of the learner. Intrinsic cognitive load is the cognitive load that is directly associated with learning the material as presented – for example, the cognitive load directly required to learn a given mathematical concept such as one-digit multiplication (one of the tasks undertaken by learners in this experiment) (Clark, Nguyen, and Sweller, 2006). This intrinsic cognitive load will vary from learner to learner, but the teacher except cannot easily modify it through the expedient of breaking down the learning process into smaller pieces (providing a lower cognitive load for the learning of each individual piece) (Clark, Nguyen, and Sweller, 2006). Extraneous cognitive load is cognitive load that is required to support this intrinsic learning; for example, learning special vocabulary or jargon, how to use a computer programme, or other extraneous tasks (Clark, Nguyen, and Sweller, 2006). This extraneous cognitive load does not contribute to the learning or expansion of knowledge significantly but it does require an increase in cognitive load associated with the amount of effort required by the learner to integrate this knowledge (Clark, Nguyen, and Sweller, 2006). Finally, germane cognitive load is the cognitive load devoted to learning and producing *schemata*, that is extensions or generalisations of knowledge that is learned during the intrinsic learning process (Clark, Nguyen, and Sweller, 2006). For example, germane cognitive load associated with single-digit multiplication involves the extension of learning of specific multiplication figures to a general method for multiplication. In the general case, extraneous cognitive load is non-productive and will not lead to further learning, while germane cognitive load will eventually reduce the need for further intrinsic cognitive load by providing mental maps or heuristics that can be used in other situations (Clark, Nguyen, and Sweller, 2006). The goal of the educator using this model for curriculum and lesson design, therefore, is to reduce the extraneous cognitive load while increasing the germane cognitive load, and if necessary manipulating the intrinsic cognitive load by providing lessons in smaller pieces (Clark, Nguyen, and Sweller, 2006). This was enacted in several ways through the existing research, including identification of learning levels, breaking learning into small tasks, providing intuitive and logic puzzles intended to build germane schemata for learners to use later, and in providing native language materials to students. Although students did express a generally high level of computer self-efficacy, there was an acknowledgement that spatial or physical learners may have difficulty in visualisation from the computer screen, and as such another approach that was used was allowing students to print manipulatives rather than use the computer based manipulatives within the intuitive exercises. This approach was following Chang and Ley's (2006) suggestion of printing materials from online learning in order to reduce extraneous cognitive load; although those researchers were targeting older learners than the current research, this still proved to be an effective approach to reducing the cognitive load on students, especially students that had language learning difficulties. I feel that these approaches were a highly effective approach to cognitive load theory that allowed the research project to reduce the impact of extraneous cognitive load on students and reduce the potential for cognitive overload. In some cases cognitive overload was still perceived, primarily through verbal or nonverbal expressions of frustration on the part of students. In this case, the level of the lessons being provided was adjusted downward, following cognitive load theory's approach to instructional design (Clark, Nguyen, and Sweller, 2006). This also proved to be effective in cases where it was required.

Summary of Analysis

This analysis chapter has provided a summary of the integration of the current research with the existing body of theory and research as well as an overview of the limitations of the study, a critical examination of the study design, practical recommendations for educators or researchers trying similar approaches in the classroom, and discussed my location within the research design. The analysis determined that the outcomes of the research was largely consistent with expectations that were identified given the theoretical framework in use as well as the empirical evidence that was presented. One area of theoretical approach that was identified as also being relevant to the research was the area of cognitive load theory, which was seen as a means of identifying extraneous learning tasks that could reduce the efficacy of computer-based mathematics learning. This theoretical concept was applied to the research design in order to identify both areas where cognitive load was managed effectively as well as areas where the management of cognitive load could have been more effective. The ultimate determination of this analysis is that, despite the limitations of the study and the changes that took place during the research design process, this proved to be an effective approach to improvement of mathematics learning and integration of computers into the mathematics learning classroom at the primary level. The next chapter concludes the study and offers reflections on areas for further research that could be built from the evidence that has been provided by this study.

Chapter 6 Conclusion

This research has provided substantial recommendations for the introduction of computers into the Kuwaiti primary school classroom for mathematics teaching. It also provided information regarding the current state of mathematics teaching and the efficacy of the existing curriculum. This conclusion chapter summarizes the outcomes of the study. It then addresses limitations of the study, as well as providing a critical review of the research design. It also discusses areas for further research in this area, and discusses recommendations for the curriculum designers and educators of Kuwait in improving the outcomes of the curriculum design. The chapter also includes personal discussion of the impact of the study on me and perceptions of the impact on the classroom as well.

Summary of Outcomes

The summary of outcomes focuses on two different areas. First, a brief summary of the findings that pertained to each of the research questions is provided. Second, a discussion of the outcomes of the hypotheses that could be tested statistically is discussed.

Research Questions

There were six research questions that were discussed within this research, each of which were discussed in various ways.

1. Using a pre-test, post-test scenario, students showed statistically significant difference in means on several of the questions involved in the testing research, especially the graphing, statistics, and addition and subtraction categories. (However, there was a drop in overall achievement in the graphing section) This resulted in a statistically significant change in the total score from 33.333 to

37.333 (from a maximum of 51, or an increase in mean percentage achievement for the full test from 65.36% to 73.2%. Thus, there was an improvement on achievement based on the experimental curriculum.

2. This issue is discussed in more detail, with the caveat that there was relatively little difference between student socioeconomic and demographic variables; the class was as a whole highly homogenous. The main difference found was in computer self-efficacy, which affected the speed at which pupils learned to use the programmes but did not affect their overall level of mathematics achievement.
3. There were significant challenges encountered during the introduction, including resistance from parents, teacher and student attitudes, difficulty funding culturally appropriate examples and the translation of the materials in order to allow for the research to be completed. These were overcome through cooperation between students, teachers, aides, administrators, and the researcher, each of whom contributed resources appropriate to overcoming these difficulties.
4. The Kuwait educational system is not flexible and has a strong goal of standardisation. Finding private sources for donations and gaining support of a school administrator was sufficient to overcome many of these difficulties, but many continued to persist over a period of time. The inflexibility of the system also means that the curriculum change is likely to be abandoned now that the research is complete, and students may potentially lose gains they have made.
5. The teacher and teacher's aide that were co-experimenting in this research had intuitive and open approaches to mathematics (which is one of the reasons they volunteered). Another potential participant declined to volunteer due to

discomfort with the research. However, evidence regarding teacher understanding of the role of mathematics in the environment as a whole in Kuwait is lacking and thus there was insufficient data collected to answer this question more generally.

6. Changes in the classroom made mathematics more fun, more exciting, and less frustrating for students, and for some led to greater mathematics achievement and mathematics self-efficacy. Overall, this was a positive change.

Hypotheses

Hypothesis 1 can be said to be proved. The research showed that there was a mild positive statistically significant improvement in the post-experimental tests as compared to the pre-experimental tests. Thus, there was some improvement on the part of students that could be detected based on the outcomes of this research.

Hypothesis 2 could not be adequately tested, as there were not enough students from differing socioeconomic backgrounds in the classroom (the students were from a largely homogenous sociodemographic background). However, one major difference between students was whether they had access to a computer in the home. 71% of students had access to computers in the home, while the remainder did not. The main difference that was found in this case was different levels of computer self-efficacy, with students with computers in the home demonstrating higher levels of computer self-efficacy than those that did not have computers in the home. However, there were not significant differences found between students of different levels of home computer access in terms of their mathematical improvements or mathematical self-efficacy. Thus, this hypothesis was not sufficiently proven, but neither was it considered to be examined adequately during the process of research.

Unique Contribution to Knowledge

There are a number of unique contributions to knowledge that have emerged from this study. One such contribution is the issue of increasing knowledge regarding education in Kuwait. As a relatively small country, Kuwait is often presumed to be homogenous with its neighbors in terms of its educational system, and as such very little research has taken place in the environs of the Kuwaiti school system itself. This is particularly true in the primary school system. In fact, only a small number of studies that were not directly focused on cross-country comparison of outcomes, but were instead focused on teaching methods and the classroom experience, were found at all. Thus, this provides specific information for researchers and practitioners on managing the outcomes of primary education in Kuwait. In particular, insights into the use of computers in the classroom and the challenges of translating materials intended for English students will be particularly relevant to practitioners that may want to use such methods. A second contribution is in its contribution to mathematics education and the use of computers. This research showed that the problem with mathematics teaching using computers is *not* the use of computers, per se – students showed a high level of self-efficacy with computers, for the most part. Instead, the software and the methods used to teach mathematics were more problematic. This clearly indicates that rather than devoting resources into how students can become more effective with computers, it may be more appropriate for the researchers to focus on creating more effective tools using the technology.

Limitations of the Study

The study was a qualitative quasi-experimental study based on a quasi experimental approach. This approach was effective in changing teaching and learning conditions in one classroom. However, its applicability is necessarily limited by the research design. The standardisation of classroom content and management across Kuwait does indicate that the research has provided some lessons learned for the Kuwaiti educational environment as a whole. However, there can not be assumed to be any generalisability to any other educational context. Additionally, the generalisablity is limited by the case study approach, which will not allow for general application the results uncritically. For example, the experimental classroom that took part in this study comprised entirely boys. This is common in Kuwaiti public schools, which have gender-segregated classrooms through to the tertiary stage of education. However, boys and girls have different achievement levels demonstrated in mathematics, and these different achievement levels may be extended to other areas of the curriculum as well. Given these differences, there is the potential that the results from this study would not provide an appropriate understanding of the mathematics learning requirements of Kuwaiti girls. Thus, the role of these results should be analytical and applied to the Kuwaiti classroom not directly, but through application of the lessons learned. The most important of the lessons learned in this study is not a specific insight regarding the use of computers in the classroom, but instead are the lessons regarding the mathematics curriculum on the whole and changes that could be made in order to improve it. Thus, the results of this study are not directly applicable to the classroom, but instead should be applied based on a critical understanding of what these results mean.

