Curriculum Integration in Senior High School Physics Courses

by

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B. Ed., University of Victoria, 1983
B. Sc., University of Victoria, 1993

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ABSTRACT

Curriculum integration has become an important theme in discussions on school reform during the past ten to fifteen years (Bullough, 1999; Erickson, 2001). Martin-Kniep, Feige and Soodak (1995) maintain that integration can help students to understand and appreciate the complexity of the world that they are living in. In addition, Hargreaves and Moore (2000) claim that curriculum integration can inspire students to discover relevance in their education. Therefore, curriculum integration is perceived by many educators as the key to helping students prepare for the great changes that the developed nations are experiencing at this time (Meier, 1996; Tchudi & Lafer, 1996).

The purpose of this study was to examine the impact of integrating a unit in Physics 11 with history of science, language arts and social studies on the academic achievement, attendance and attitudes of high school students. A second purpose was to assess whether it is feasible to provide curriculum integration without restructuring the current high school organization and offering in-depth professional development for teachers. A mixed methods research design was used to examine the effectiveness of this strategy by comparing a treatment group with a comparison group.

Significant gains were realized in student attendance, unit and test marks. There was a clear impact on achievement and attitudes of students through integration. Analysis of individual student writings and projects not only demonstrated that integration had occurred, but also gave interesting insights into student learning and perceptions of science content, understanding and relevance. Interview data with participating teachers and reflections by the action teacher revealed numerous benefits of teachers working together on integrated curriculum. Moreover, these data made it clear that a simple model of integration was viable in the current school structure. This study demonstrated the benefits of using curriculum integration in order to help prepare students more thoroughly for further studies and work in the real world. It also presented a practical and realistic method of curriculum integration without requiring restructuring, funding and formal professional development.

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Chapter 1

Introduction, Context and Focus

Introduction

It is the beginning of the 21st century. The people of developed nations are living in a world that is experiencing profound changes at all levels of life in part due to the development of technology and science. The internet, cell phones and wireless handheld devices have changed communication, pace of life and expectations. North American students graduating from high school are entering a bewildering world. It is a world that is more connected, but causes greater isolation of individuals; a world that has greater life expectancy, but faces the challenge of dealing with global warming; a world that is aware of fair trade and exploitation of undeveloped nations, but has to cope with terrorism and conspiracy. What can educators do to help prepare these students for the complex, exhilarating and challenging life of the 21st century?

Curriculum Integration

Curriculum integration has become an essential theme in discussions on school reform during the past ten to fifteen years (Bullough, 1999; Erickson, 2001; Tchudi & Lafer, 1996). Educators involved with curriculum integration have become aware of the impact of this approach to education. Martin-Kniep, Feige and Soodak (1995) stated that well thought out integration can help students to “understand the connections between apparently disparate bodies of knowledge and better appreciate the inherent complexity of the world we live in” (p. 227). Erickson explained that the purpose of the integrated curriculum was “to cause students to integrate their thinking at a conceptual level by seeing the patterns and connections between transferable, conceptual ideas and the topic under study" (p. 69). Many educators have observed how an integrated curriculum can inspire students' focus and engagement (Hargreaves & Moore, 2000). Furthermore, the current dissatisfaction of many students with their education (Jacobs, 1989; Tchudi & Lafer) makes the promotion of integration an imperative consideration.

What about the advantages outlined by Martin-Kniep et al. (1995) and Erickson (2001)? Does their value indicate that curriculum integration should be considered a priority? Integration is not a new idea, but it has been resurrected once again. Why? What makes curriculum integration so important in the 21st century? Why do Tchudi and Lafer (1996) advocate interdisciplinary, integrated teaching as the most auspicious reform movement available to present day teachers? The literature review of curriculum integration points to two possible reasons. The first reason is concerned with the current expectations and required skills and expertise to obtain fulfilling work as adults, and the second reason concerns pedagogy. The work world of developed nations has dramatically changed during the past years. For instance, astronomers are no longer merely working with other astronomers and mathematicians. Rather, in order to understand the role of their specialty in the context of today's world, astronomers must be able to converse intelligently and constructively with members of other disciplines. At the Dominion Astrophysical Observatory in Victoria, BC, J. J. Kavelaars, an astronomer, studies the solar system. In the past he has worked on teams that have discovered moons around Neptune. Currently Kavelaars is engaged with mapping the Kuiper Belt, a field of asteroids on the outer reaches of the solar system. In his every day work, meetings with historians, geophysicists, statisticians and technicians have become a crucial component of his research and studies (personal communication, June 2005). This example of the change in work expectations for astronomers illustrates a fundamental shift in the work world of the 21st century. Miller and McCartan (1990) argued that not only are blended fields, such as biophysics and ethno-history, becoming more common, but also that the most significant research in these fields is happening in the areas where these disciplines overlap. For example, studies by particle physicists on characteristics of fundamental components of matter have become relevant to cosmologists as they attempt to understand the beginning and evolution of the universe (Haseltine, 2002). Therefore, using curriculum integration could prepare students for the increasingly broader and more complex demands on people in the workforce.