Secondarily, there is the issue of participant and research bias in the research, which may have had an effect on the outcomes. The teachers and researcher found that the experiment required significant involvement with individual students in order to teach them the goals of the mathematics enrichments (both the skill drills and the enrichment activities). The teachers and I also found that we were consistently explaining the mathematical concepts behind the activities, which the teacher remarked was not something that routinely took place in the classroom. Thus, the results of the study may have resulted from increased classroom attention that was paid to individual students, as much as it resulted from the introduction of the computer-based teaching method. It is difficult to determine which is the case, and is one of the limitations of the research. The quasi experimental approach to the research process did not allow for the identification of differential effects between classroom involvement and the changes in the curriculum (this issue is addressed below.) However, this also provides the opportunity for increased research into this area, specifically using a control-based study that would allow for comparison between two or more groups in order to determine which of these effects was more important. This is suggested in the discussion below.

One of the main limitations of this research lies in the moderate internal reliability of the test instrument, which was probably related to the small number of questions involved in many of the test questions as well as the inconsistency with which the students answered them. This was unavoidable given the level at which the test was designed, which was intended to provide support for a primary level understanding of mathematical concepts and which had to cover a wide variety of subjects. However, it does indicate that this research should, from a quantitative point of view, be considered to be exploratory rather than confirmatory. This requires that the research should be considered to be suggestive, rather than being an absolute determination of the resulting materials.

The small scale of the study is also one of the limitations of the research. This small scale was necessary due to the generally small size of schools in Kuwait, as well as the resources available. Specifically, the teachers within the school available were not all comfortable with the research project, making it difficult to provide the appropriate level of matching environment that could provide a more robust statistical outcome. The small scale is such that the statistical results do not meet the criteria of the central limit theorem, and thus there can be no assumptions regarding the population made given the distribution of responses in the sample. Thus, the results of this study cannot be directly generalised to the overall population of students at the third and fourth grade level in Kuwait.

In many respects, the limitations of this study from a quantitative point of view were compensated for from a qualitative point of view. For example, the information regarding student and teacher mathematical conceptualizations and self-efficacy provides some insight into mathematics learning and teaching in Kuwait and offers the opportunity to identify areas that could be engaged in further research projects. Furthermore, the actual experience of integration of significant computer usage into the Kuwaiti classroom was also significant, and this could prove to be highly useful in future experiments of this type as it allows for identification of potential challenges and difficulties that may be encountered in this environment. As the goal of the research was to provide an active improvement in the classroom rather than strictly being focused on the objective observation of change, the research can be considered to be a success in other ways despite the relatively weak statistical outcomes that were seen in the qualitative analysis of the study. It is likely that an increased level of involvement with the study subjects, for example a more extensive mathematics training programme or a longer period of time, would actually produce stronger and more consistent results in the statistical outcomes. The time limitation of the study did not allow for a long period of consistent learning for students, which would have been highly beneficial. However, overall the results can be said to be satisfactory and beneficial for students despite the limitations that can be seen in the study.

Critical Review of the Study Design

The study design was a quasi-experimental design that was intended to not only observe and measure the effects of the suggested curriculum, but also to adjust the classroom management and curriculum approach in use during the course of the experiment in order to provide the best possible outcomes for the experiment during the process of it being conducted. It should be stated that this approach does not provide statistical rigor and does not offer the virtues of reliability and validity that would be found in a rigorously designed quantitative survey. However, this was not the goal of the current research. Instead, the current research was intended to not only make changes in the classroom environment, but also to collect data on a range of classroom variables and conditions that would be difficult for me to integrate into a single quantitative experiment. This included feedback from teachers, aides, and administrators, interview feedback and casual feedback from students engaged with the research, and if applicable information from parents and other members of the school staff (assuming this feedback was offered). The integration of this data was intended to support the development of a curriculum that could hold up to experience in the classroom, and in this respect the research succeeded. It provided specific information regarding the use of computers in the classroom, as well as more general information regarding the state of mathematics teaching and curriculum in Kuwait, and in fact provided substantially more information than was expected in the research design. Overall, the research design served its purpose and the results serve as useful indicators of where future research is required, as well as a preliminary proof of concept for the value to be found in integrating computers into the Kuwaiti elementary school classroom.

The research study approach evolved considerably from its initial conceptualisation during the process of allocation of resources and integration into the classroom. The first change, which was required due to lack of available resources to enact the specific design, was a change from an experimental case-control design to a quasi-experimental test-retest design. I feel that this design change does weaken the findings of the study and reduce the overall utility of the study to that of a strong exploratory analysis. This is confirmed by the internal reliability analysis, which routinely indicated through the Cronbach's alpha score that the strength of the testing measure was that of a strong exploratory study rather than confirmatory research. Given the Constructionist approach to the research and my intention to not only provide useful research information, but also to actually make a change in the mathematics learning experience of the student participants, this does not necessarily represent a weakness in the outcomes of the research study. However, it does represent a significant change in the research study approach that was emergent, rather than being planned.

The use of the interactionist and participatory approach with the adult and child research subjects was highly useful in terms of involving the participants in the research and in promoting the sharing of ownership between the participants and the researcher. The research outcomes were not simply the result of an imposition of experiment on the classroom, but was instead the result of an organic learning process that involved everyone – researcher, teachers, and students – in an iterative process of learning and experimentation. I have attempted to include the voices of both teachers and students within this research product as a means of both valorising their voices and increasing their input into the validity and effectiveness of the teaching approach that was used. While the process of negotiating the experimental protocol was at times difficult, particularly in cases where the interests of two of the groups of student participants came into conflict, I feel this was a much more satisfactory process and outcome than would have been encountered had the approach of simply imposing the required standards over the participants been chosen. This research process, which is commonly used in participatory and quasi-experimental in the classroom, is thus thought to be highly effective.

However, not all of the research design issues can be said to have been resolved as elegantly as the integration of research participants. A particular issue that was encountered was finding the appropriate software for use in the classroom. The majority of available elementary mathematics teaching software and online materials that was found by the participants and me was in English. Although the student learners had begun learning English and in some cases were very fluent, this was considered to be a challenge that would place the learning process outside the scope of the intended project.

A further concern was the use of English-language materials in mathematics learning in terms of the potential introduction of cognitive overload. According to cognitive load theory, this would represent a type of extraneous cognitive load, which even in good non-native English speakers would add to the overall cognitive learning load of the experience and reduce the overall level of cognitive capability that could be devoted to the intrinsic and germane tasks of learning the mathematics processes that were the target of the research (Paas, Renki, and Sweller, 2003). The use of non-native language materials is a relatively common problem within the use of online research materials. Although there are strategies that can reduce the affect of this cognitive overload on the learning process, they are primarily designed for and intended for adult learners, rather than child participants and learners (Chang and Ley, 2006). However, this does not mean that this approach has no value in the classroom environment, and it was used in part in order to compensate for the challenges that were observed. Chang and Ley’s (2006) strategy of using printed materials was modified in order to include translated materials from the N-RICH Web site in order to allow children to access the materials in their native language. These translations were undoubtedly not perfect, and as some children in the class were receiving additional support for language-based learning difficulties it is possible that they were not effective in all cases. However, the use of translated materials provided a way to reduce the cognitive load on learners and allow them to focus on the mathematics, rather than linguistic, tasks involved. The students were also allowed to print out materials from the programs, rather than using the online manipulatives, if necessary; this allowed for the inclusion of multiple spatial and representational learning styles to be successful in the process of learning, which provided an additional way to reduce cognitive overload following the recommendations of Chang and Ley (2006). Overall, this proved to be a satisfactory approach for the limited experimental process that this research involved. However, the approach is not likely to work in long-term implementation within the classroom due to the intensiveness of the translation process and the need to maintain a fully translated set of materials.

However, there were some difficulties in the classroom management and the research design that are worth noting. First, the lack of control classroom reduced the ability to compare the results of the experimental classroom to the results that would be achieved in the standard classroom. Thus, while it is certainly possible to state that there was an overall feeling of excitement and improved attitudes toward mathematics, and that the children improved in comparison to their pre-programme performance, this does not indicate whether these improvements were significant or whether they would have occurred regardless of the use of standard or modified curriculum. Thus, this serves as a significant weakness in the study.

A second weakness in the study design was the amount of time required to support the student outcomes. The in-class time required by researcher, teacher, and classroom aide was significantly higher than the expected amount of time, and much of this time was spent explaining not only the mechanics of the new mathematics tools, but also the mathematical concepts behind them. Some of this was understandable, as many of the enrichment activities particularly addressed issues that had not yet been encountered in the standard curriculum. However, much of this assistance was with concepts and materials that had already been addressed in the curriculum, at least nominally. In some cases, children simply did not know how to approach a problem or how to apply knowledge they already had in order to gain access to new understanding. In many ways, this exemplifies the weakness of mathematics teaching in the Kuwaiti system, in which the algorithmic application of formulas to real-world situations is prioritized over understanding concepts. This was also not considered to be a negative aspect by the researchers or by me, which is why it was continued. However, this does provoke a dilemma for the study design: have students improved because of computer-adaptive skill drills and enrichment activities, or have they in fact improved because of the increased attention to explaining and reinforcing basic concepts on the part of the classroom managers? This is not a question that can easily be answered within the context of this research. However, it does serve as a central point of inquiry for a suggested improvement in the research, as discussed below.

Overall, the research method that was chosen was a sound quasi experimental approach that has yielded positive results. These results are far from conclusive and there are still some unanswered questions, particularly in regard to the role of individual student mathematics and computer self-efficacy on the outcomes of this testing process. This was not an issue that was designed into the experimesnt to be considered in a quantitative fashion, although it was addressed in the student interviews that were performed throughout the duration of the experimental classroom involvement. However, from observation, I have noted that students with higher existing mathematics self-efficacy did show a higher level of involvement with the mathematics programs, and that this may have affected the outcomes of the research study for these children. This was not uniformly the case, and in a couple cases those with low initial self-efficacy were shown to have gradually improving views on not only the utility of mathematics, but also its role in the real world. None of the students truly developed an intuitivist approach to the learning of mathematics; however, this would have been an unrealistic expectation given the limited duration of the experiment and the previous mathematics learning models to which the children had previously been exposed. Ultimately, children began the study with a well developed representational view of mathematics that tended toward the formalist or logicist approach, and which was based on their former experience with mathematics training. Although the intuitive learning experience was seen to be positive by many if not most of the students in this discussion, this is unlikely to promote a sea change in their views toward mathematics on the whole. I hope that at least some of the children involved in the study will experience a shifted view of mathematics that allows them a more satisfactory learning experience due to their involvement in this study. However, the main benefit to the students involved is viewed to be the experience of mathematics as fun learning activity rather than a strictly required drill-based practice. The experimental approach did integrate mathematics drills, although these were framed as a competitive game and were not given on pencil and paper like the students were used to. However, the use of a combination of intuitive and formalist approaches to the mathematics learning was a wider approach than had been used in the past. Thus, this was a change in the experience of the children involved within this study, and as such can be thought to be a positive improvement in their learning environment.

Recommendations for Further Study

One recommendation for research is to use an expanded, fully experimental study for implementation of the curriculum and classroom management approach design used in this research across a wider number of classrooms. A full control experimental approach would be designed to rigorously test the use of the computer-based, adaptive skill drills and enrichment activities in the classroom. The suggested approach is to include eight classrooms from a larger school, including four girl's classrooms and four boy's classrooms. One of each of the classrooms would be assigned as a control classroom, and curriculum would not be changed form the Kuwaiti national standard curriculum. A second classroom would receive the support of enrichment activities, a third would receive the computer adaptive skill drills, and a fourth would receive both adaptive skill drills and enrichment activities. The students would each receive a standard level of teacher explanation and involvement, except for the initial teaching that would allow the students receiving either skills or enrichment inclusions to understand the tasks required. The research project would ideally be conducted over the course of a year, with regular and intermittent testing of all four groups in order to determine progress over time. The goal of this study would be to determine in a quantitative experimental fashion what the outcomes of the proposed curriculum changes would be, as well as what the effects of each individual component would be. In order to conduct this experiment successfully, there would need to be significant amounts of coordination among the research team members (including classroom teachers and aides for each of the classrooms as well as the researcher) in order to ensure that the outcomes were consistent over time. It would also be necessary for the research to include observational and other characteristics, in order to ensure that the learning experience of children was not negatively affected (below the baseline of appropriate outcomes as determined by the learning experience provided by the standard curriculum). This would be necessary to ensure that children were not harmed during the process of conducting this research. This would then allow for the Kuwaiti government to clearly determine whether and to what extent classroom computer mathematics teaching should be integrated into the primary curriculum. This experiment could be extended across grades if I had sufficient access to research funds, as well. This would allow for a more cross-grade discussion of the appropriate place for computers in the classroom. However, this research would require substantially more resources than were available at the level of the current research, and given the scope of involvement and the length of the research may also require government involvement. The appropriate place for this research to take place may be during the process of defining government curriculum standards during the next round of reform measures.

A second area of research is actually focused on teachers rather than students. Currently, there is little research available regarding the overall mathematics preparation levels of Kuwaiti teachers, or of their attitudes toward mathematics or mathematical self-efficacy. However, understanding these issues is key to understanding how reforms can most effectively take place. Because the mathematical attitudes and conceptions of teachers are often passed on to students, whether the teachers intend to pass on these attitudes and conceptions or not, it is important to understand where practicing teachers fall on these routines. This would also provide information that would allow for refinement of teaching methods and curriculum requirements. While the above research is highly intensive and requires substantial resource and time commitments, this research would be relatively simple to conduct. Specifically, it could be conducted using a survey approach, in which a questionnaire was designed to measure and assess mathematical conceptions, attitudes, and self-efficacy, as well as demographic information and information on their teaching experiences. This questionnaire could then be distributed to a wide sample of practicing teachers in Kuwait, and analyzed statistically in order to provide insight into the mathematics attitudes of the teaching force in Kuwait as a whole. This would provide a relatively simple way to measure this in a reliable and valid statistical approach.

Recommendations for Implementation in the Classroom

One of the major outputs of this study was a series of recommendations for implementation of a similar programme in the classroom, should teachers want to use computers in a constructionist approach to creation of mathematics learning. These recommendations were derived from the observation and experience of the researcher, as well as input from the classroom teacher and classroom aide that also participated in the research. The recommendations were derived from both the mistakes that the research team made as well as their successes. A brief synopsis of these recommendations is as follows:

- Consider the needs of each student individually in terms of intensiveness, skill level, frustration levels, and requirement for basic skills learning as compared to intuitive improvement rather than using one-size fits all approach.
- However, do not restrict any child from the use of the intuitive tools on the basis of low achievement within the basic skills area. As one of the goals of the learning project is to improve *enjoyment* of mathematics, in addition to mere *understanding* or ability to use algorithmic approaches to solving problems, restriction of students from the intuitive games is counterproductive.

- Approach both intuitive and formalist mathematics learning experiences as games in order to involve the intellect of children without engaging their boredom levels or senses of sameness with everyday work.
- Allow children to learn in groups (collaboratively), alone, or as a combination of collaborative and individual learning as suits their personal learning styles and desires. This will improve the experience of learning for the students involved in the process and increase their involvement levels.
- If the full class is not to use the computer-based manipulatives, programs, and learning tools at once, consider removing the computer group from the classroom or, if possible, shielding the computer area from the remainder of the classroom. This does remove the computers from the classroom environment, which reduces the ubiquity and potential building of comfort. However, it will improve the experience of other students in the classroom due to a lower level of distraction from those engaged in the computer classroom experience. This is particularly true in high-collaboration environments or if the computer games in use make noise.
- Pay attention to the expressed and unexpressed frustration levels of the students involved in the computer-based learning process. Students that found that they were becoming frustrated during the computer learning process rapidly disengaged and did not continue to try with the computer exercises in this experiment. This is likely due in part to the non-graded aspect of the research, which meant that students did not feel they had to complete exercises in order to maintain grades. However, the lack of involvement did not lead to positive

outcomes in the short term for these students, and it proved to be difficult to get students to re-engage once they had disengaged from the computer-based learning process. By simply avoiding the reduction in engagement levels, it would be considerably easier to maintain interest in the learning process.

- Natural-language learning and other reductions in extraneous cognitive load are likely to improve the learning experience of children and increase their ability to learn the materials being presented without having to learn a high level of additional information. To this end, it is important to focus intently on the skills required to learn the material itself, rather than extraneous skills needed to absorb the material or learn the frameworks being used. As such, acquisition or translation of native language computer-based learning materials, as well as assessment of the level of computer skills and self-efficacy and gearing of involvement with computers to this general level, are considered to be key to ensuring an effective outcome in a classroom-based experiment of this type.

Recommendations for Educators and Curriculum Designers

One of the major goals of this research was to provide recommendations for educators and curriculum designers in Kuwait that could be used to improve the outcomes of Kuwaiti mathematics education in the primary years. The results of these findings cannot easily be generalized past the primary years, as the educational structures, standards, student maturity and self-efficacy, as well as the epistemologies of students was modified by the gap between these two periods. However, there is no need for the recommendation to be tightly restricted to the fourth grade boys that the research was focused on. Instead, the results of the study can likely be generalized across the primary school years for both boys and girls.

The first recommendation is to take steps to integrate computers into the classroom, and not just into the schools in the form of the more common computer labs. By having the computers in the classroom, and by having more than a single computer available for student use, the teachers were reminded to use the computers not only for classroom management or for limited-access, non-tutorial purposes, but to encourage students to use them for tutorials and enrichment activities. This increased the use of computers in the classroom for the students, which a post-study discussion with Mr. K indicates has persisted over some period of time.

The second recommendation is to consider adding specifically computer-based mathematics instruction to the current official curriculum for at least some students. This approach proved to be effective, especially for those that were struggling with basic mathematics and those that were already high achievers in mathematics. Those that were struggling with mathematics benefited from the unpressured, non-judgmental and non-graded access to computational tutorial resources. This access allowed them to learn at a semi-self paced rate and in a way that adjusted to their own needs. The use of this type of adaptive learning allows for the student to improve their mathematical self-efficacy and, even if they do not achieve the highest levels of mathematical knowledge and understanding, they was able to gain an increased efficacy and improved attitude toward mathematics. For students that are performing at the higher levels of the curriculum, there are also benefits. These students benefit from the transformation of their concept of mathematics from being a task-driven exercise intended for application to the idea of mathematics as an intellectual or exploratory exercise intended for discovery.

Not all children will develop this understanding of mathematics - although all children in the classroom enjoyed the mathematical enrichment activities, only a few began to develop a true capacity for mathematics as an exercise in original thought. However, this is a vital supplement to the understanding of mathematics as a tool for solving real-world problems. Both of these approaches was necessary in order to promote Kuwait’s current and future economic growth. The concept of mathematics as a logical and real-world applicable tool is vital for engineering, computer science, and other mathematics driven fields. These fields are key to building technological capacity and understanding. However, in order to build true depth in research and development and basic science, which will play a vital role in developing Kuwait as a major player on the world stage in terms of technological development and a source of new technologies, it is necessary to also build the second kind of development capacity. Mathematicians and applied scientists will need to be able to consider mathematics as a means of exploration, rather than simply as a means of algorithmic application of specific formulae to given problems. Without building this capacity in advance, Kuwait will not be able to fully develop its non-petroleum economic resources. Thus, this is a goal to be encouraged, rather than maintaining the current focus on logicist application of mathematical features.

A more general observation, which does not apply specifically to the mathematics curriculum, is the role of evidence-based learning methods in development of the mathematics curriculum. Currently, the process by which Kuwait’s national curriculum is arrived at is unclear, and the curricular requirements do not explicitly spell out methodologies or treatments that are empirically based. The initial attempt at reform, during the 2004-2008 period, was clearly insufficient to reform mathematics achievement at the lower levels, given the performance on the 2007 TIMSS test as compared to the 1997 TIMSS test. This testing difference demonstrated that the reforms put into place during this period might actually have reduced the efficacy of the mathematics teaching program. The researcher's observations also indicated that the mathematics curriculum in place did not necessarily meet the needs of the students, many of whom found the work too difficult, too easy, or simply incomprehensible. Through revision of the curriculum based on experimentation and evidence with children in the schools themselves, the fit between curriculum and student achievement levels and interests can be improved in order to increase its efficacy. This is a situation that I suspects applies not only to the mathematics curriculum, but also other areas of the curriculum, and at other levels of the curriculum as well. Given this condition of the elementary mathematics curriculum, it is highly recommended that further curriculum reforms should focus on building evidence-based curriculum and lessons and developing these curricula from the standpoint of positive learning, rather than simple application.

Personal Reflection on the Research

I had not previously performed classroom participant research or quasi-experimental methods prior to this research process, and it proved to be an enlightening personal experience. The first difficulty that was found was socially defining and locating myself within the classroom environment. As in most countries, primary education in Kuwait is a highly ritualized experience, with each individual within the school having a set role in which there are specific actions, habits, and customs expected. As I was outside any of the roles involved in this area, it was often difficult to locate a specific role for the researcher. In many cases, he functioned in the role of classroom aide, following the teacher's lead while engaging with the students in an assistive capacity. However, this was complicated by the need to collect information regarding the outcomes of the research and the leadership involvement role that he took in the process of the research. The social development of relationships between the teachers and I cast me into the role of subject matter expert and sometimes as gatekeeper of formalized knowledge regarding the process of learning. Although this was in part due to my role *as* researcher, this was a difficult role to fulfil in many cases and one that I was not necessarily comfortable with. This was due to the observation that, although I was working under a theoretical framework and did have considerable formalist knowledge, the teachers and administrators also had knowledge that I did not have. In particular, in more than one instance I found myself seeking information regarding classroom management and student learning styles from the teachers. I would have found myself more at home with a partnership approach with the teachers involved in the study, however this did not prove to develop over time. However, this is not meant to say that the teachers and I did not have positive experiences in interaction. I feel that the interaction between the students, teachers, and myself was highly effective and led to a far more effective research process than would otherwise have been encountered. Thus, even though I had difficulty locating myself in the classroom and the eventual location was not what he would have preferred, the outcomes of the study were not necessarily reduced or decreased in effectiveness due to this change in position.

This research changed dramatically from the initial conceptualization that I considered during the process of design. First, the study was shortened as the period of time available for research for me and for the school was shortened. This increased the importance of teacher involvement in the experimental research, as well as changing the intensity of the programme as designed. Second, the number of classrooms that were included in the study was reduced due to lack of resources available to include more classrooms. This resulted in the loss of a control study, changing the study design to a quasi-experimental design from a full experimental design. However, I do not feel that these changes were necessarily negative in terms of the outcomes of the study. In exchange for experimental rigor, the research was able to more fully integrate the inputs of student, teacher, and administrator experience into the study. In exchange for a longer, more dispersed experiment including more classrooms and more students, the research affected a single classroom with an intensive revision of their ideas about mathematics and the purposes of mathematics. Ultimately, the research potentially made the results of the study less generalisable, but may have had a more concentrated effect on the mathematics perceptions and ultimately the futures of the students within the classroom. Thus, even though the research was different from the initial conception, I feel it was a rewarding and worthwhile research experience.

In terms of involvement in the classroom, this was also substantially different from my expectations. I had expected to work in-depth with teachers, aides and administrators, but the initial design of the study left me working at a distance from the children in the classroom. The research design revisions changed this equation, and rather than working with a number of classrooms individually, I found that I was working with a single classroom intensively. The classroom experience ended up integrating more of the ideas and experiences of the children into the research than had initially been planned. However, it also provided me with a more detailed view of the previous experiences of children in the mathematics curriculum, how they viewed mathematics, what kind of experience they had with computers and how they viewed computers, and what kind of difficulties and frustrations they had with mathematics in general. This provided a view that was important for integration into the research, and provided a slightly different view of the students than I had intended. However, it also provided an enhanced understanding of why this research was important. Understanding the issue of inadequate mathematics curricula from a standpoint of statistics and comparative performance provides insight into what challenges Kuwait as a whole will face with its educational system. However, understanding difficulties in the mathematics curriculum from a student that simply does not understand the mathematical concepts he is being asked to apply, and who applies these concepts from rote memory without realizing the significance, is another issue entirely. Watching students and helping them as they learn to manipulate not just figures and numbers, but the very idea of mathematics, is one of the most important experiences of my life and one that I hope can continue to be repeated. The gains in this classroom were modest, and many students did not make significant gains in terms of their level of mathematical understanding and knowledge. However, the revolutionary factor was not in simple test scores, but in enjoyment of mathematics and the understanding of mathematics as something that could be fun and exciting, rather than simply something that must be endured. The integration of group activities was, I feel, particularly important for building an improved understanding of the use of mathematics as a way of thought, rather than simply a logical system or means of calculation.

It is not possible to tell how durable the effects of this experiment will be. Given that I am not placed in the school as a full-time educator, there will not truly be a way to monitor the ongoing progress. Furthermore, as a public school, the subject school has only a limited capability to deviate from the government-approved curriculum and learning plans. Given this, there is no way to determine whether the computer-based educational system that was derived from the cooperation between me, the teachers, the administrators, and the students, will survive. Although I have had communications from the head teacher that indicate that at least some of these practices was preserved, given the time and resource intensive nature of the mathematics training curriculum that was devised, I suspect that this will remain in place only for a select few students. However, it is hoped that despite this time and resource intensive nature, the computer-based mathematics curriculum that was put into place can be maintained on at least a limited basis for those students that benefited the most from the program. It is also hoped that the students that have achieved a different view of mathematics from the formalist or logicist view that was beginning to be formed can sustain this modified view over time. However, even if this does not result in sustained change in student or school practices or viewpoints, I feel that the research was a success given the time and resource challenges it was faced with, as well as the considerable structural difficulties involved in integrating computers into the mathematics curriculum in a robust manner.

Conclusion

This research has provided some level of insight into the practice of mathematics teaching in the Kuwaiti elementary school. What it found was moderately disheartening for the Kuwaiti school system. With a curriculum that focuses on mathematics strictly as a logical, real-world problem solving tool, there is little flexibility in the curriculum that allows mathematics as a pursuit that is not focused on these problem solving requirements to grow. Advanced students are not offered the opportunity to expand their understanding of mathematics, while students that achieve more slowly than the norm are not offered any changes in approach that would help them to learn in a different way. However, these conditions of rigidity in curriculum were not matched by rigidity in teaching methods. The teachers and administrators at the school recognized the deficiencies of the curriculum and worked with the research in order to try something different – student-led, adaptive, computerized mathematics lessons that allowed students to work at their own level while enforcing a balance between skills reinforcement and enrichment activities. This approach was successful with students that were primed to consider computer-based activities fun and desirable, and who required little tutelage in the basics of computer usage in order to come up to speed on the expectations of the program. Under this programme, the existing mathematics curriculum was supplemented by 45 minutes per week of mathematics computer time, which was split (depending on the student's own needs) between the adaptive and reward-driven "skill drill" exercises and the cooperative-competitive enrichment exercises. This programme did lead to a modest, but statistically significant, increase in testing scores based on the instrument that was devised in order to test age and skill appropriate mathematics achievement.

However, the more profound difference that this programme made was in the classroom experience and view toward mathematics. The involvement of computers in mathematics teaching, although it was logistically difficult and required intensive involvement from the classroom teacher and researcher as well as hiring a temporary classroom aide specifically for assistance with the programme, proved to be highly popular with students. Many of the students achieved significant gains in terms of their computer-based mathematics skills over time, with almost all students achieving advances in their skill drill adaptive exercises. Additionally, the enrichment exercises, which were performed either alone or as a group, were highly effective in encouraging mathematical experimentation and mental manipulation. The involvement with these enrichment exercises varied, as students were assigned to skill drill exercises at varying levels depending on their current achievement level. However, while the top achievers in the class had only a limited amount of skill drill exercises required (although they could choose to do more), the lower achievers were guaranteed completion of a certain amount of the enrichment based exercises regardless of their level of achievement. Overall, the research was determined to be a success by both me and the teachers, despite the changes from the initial structure of the research design and the scope of the project. Unfortunately, given the demands of Kuwait's standard curriculum for mathematics and the intensive nature of the experiment, as well as the expense of the equipment, the continued involvement of the students in the experimental curriculum protocol is not assured. However, the teacher involved in the study has indicated intent to continue to integrate the teaching curriculum into his regular classroom management. This research has provided substantial insight into not only the improvements that could be made in the

Kuwaiti mathematics curriculum, but also the challenges that are posed by the structural and institutional design of the Kuwaiti school system and the existing curriculum. Overall, the research has provided some substantial recommendations for improvement of the Kuwaiti mathematics curriculum for the primary years, as well as the overall improvement of the approach to mathematics learning. It is hoped that these findings will result in improved outcomes for Kuwaiti mathematics and technical learning and integration of computers into the classroom, in order to improve the educational system in preparation for the coming economic shift.

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Appendix A Study Instruments

Teacher Survey

Please answer all questions to the best of your ability. If you have further comments, please write them on the back of the sheet.

1. Do you have a computer in your home? ___ Yes ___ No

2. If yes, for how many years have you had access to a computer in your home? ___ Years

3. On a scale of 1 to 5, how much do you know about computers? (1 = Not much, 5 = quite a bit)

4. On a scale of 1 to 5, how confident are you with computer use? (1 = Not confident at all, 5 = very confident)

5. These are some roles that a computer might have in your classroom. Which of these roles do you think are appropriate?

___ Marking and grading

___ Making worksheets and materials

___ Internet and research

___ Use by students

    ___ Word Processing by students

    ___ Games by students

    ___ Use as a reward for good students

    ___ Use in student learning

    ___ Use in mathematics teaching (practice drills)

    ___ Use in mathematics teaching (skill building)

___ Use in literacy teaching

___ Multimedia (audios, videos)

6, Considering the same roles as above, which of these roles have you received formal training in? (Either in teacher training or during post-training continuing education)

___ Marking and grading

___ Making worksheets and materials

___ Internet and research

___ Use by students

___ Word Processing by students

___ Games by students

___ Use as a reward for good students

___ Use in student learning

___ Use in mathematics teaching (practice drills)

___ Use in mathematics teaching (skill building)

___ Use in literacy teaching

___ Multimedia (audios, videos)

7. On a scale of 1 to 5, how much technical support do you have for computers in your classroom or in a computer lab? (1 = not much or no technical support, 5 = a lot of technical support)

8. Do you have access to computers in any of the following places? If so, how many hours a week can you use them for your class?

___ In your classroom ___ Hours/week

___ A shared lab or resource room ____ Hours/week

___ Library or media room ___ Hours/week

9. How much do your school's administrators support the use of computers in the school? (1 = not at all, 5 = a lot)

10. Which of these attitudes best describes your beliefs about mathematics?

___ I believe that mathematics is a formal system of logic

___ I believe that mathematics is primarily a practical tool and can be applied to real-world situations

___ I believe that mathematics is a flexible way of thinking

11. What type of formal training did you receive in the use of computers in the classroom?

12. Have you ever used computers in mathematics teaching in the classroom? If yes, Please describe the training (number of hours, tools used, and subjects and techniques covered)

13. Do you currently use computers computers in the classroom for any purpose? If so, for which purposes?

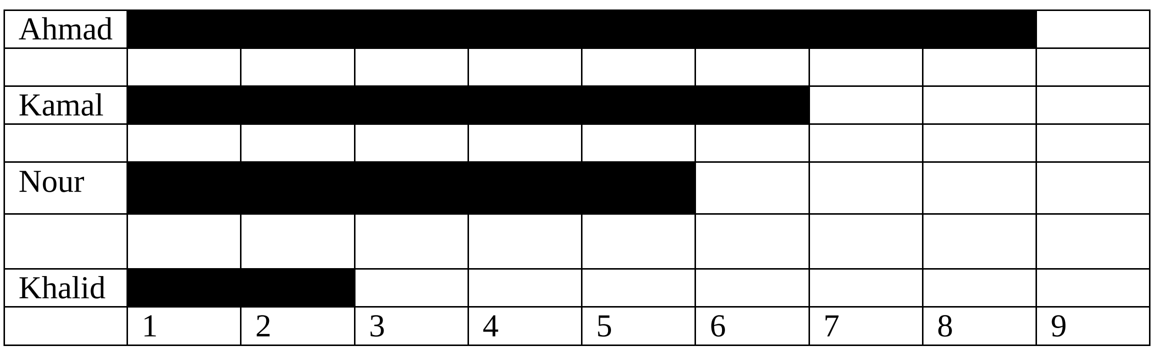
Student Pre-test

The initial testing instrument was split into two pieces following pilot testing of the original instrument, which determined that the initial research instrument was too long and led to loss of attention and reduction of performance in the latter half of the test. Division of the initial test was performed in order to provide different questions for the pre and post test, which was seen as a way of increasing the test-retest validity of the study as well. Issues of test-retest validity are addressed in the findings of the study. In cases where there was only a single question, the question was modified in the post-test in order to increase the validity of these findings.

Graphical Representations

Use the graph below to answer the questions.

Number of Goals per Game



1. What does the graph above represent? (Football goals)
2. What measurement is used in this graph (Goals per player)
3. Is the graph above horizontal or vertical?

Range, Median and Mode

4. What is the most repeated number in a set of data? (mode)
5. What is the number in the middle when all the data are arranged? (median)

6. What is the difference between the largest and smallest numbers? (range)

Use this chart to answer the following questions:

Classroom	1	2	3	4	5	6	7
Number of Students	22	12	18	21	22	19	13

7. Arrange the numbers in ascending order.

8. How many classrooms are represented?

9. What is the range of students?

10. What is the median number of students?

11. What is the mode?

Place Value To Thousands

Write out these numbers in words:

12. 28 535

13. 19 851

Write out the following numbers as a single number:

14. 4 000 + 500 + 50 + 2 =

15. 1 000 + 200 + 40 + 9 =

Write the place value for each underlined digit

16. <u>1</u>9205

Patterns

Complete the following number patterns

17. 428 4 280 42 800

Number Order

Arrange the following numbers in acending order (smallest to largest)

18. 4 910, 4501, 4905, 4010

Arrange the following numbers in descending order (largest to smallest)

19. 4 910, 4501, 4905, 4010

Write a number between these two numbers

20. 10 220 ________ 10240

Time Definitions

21. Match the time units with the appropriate definitions

1- One Century (D)	(A) 365 days
2- One Day (B)	(B) 24 hours
3- One Week (E)	(C) 10 years
4- One Year (A)	(D) 100 years
5- One Decade (C)	(E) 7 days

22. Compare the time units using <, > or =.

6-One week (<) one month	7- 90 minutes (>) one hour
8- 350 days (<) one year	9- 50 years (<) one century
10- one century (>) one year	11- 60 seconds (=) one minute
12- 36 hours (>) one day	13- 9 years (<) one decade

Addition and Subtraction

23. Add the following numbers.

80 + 50 = 13 800 + 500 = 1300 8000 + 5000 = 13000	4- 90 + 70 = 160 900 + 700 = 1600 9000 + 7000 = 16000

24. Subtract the following numbers

70 – 20 = 50 700 – 200 = 500 7000 – 2000 = 5000	65 – 50 = 15 650 – 500 = 150 6500 – 5000 = 1500

25. Add or subtract the following, using the thousands digit or mental calculation.

450 + 130 = 580	640 – 220 = 420	180 +400= 580
560 – 360 =920	500 +460=1060	820 – 310 = 510

36) Add the following.

67 + 21 = 88	468 + 354 = 822
805 + 280 = 1085	237 + 555 = 792
43 + 65 + 29 = 137	92 + 543 + 737 = 1672

26. Add the following numbers: 43, 4921, 203, 293 (5460)

Multiplication and Division

27. Multiply the following numbers.

2 X 3 = 6	5 X 4 = 20	5 X 6 = 30
9 X 4 = 36	7 X 5 = 35	5 X 3 = 15
(9 X 7 = 63	2 X 4= 8	0 X 6 = 0

28. Divide the following numbers.

15 3 = 5	18 9 = 2	18 3 = 6
36 6 = 6	42 6 = 7	72 9 = 8

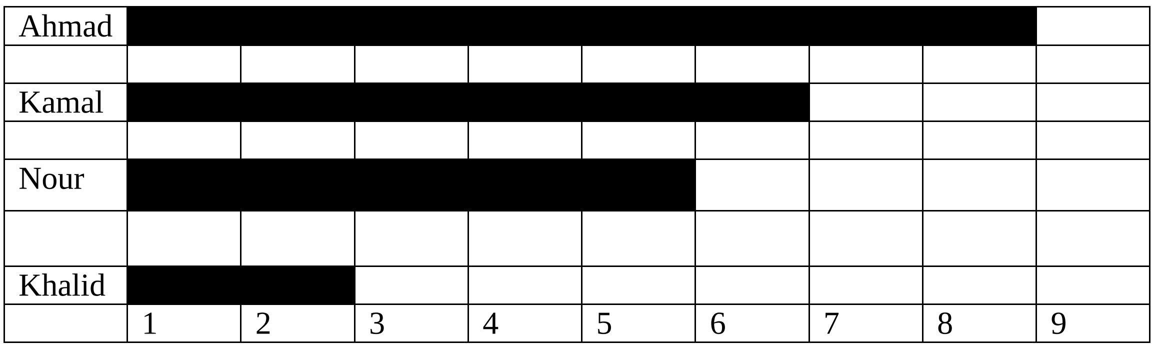
49 7 = 7	32 8 = 4	35 5 = 7

Student Post-Test

Graphical Representations

Use the graph below to answer the questions.

Number of Goals per Game



1. What does the graph above represent? (Football goals)
2. What measurement is used in this graph (Goals per player)
3. Is the graph above horizontal or vertical?

Place Value To Thousands

Write out these numbers in words:

4. 34 452
5. 29 434

Write out the following numbers as a single number:

6. 3 000 + 100 + 30 + 8 =
7. 1 0000 + 900 + 90 + 1 =

Write the place value for each underlined digit

8. 93301

Patterns

Complete the following number patterns

9. 132 1 320 13 200

Number Order

Arrange the following numbers in acending order (smallest to largest)

10. 53 255 , 53 250, 53 301, 53 505

Arrange the following numbers in descending order (largest to smallest)

11. 53 255 , 53 250, 53 301, 53 505

Write a number between these two numbers

12. 15 902 ________ 15930

Time Definitions

13. Match the time units with the appropriate definitions

1- One Century (D)	(A) 365 days
2- One Day (B)	(B) 24 hours
3- One Week (E)	(C) 10 years
4- One Year (A)	(D) 100 years
5- One Decade (C)	(E) 7 days

14. Compare the time units using <, > or =.

6-One week (<) one month	7- 90 minutes (>) one hour
8- 350 days (<) one year	9- 50 years (<) one century
10- one century (>) one year	11- 60 seconds (=) one minute
12- 36 hours (>) one day	13- 9 years (<) one decade

Addition and Subtraction

15. Add the following numbers.

20 + 30 = 50 200 + 300 = 500 2000 + 3000 = 5000	4- 90 + 30 = 120 900 + 300 = 1200 9000 + 3000 = 12000

16. Subtract the following numbers

50 – 40 = 10 500 – 400 = 100 5000 – 4000 = 1000	90 – 75 = 15 900 – 750 = 150 9000 – 7500 = 1500

17. Add or subtract the following, using the thousands digit or mental calculation.

520 – 150 = 370	420 +290 = 710	940-370 = 570
630+180 = 810	170 + 480=650	1810 – 190 =620

18. Add the following.

21 + 56 = 77	458 + 304 = 762
800 + 318 = 1118	237 + 245 = 482
42 + 55 + 22 = 122	92 + 543 + 919 = 1554

19. Add the following number: 390, 281, 30, 1923 (2624)

Multiplication and Division

20. Multiply the following numbers

2 X 7 = 14	1 X 4 = 4	6 X 9 = 54
5 X 9 = 45	8 X 0 = 8	9 X 2 = 18
2 X 0 = 0	9 X 6 = 54	5 X 2 = 10

21. Divide the following numbers.

24 3 = 8	40 4 = 10	45 9 = 5
27 9 = 3	48 6 = 8	20 5 = 4
56 8 = 7	27 9 = 3	16 4 = 4

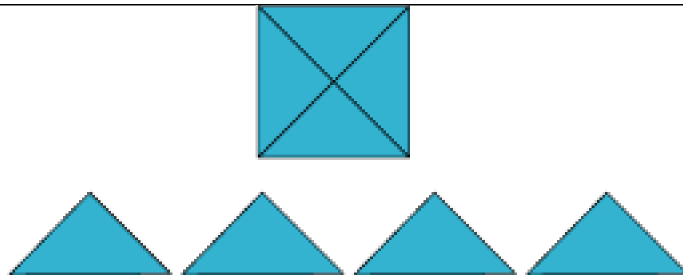
Appendix B Research Tools

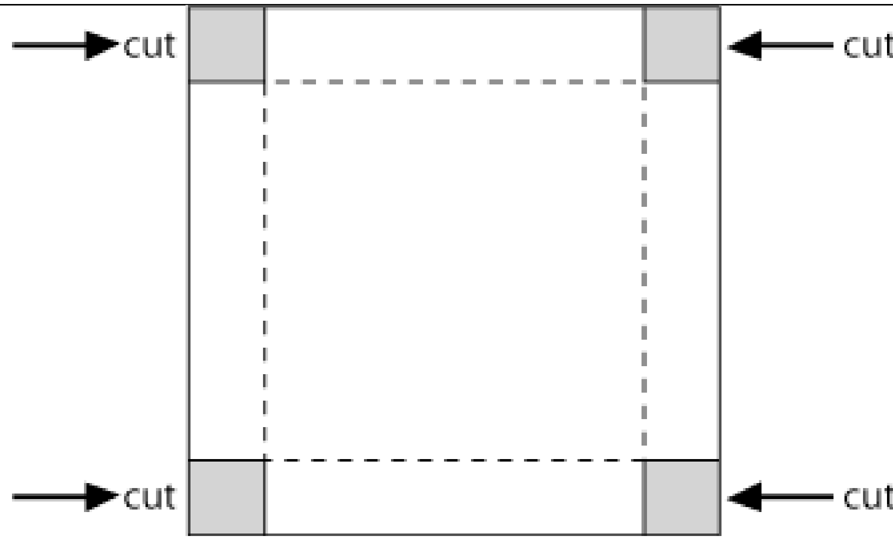
Selected N-RICH Intuitive Mathematics Puzzles

These puzzles represent a selection of the most popular puzzles that were used by students during the intuitive mathematics development portion of their development process. They were derived from the N-RICH Key Stage 2 materials, which reflect materials suitable for 7 to 11 year olds under the UK mathematical teaching system. These materials were published on the N-RICH Web site from 2008 to mid-2009. The materials were translated for accessibility to students and in order to not imposing cognitive overload on them. Students were given free choice of these materials, and allowed to try any that they liked. In some cases, these were actually games, rather than puzzles, in which case points were rewarded on completion of the game.

Name	Puzzle
Tug of War	This game is for two players - you can use the interactivity below, or you could draw a number line on a piece of paper and find a counter to use. In both cases, you will need two dice. Decide who is Plus and who is Minus. Plus moves from left to right and Minus moves from right to left. (Why do you think we have suggested this way round?) Take it in turns to throw the two dice and add the scores. Move that number of places in your direction. If the counter reaches 1, Minus has won. If the counter reaches 27, Plus has won. Is it better to play a game where you have to reach the end exactly, or where you can go over the end? What do you think and why? Once you have got the idea of this game, you can make some changes: Play again, but this time you are allowed to add or subtract the two numbers on the dice. Does this make the game better to play? Why or why not?

	Can you think of some different rules of your own? Let us know what games you invent. [This game included an applet that was used to play the game]
Tug Harder!	This game is for two players - you can use the interactivity below, or you could draw a number line on a piece of paper and find a counter to use. In both cases, you will need two dice. Decide who is Positive and who is Negative. Positive moves from left to right and Negative moves from right to left. (Why do you think we have suggested this way round?) Take it in turns to throw the two dice and add the scores then move that number of places in your direction. If the counter reaches −13, Negative has won. If the counter reaches 13, Positive has won. Is it better to play a game where you have to reach the end exactly, or where you can go over the end? What do you think and why? Now change the game. This time, when you throw the dice, you can decide whether to add, subtract, multiply or divide the numbers on the dice. You must reach −13 or 13 exactly to win. Does this make a better game? What do you think? Why or why not? How else could you change the game? Please send us your ideas!
Thousands and Millions	Do human beings live for as long as a million hours? If you have been alive for a million seconds, how many birthdays have you had? What year was it one billion minutes ago? How long would it take to count to a million ? Suppose you were worth your weight in £1 coins. How much would you be worth? Could you fit the population of London into one hundred thousand double-decker buses? Could you run one thousand metres in one minute? Could you eat exactly one tonne of food in a year without getting either very thin or very fat? Could you walk as much as one hundred thousand miles during your lifetime? Could one thousand drink cans fit into one cubic metre?
Four Triangles	If you cut a square diagonally from corner to corner you get four right-angled isosceles triangles.

	 How many different shapes can you make by fitting the four triangles back together? You may only fit long sides to long sides and short sides to short sides. The whole length of the side must be joined. Record what you do on squared paper. You could use this interactivity to try out your ideas. [Includes an interactive applet that was used to test the attempts at folding]
Legs 11	Choose any two numbers from the 7 times table. Add them together. Repeat with some other examples. Notice anything interesting? Now do the same with a different times table. What do you notice this time? Convince yourself it always happens Choose two digits and arrange them to make two double-digit numbers. For example, if you choose 5 and 2, you can make 52 and 25. Now add your two-digit numbers. Repeat with some other examples. Notice anything interesting? Convince yourself it always happens. Look at this sequence of numbers: 11, 101, 1001, 10001, 100001, . . . Divide numbers in this sequence by 11, WITHOUT using a calculator. Notice anything interesting? Convince yourself it always happens. Take any four-digit number, move the first digit to the 'back of the queue' and move the rest along. For example 5238 would become 2385. Now add your two numbers. Is the answer always a multiple of 11? Can you convince yourself? What happens when you do this with three-digit numbers? Five-digit numbers? Six-digit numbers? 38-digit numbers ... ? Prove your findings!
Making Boxes	In this problem you start with some sheets of squared paper measuring 15 × 15 and use them to make little boxes without lids. You do this by cutting out squares at the corners and then folding up the sides. (The folds are indicated by the dotted lines in the diagram.)



Begin by cutting one square out of each corner. Fold up the sides. What is the size of the base? How high are the sides? So what is its volume?

Now cut a 2 × 2 square out of each corner and fold up the sides.

Does it look as if it holds more than the first box, less than the first box or just the same amount?

What is the size of the base now? How high are the sides now? So what is its volume?

Now cut a 3 × 3 square out of each corner and fold up the sides.

Does it look as if it holds more than the other boxes, less than the other boxes or just the same amount?

What is the size of the base now? How high is it now? So what is its volume?

If you keep on doing this, taking larger and larger squares from the corners, which box will have the largest volume?

Figure 5 Selection of mathematical intuition building activities (drawn from NRICH Web Site)

Appendix C Statistical Results

A. Inter-item Correlation Matrices for Individual Sub-Scales of Student Instrument

	graph_1	graph_2	graph_3
graph_1	1.000	.497	.067
graph_2	.497	1.000	-.151
graph_3	.067	-.151	1.000

Table 15 Inter-item correlation matrix, Graphing and Representation

	stat_1	stat_2	stat_3	stat_4	stat_5	stat_6	stat_7	stat_8
stat_1	1.000	.007	.175	.007	.007	.007	-.251	.418
stat_2	.007	1.000	-.343	.161	.329	.329	.251	-.084
stat_3	.175	-.343	1.000	.161	-.007	.161	-.418	.084
stat_4	.007	.161	.161	1.000	-.007	.329	-.084	-.084
stat_5	.007	.329	-.007	-.007	1.000	.497	.084	.251
stat_6	.007	.329	.161	.329	.497	1.000	-.084	.084
stat_7	-.251	.251	-.418	-.084	.084	-.084	1.000	-.333
stat_8	.418	-.084	.084	-.084	.251	.084	-.333	1.000

Table 16 Inter-item correlation matrix, Statistics

	place_1	place_2	place_3
place_1	1.000	.122	.130
place_2	.122	1.000	.290
place_3	.130	.290	1.000

Table 17 Inter-item correlation matrix, Place Value

	order_1	order_2	order_3
order_1	1.000	-.125	.158
order_2	-.125	1.000	-.316
order_3	.158	-.316	1.000

Table 18 Inter-item correlation matrix, Orderin

	time_1	time_2	time_3	time_4	time_5	time_6	time_7	time_8
time_1	1.000	-.111	.053	-.370	.053	.053	-.296	.652
time_2	-.111	1.000	.053	.053	-.370	-.159	-.059	.178
time_3	.053	.053	1.000	-.008	.193	.193	-.103	.122
time_4	-.370	.053	-.008	1.000	-.008	.395	.348	-.329
time_5	.053	-.370	.193	-.008	1.000	-.008	-.103	-.103
time_6	.053	-.159	.193	.395	-.008	1.000	.122	.122
time_7	-.296	-.059	-.103	.348	-.103	.122	1.000	-.263
time_8	.652	.178	.122	-.329	-.103	.122	-.263	1.000

Table 19 Inter-item correlation matrix, Time

	add 1	add 2	add 3	add 4	add 5	add 6	add 7	sub 1	sub 2	sub 3	add sub 1	add sub 2	add sub 3
add_1	1.000	.015	.071	.044	.120	.299	-.418	-.098	.314	.071	-.029	-.099	-.306
add_2	.015	1.000	-.038	.071	.130	.519	-.259	-.159	.201	.330	.387	-.222	.071
add_3	.071	-.038	1.000	.324	.059	.059	.059	-.145	-.269	-.007	-.099	-.510	-.194
add_4	.044	.071	.324	1.000	.000	.000	.365	-.050	.044	-.022	-.480	-.194	-.422
add_5	.120	.130	.059	.000	1.000	.250	.250	.204	.299	.059	.299	.059	.000
add_6	.299	.519	.059	.000	.250	1.000	-.125	.204	.299	.414	.120	-.296	-.183
add_7	-.418	-.259	.059	.365	.250	-.125	1.000	.204	-.060	.059	-.239	.237	.183
sub_1	-.098	-.159	-.145	-.050	.204	.204	.204	1.000	.293	.048	.098	.048	.348
sub_2	.314	.201	-.269	.044	.299	.299	-.060	.293	1.000	.580	-.029	.240	-.131
sub_3	.071	.330	-.007	-.022	.059	.414	.059	.048	.580	1.000	-.099	-.007	-.022
addsub_1	-.029	.387	-.099	-.480	.299	.120	-.239	.098	-.029	-.099	1.000	.071	.567
addsub_2	-.099	-.222	-.510	-.194	.059	-.296	.237	.048	.240	-.007	.071	1.000	.324
addsub_3	-.306	.071	-.194	-.422	.000	-.183	.183	.348	-.131	-.022	.567	.324	1.000

Table 20 Inter-item correlation matrix, Addition and Subtraction

	mult_1	mult_2	mult_3	mult_4	mult_5	mult_6	div_1	div_2	div_3	div_4	div_5	div_6
mult_1	1.000	.044	.149	.044	.348	-.346	.111	.218	.183	.071	.111	.000
mult_2	.044	1.000	.098	.314	-.098	.302	.393	.486	.299	.387	.218	.299
mult_3	.149	.098	1.000	-.293	-.111	.000	.348	.293	.204	.265	.149	.000
mult_4	.044	.314	-.293	1.000	-.293	.076	-.131	-.029	-.239	.015	.567	.299
mult_5	.348	-.098	-.111	-.293	1.000	-.258	-.050	.098	.204	.053	-.248	-.204
mult_6	-.346	.302	.000	.076	-.258	1.000	.115	.302	.158	.205	.115	-.079
div_1	.111	.393	.348	-.131	-.050	.115	1.000	.393	.365	.260	.111	.183
div_2	.218	.486	.293	-.029	.098	.302	.393	1.000	.299	.201	.218	.120
div_3	.183	.299	.204	-.239	.204	.158	.365	.299	1.000	.713	-.183	.250
div_4	.071	.387	.265	.015	.053	.205	.260	.201	.713	1.000	-.118	.324
div_5	.111	.218	.149	.567	-.248	.115	.111	.218	-.183	-.118	1.000	.000
div_6	.000	.299	.000	.299	-.204	-.079	.183	.120	.250	.324	.000	1.000

Table 21 Inter-item correlation matrix, Multiplication and Division

	graph_avg	stat_avg	place_avg	order_avg	time_avg	add_sub_avg	mult_div_avg
graph_avg	1.000	.204	-.202	.243	.037	.157	-.138
stat_avg	.204	1.000	.453	.229	.006	.528	.386
place_avg	-.202	.453	1.000	-.113	.048	.204	.424
order_avg	.243	.229	-.113	1.000	.016	.322	-.024
time_avg	.037	.006	.048	.016	1.000	.091	-.064
add_sub_avg	.157	.528	.204	.322	.091	1.000	.354
mult_div_avg	-.138	.386	.424	-.024	-.064	.354	1.000

Table 22 Inter-item correlation matrix, Sub-scale Average scores

	graph_tot	stat_tot	place_tot	order_tot	time_tot	add_sub_tot	mult_div_tot
graph_tot	1.000	.204	-.202	.243	.037	.157	-.138
stat_tot	.204	1.000	.453	.229	.006	.528	.386
place_tot	-.202	.453	1.000	-.113	.048	.204	.424
order_tot	.243	.229	-.113	1.000	.016	.322	-.024
time_tot	.037	.006	.048	.016	1.000	.091	-.064
add_sub_tot	.157	.528	.204	.322	.091	1.000	.354
mult_div_tot	-.138	.386	.424	-.024	-.064	.354	1.000

Table 23 Inter-item correlation matrix, Sub-scale Total scores

B. **Pre-test Descriptive Statistics**

Subscale	Variable	Mean	Median	Mode	Std. Deviation
Graphing and Representation	graph_1	0.875	1	1	0.33783
	graph_2	0.625	1	1	0.49454
	graph_3	0.4167	0	0	0.50361
Statistics	stat_1	0.4583	0	0	0.50898
	stat_2	0.5417	1	1	0.50898
	stat_3	0.5417	1	1	0.50898
	stat_4	0.5417	1	1	0.50898
	stat_5	0.5417	1	1	0.50898
	stat_6	0.5417	1	1	0.50898
	stat_7	0.5	0.5	NA	0.51075
	stat_8	0.5	0.5	NA	0.51075
Places	place_1	0.7083	1	1	0.46431
	place_2	0.7917	1	1	0.41485
	place_3	0.6667	1	1	0.48154
Patterns	pattern	0.75	1	1	0.44233
Ordering	order_1	0.6667	1	1	0.48154
	order_2	0.6667	1	1	0.48154
	order_3	0.8333	1	1	0.38069
Time	time_1	0.75	1	1	0.44233
	time_2	0.75	1	1	0.44233
	time_3	0.7083	1	1	0.46431
	time_4	0.7083	1	1	0.46431
	time_5	0.7083	1	1	0.46431
	time_6	0.7083	1	1	0.46431
	time_7	0.7917	1	1	0.41485
	time_8	0.7917	1	1	0.41485
Addition and Subtraction	add_1	0.5833	1	1	0.50361
	add_2	0.7083	1	1	0.46431
	add_3	0.5417	1	1	0.50898
	add_4	0.625	1	1	0.49454
	add_5	0.6667	1	1	0.48154
	add_6	0.6667	1	1	0.48154
	add_7	0.6667	1	1	0.48154
	sub_1	0.75	1	1	0.44233
	sub_2	0.5833	1	1	0.50361
	sub_3	0.5417	1	1	0.50898
	addsub_1	0.5833	1	1	0.50361
Multiplication and Division	addsub_2	0.5417	1	1	0.50898
	addsub_3	0.625	1	1	0.49454
	mult_1	0.625	1	1	0.49454
	mult_2	0.5833	1	1	0.50361
	mult_3	0.75	1	1	0.44233
	mult_4	0.5833	1	1	0.50361
	mult_5	0.75	1	1	0.44233
	mult_6	0.8333	1	1	0.38069

	div_1	0.625	1	1	0.49454
	div_2	0.5833	1	1	0.50361
	div_3	0.6667	1	1	0.48154
	div_4	0.7083	1	1	0.46431
	div_5	0.625	1	1	0.49454
	div_6	0.6667	1	1	0.48154

Table 24 Pre-test descriptive statistics, individual items

C. **Test-Retest Reliability (Spearman Brown Prophesy Coefficient)**

Cronbach's Alpha	Part 1	Value	.799
		N of Items	59[a]
	Part 2	Value	.736
		N of Items	59[b]
	Total N of Items		118
Correlation Between Forms			.912
Spearman-Brown Coefficient	Equal Length		.954
	Unequal Length		.954
Guttman Split-Half Coefficient			.890

a. The items are: graph_1, graph_2, graph_3, stat_1, stat_2, stat_3, stat_4, stat_5, stat_6, stat_7, stat_8, place_1, place_2, place_3, pattern, order_1, order_2, order_3, time_1, time_2, time_3, time_4, time_5, time_6, time_7, time_8, add_1, add_2, add_3, add_4, add_5, add_6, add_7, sub_1, sub_2, sub_3, addsub_1, addsub_2, addsub_3, mult_1, mult_2, mult_3, mult_4, mult_5, mult_6, div_1, div_2, div_3, div_4, div_5, div_6, graph_avg, graph_tot, stat_avg, stat_tot, place_avg, place_tot, order_avg, order_tot.

b. The items are: time_avg, time_tot, add_sub_avg, add_sub_tot, mult_div_avg, mult_div_tot, total_score, tot_pct, graph_1_2, graph_2_2, graph_3_2, stat_1_2, stat_2_2, stat_3_2, stat_4_2, stat_5_2, stat_6_2, stat_7_2, stat_8_2, place_1_2, place_2_2, place_3_2, pattern_2, order_1_2, order_2_2, order_3_2, time_1_2, time_2_2, time_3_2, time_4_2, time_5_2, time_6_2, time_7_2, time_8_2, add_1_2, add_2_2, add_3_2, add_4_2, add_5_2, add_6_2, add_7_2, sub_1_2, sub_2_2, sub_3_2, addsub_1_2, addsub_2_2, addsub_3_2, mult_1_2, mult_2_2, mult_3_2, mult_4_2, mult_5_2, mult_6_2, div_1_2, div_2_2, div_3_2, div_4_2, div_5_2, div_6_2.

D. Descriptive Statistics for Individual Items (Post-tests)

	Mean	Median	Mode	Std. Deviation
graph_1	0.9167	1	1	0.28233
graph_2	0.8333	1	1	0.38069
graph_3	0.625	1	1	0.49454
stat_1	0.7917	1	1	0.41485
stat_2	0.7917	1	1	0.41485
stat_3	0.75	1	1	0.44233
stat_4	0.75	1	1	0.44233
stat_5	0.75	1	1	0.44233
stat_6	0.6667	1	1	0.48154
stat_7	0.75	1	1	0.44233
stat_8	0.625	1	1	0.49454
place_1	0.8333	1	1	0.38069
place_2	0.8333	1	1	0.38069
place_3	0.6667	1	1	0.48154
pattern	0.7917	1	1	0.41485
order_1	0.7083	1	1	0.46431
order_2	0.6667	1	1	0.48154
order_3	0.8333	1	1	0.38069
time_1	0.7917	1	1	0.41485
time_2	0.75	1	1	0.44233
time_3	0.7083	1	1	0.46431
time_4	0.7083	1	1	0.46431
time_5	0.75	1	1	0.44233
time_6	0.7083	1	1	0.46431
time_7	0.7917	1	1	0.41485
time_8	0.7917	1	1	0.41485
add_1	0.625	1	1	0.49454
add_2	0.875	1	1	0.33783
add_3	0.7083	1	1	0.46431
add_4	0.6667	1	1	0.48154
add_5	0.75	1	1	0.44233
add_6	0.6667	1	1	0.48154
add_7	0.6667	1	1	0.48154
sub_1	0.8333	1	1	0.38069
sub_2	0.625	1	1	0.49454
sub_3	0.6667	1	1	0.48154
addsub_1	0.625	1	1	0.49454
addsub_2	0.75	1	1	0.44233
addsub_3	0.625	1	1	0.49454
mult_1	0.5833	1	1	0.50361
mult_2	0.6667	1	1	0.48154
mult_3	0.8333	1	1	0.38069
mult_4	0.6667	1	1	0.48154
mult_5	0.875	1	1	0.33783
mult_6	0.875	1	1	0.33783

div_1	0.5833	1	1	0.50361
div_2	0.625	1	1	0.49454
div_3	0.6667	1	1	0.48154
div_4	0.75	1	1	0.44233
div_5	0.75	1	1	0.44233
div_6	0.7917	1	1	0.41485

Table 25 Descriptive statistics for individual items (post-tests)

E. Means Comparison for Pre-Test, Post-Test and Total (Individual Items)

test_run	pretest		posttest		Total	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
graph_1	0.875	0.33783	0.9167	0.28233	0.8958	0.30871
graph_2	0.6667	0.48154	0.8333	0.38069	0.75	0.43759
graph_3	0.4167	0.50361	0.625	0.49454	0.5208	0.50485
stat_1	0.4583	0.50898	0.7917	0.41485	0.625	0.48925
stat_2	0.5417	0.50898	0.7917	0.41485	0.6667	0.47639
stat_3	0.5417	0.50898	0.75	0.44233	0.6458	0.48332
stat_4	0.5417	0.50898	0.75	0.44233	0.6458	0.48332
stat_5	0.5833	0.50361	0.75	0.44233	0.6667	0.47639
stat_6	0.5417	0.50898	0.6667	0.48154	0.6042	0.4942
stat_7	0.5	0.51075	0.75	0.44233	0.625	0.48925
stat_8	0.5	0.51075	0.625	0.49454	0.5625	0.50133
place_1	0.7083	0.46431	0.8333	0.38069	0.7708	0.42474
place_2	0.7917	0.41485	0.8333	0.38069	0.8125	0.39444
place_3	0.7083	0.46431	0.6667	0.48154	0.6875	0.46842
pattern	0.75	0.44233	0.7917	0.41485	0.7708	0.42474
order_1	0.6667	0.48154	0.7083	0.46431	0.6875	0.46842
order_2	0.6667	0.48154	0.6667	0.48154	0.6667	0.47639
order_3	0.8333	0.38069	0.8333	0.38069	0.8333	0.37662
time_1	0.75	0.44233	0.7917	0.41485	0.7708	0.42474
time_2	0.75	0.44233	0.75	0.44233	0.75	0.43759
time_3	0.7083	0.46431	0.7083	0.46431	0.7083	0.45934
time_4	0.7083	0.46431	0.7083	0.46431	0.7083	0.45934
time_5	0.7083	0.46431	0.75	0.44233	0.7292	0.44909
time_6	0.7083	0.46431	0.7083	0.46431	0.7083	0.45934
time_7	0.7917	0.41485	0.7917	0.41485	0.7917	0.41041
time_8	0.7917	0.41485	0.7917	0.41485	0.7917	0.41041
add_1	0.5833	0.50361	0.625	0.49454	0.6042	0.4942
add_2	0.7083	0.46431	0.875	0.33783	0.7917	0.41041
add_3	0.5417	0.50898	0.7083	0.46431	0.625	0.48925
add_4	0.625	0.49454	0.6667	0.48154	0.6458	0.48332
add_5	0.6667	0.48154	0.75	0.44233	0.7083	0.45934
add_6	0.6667	0.48154	0.6667	0.48154	0.6667	0.47639
add_7	0.6667	0.48154	0.6667	0.48154	0.6667	0.47639
sub_1	0.75	0.44233	0.8333	0.38069	0.7917	0.41041
sub_2	0.5833	0.50361	0.625	0.49454	0.6042	0.4942
sub_3	0.5417	0.50898	0.6667	0.48154	0.6042	0.4942
addsub_1	0.5833	0.50361	0.625	0.49454	0.6042	0.4942
addsub_2	0.5417	0.50898	0.75	0.44233	0.6458	0.48332
addsub_3	0.625	0.49454	0.625	0.49454	0.625	0.48925
mult_1	0.625	0.49454	0.5833	0.50361	0.6042	0.4942
mult_2	0.5833	0.50361	0.6667	0.48154	0.625	0.48925
mult_3	0.75	0.44233	0.8333	0.38069	0.7917	0.41041
mult_4	0.5833	0.50361	0.6667	0.48154	0.625	0.48925
mult_5	0.75	0.44233	0.875	0.33783	0.8125	0.39444

mult_6	0.8333	0.38069	0.875	0.33783	0.8542	0.35667
div_1	0.625	0.49454	0.5833	0.50361	0.6042	0.4942
div_2	0.5833	0.50361	0.625	0.49454	0.6042	0.4942
div_3	0.6667	0.48154	0.6667	0.48154	0.6667	0.47639
div_4	0.7083	0.46431	0.75	0.44233	0.7292	0.44909
div_5	0.6667	0.48154	0.75	0.44233	0.7083	0.45934
div_6	0.6667	0.48154	0.7917	0.41485	0.7292	0.44909

Table 26 Results of Pre-test, Post-test, and Total Means and Standard Deviation Comparisons

F. Paired-Samples T-tests (Individual Items)

Note: Highlighted pairs are those that indicated a statistically significant difference in the means, using a confidence level of .05.

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	graph_1 - graph12	-.04167	.46431	.09478	-.23773	.15439	-.440	23	.664
Pair 2	graph_2 - graph22	-.16667	.38069	.07771	-.32742	-.00591	-2.145	23	.043
Pair 3	graph_3 - graph32	-.20833	.50898	.10389	-.42326	.00659	-2.005	23	.057
Pair 4	stat_1 - stat12	-.33333	.56466	.11526	-.57177	-.09490	-2.892	23	.008
Pair 5	stat_2 - stat22	-.25000	.53161	.10851	-.47448	-.02552	-2.304	23	.031
Pair 6	stat_3 - stat32	-.20833	.41485	.08468	-.38351	-.03316	-2.460	23	.022
Pair 7	stat_4 - stat42	-.20833	.50898	.10389	-.42326	.00659	-2.005	23	.057
Pair 8	stat_5 - stat52	-.16667	.56466	.11526	-.40510	.07177	-1.446	23	.162
Pair 9	stat_6 - stat62	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083
Pair 10	stat_7 - stat72	-.25000	.44233	.09029	-.43678	-.06322	-2.769	23	.011
Pair 11	stat_8 - stat82	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083
Pair 12	place_1 - place12	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083
Pair 13	place_2 - place22	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 14	place_3 - place32	.04167	.35864	.07321	-.10977	.19311	.569	23	.575
Pair 15	pattern - pattern2	-.04167	.35864	.07321	-.19311	.10977	-.569	23	.575
Pair 16	order_1 - order12	-.04167	.35864	.07321	-.19311	.10977	-.569	23	.575
Pair 19	time_1 - time12	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 23	time_5 - time52	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 24	time_6 - time62	.00000	.29488	.06019	-.12452	.12452	.000	23	1.000
Pair 27	add_1 - add12	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 28	add_2 - add22	-.16667	.38069	.07771	-.32742	-.00591	-2.145	23	.043
Pair	add_3 - add32	-	.38069	.07771	-.32742	-.00591	-	23	.043

29		.16667					2.145		
Pair 30	add_4 - add42	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 31	add_5 - add52	-.08333	.28233	.05763	-.20255	.03588	-1.446	23	.162
Pair 34	sub_1 - sub12	-.08333	.28233	.05763	-.20255	.03588	-1.446	23	.162
Pair 35	sub_2 - sub22	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 36	sub_3 - sub_3_2	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083
Pair 37	addsub_1 - addsub12	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 38	addsub_2 - addsub22	-.20833	.41485	.08468	-.38351	-.03316	-2.460	23	.022
Pair 40	mult_1 - mult12	.04167	.20412	.04167	-.04453	.12786	1.000	23	.328
Pair 41	mult_2 - mult22	-.08333	.28233	.05763	-.20255	.03588	-1.446	23	.162
Pair 42	mult_3 - mult32	-.08333	.28233	.05763	-.20255	.03588	-1.446	23	.162
Pair 43	mult_4 - mult42	-.08333	.28233	.05763	-.20255	.03588	-1.446	23	.162
Pair 44	mult_5 - mult52	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083
Pair 45	mult_6 - mult62	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 46	div_1 - div12	.04167	.20412	.04167	-.04453	.12786	1.000	23	.328
Pair 47	div_2 - div22	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 49	div_4 - div42	-.04167	.20412	.04167	-.12786	.04453	-1.000	23	.328
Pair 50	div_5 - div52	-.08333	.40825	.08333	-.25572	.08905	-1.000	23	.328
Pair 51	div_6 - div62	-.12500	.33783	.06896	-.26765	.01765	-1.813	23	.083

Table 27 Paired samples t-tests for individual items

		N	Correlation	Sig.
Pair 1	graph_1 & graph12	24	-.114	.596
Pair 2	graph_2 & graph22	24	.632	.001
Pair 3	graph_3 & graph32	24	.480	.018
Pair 4	stat_1 & stat12	24	.266	.209
Pair 5	stat_2 & stat22	24	.352	.092
Pair 6	stat_3 & stat32	24	.628	.001
Pair 7	stat_4 & stat42	24	.435	.034
Pair 8	stat_5 & stat52	24	.293	.165
Pair 9	stat_6 & stat62	24	.769	.000
Pair 10	stat_7 & stat72	24	.577	.003
Pair 11	stat_8 & stat82	24	.775	.000
Pair 12	place_1 & place12	24	.697	.000
Pair 13	place_2 & place22	24	.872	.000

Pair 14	place_3 & place32	24	.713	.000
Pair 15	pattern & pattern2	24	.652	.001
Pair 16	order_1 & order12	24	.713	.000
Pair 19	time_1 & time12	24	.889	.000
Pair 23	time_5 & time52	24	.900	.000
Pair 24	time_6 & time62	24	.798	.000
Pair 27	add_1 & add12	24	.917	.000
Pair 28	add_2 & add22	24	.589	.002
Pair 29	add_3 & add32	24	.698	.000
Pair 30	add_4 & add42	24	.913	.000
Pair 31	add_5 & add52	24	.816	.000
Pair 34	sub_1 & sub12	24	.775	.000
Pair 35	sub_2 & sub22	24	.917	.000
Pair 36	sub_3 & sub_3_2	24	.769	.000
Pair 37	addsub_1 & addsub12	24	.917	.000
Pair 38	addsub_2 & addsub22	24	.628	.001
Pair 40	mult_1 & mult12	24	.917	.000
Pair 41	mult_2 & mult22	24	.837	.000
Pair 42	mult_3 & mult32	24	.775	.000
Pair 43	mult_4 & mult42	24	.837	.000
Pair 44	mult_5 & mult52	24	.655	.001
Pair 45	mult_6 & mult62	24	.845	.000
Pair 46	div_1 & div12	24	.917	.000
Pair 47	div_2 & div22	24	.917	.000
Pair 49	div_4 & div42	24	.900	.000
Pair 50	div_5 & div52	24	.612	.001
Pair 51	div_6 & div62	24	.725	.000

Table 28 Paired samples correlations, individual items