The second reason that contributes to the interest in curriculum integration as indispensable for school reform, deals with pedagogy. It has been shown that learning is more effective when knowledge is structured into relevant units (Gaff, 1989). Using the disciplinary model has led to a "linear, sequential, easily quantifiable ordering system" (Doll, 1993, p.3). Students are capable of memorizing and understanding concepts superficially, but they lack in great part the ability to transfer knowledge from one discipline to another (Perkins, 1991; Tchudi & Lafer, 1996). A common complaint from upper level science teachers is that their students understand concepts, but are not capable of using mathematical skills required to develop and apply the concepts. The skills that are learned in mathematics classes are not transferred to courses in chemistry and physics. Advocates of curriculum integration have suggested that the integrated curriculum can provide the opportunity for students to develop deeper understanding, transfer across disciplines and a greater appreciation of the relevance of their education (Fogarty, 1991a; Jacobs, 1989; Lounsbury, 1992). No one claims that the interdisciplinary approach would solve all concerns with the present education system. However, given the changing demands in the workforce and abilities to live a satisfying life, and the lack of relevance and transfer of learned skills, the benefits of curriculum integration promise a rewarding alternative.

Challenges for Curriculum Integration

If there are so many worthwhile advantages to curriculum integration, why have school systems not adopted this method wholeheartedly throughout North America? Most of the classrooms in elementary and especially high schools teach from the four main disciplines (Gehrke, 1998), humanities, science, practical arts and fine arts (Fogarty, 1991a). Educators, who have studied the implementation or lack of implementation of curriculum integration, have discovered that there are substantial impediments to this curriculum design, which need to be overcome. If teachers have not experienced integrated curricula as students themselves, it is very unlikely that they will teach using this method (Basista & Mathews, 2002; Gaff, 1989). Another reason that teachers might hesitate to use curriculum integration is their personal knowledge base. “In the United States secondary teachers are educated in very narrow disciplines, while elementary teachers have little specific discipline training. Thus teachers who are expected to work together to provide an integrated approach to learning may find their own lack of information the greatest impediment of all” (Kysilka, 1998, p. 208). There is also the issue of funding. Using curriculum integration successfully appears to require a large financial support (Meier, 1996). The restructuring of timetables, professional development for teachers and the requirements of new and different curriculum resources, are all costly components of providing curriculum integration.

Nevertheless, despite these possible hindrances to the use of curriculum integration, this method of education has been promoted as an important complement to or replacement of traditional curriculum designs (Gehrke, 1998; Hargreaves & Moore, 2000; Kysilka, 1998). Curriculum integration has so much to offer education that regardless of the difficulties, it is worthwhile pursuing. Senior high school physics teachers are challenged by this mandate. The content taught at the senior level completely fills the available 100 hours of contact time and it appears that there is little opportunity to promote interdisciplinary connections. As discussed above, concepts in a particular subject area are much more specialized at this level and many teachers are simply not qualified to make cross-curricular connections because they do not have the background in other subject areas. There have been some cases of physics being successfully integrated with mathematics (Hatch & Smith, 2004; Saeki, Ujiie & Tsukihashi, 2001). Since the study of physics depends very much on mathematics, it is not surprising that these closely related areas were successfully integrated. Therefore, the central focus of this study was to ascertain whether a unit of Physics 11 could be integrated with topics from the humanities, given the impediments to integration as previously discussed. Was it possible for integration to be achieved at a level that made an impact and benefited students in the existing school structure? The objective of this study was to explore whether a simple model of integration could enhance the education of Physics 11 students, while avoiding the limitations of timetables, lack of funds and professional development for teachers.

Summary

Curriculum integration has been shown to be a very important aspect of current school reform. It presents a number of possible ways of preparing students for the complex world after high school and of deepening their learning. The Pan-Canadian Framework for Science (CMEC, 1997) promotes science literacy for all Canadians that will allow them to participate more fully in the public debate about science, technology, society and environment issues. At the same time, there are a number of obstacles due to lack of teacher knowledge and funding. This study expected to demonstrate that it is beneficial for teachers to put effort into curriculum integration in order to help prepare their students more thoroughly for further studies and work in the real world. Given the potential impact on the achievement and attitudes of the students, the study aspired to consider a viable method of curriculum integration in order to alleviate some of the present obstacles to this method of education.

In the next chapter, the relevant literature on integrated curricula will be examined and summarized. The background of curriculum integration will be briefly discussed as well as a number of successful implementations of this education method.

Chapter 2

Literature Review

Introduction

This chapter is a review of the literature relating to curriculum integration. It is divided into three sections, the background of curriculum integration; the benefits of curriculum integration and examples of successful implementation of this teaching method; and the requirements and possible obstacles of curriculum integration. The first section on the background will include numerous definitions. Various forms of curriculum integration will be discussed as well as the influence of John Dewey on this method of education. It will also include a brief outline of the historical development of curriculum integration. The section on the benefits of integrated curriculum will discuss literature that reflects the renewed interest in this method of teaching and its advantages. A summary of examples of curriculum integration in a number of different school districts in a variety of teaching areas will be included. In the last section, the requirements for using curriculum integration successfully will be outlined, as well as a number of obstacles that challenge the immediate and wholehearted adoption of this approach.

Background of Curriculum Integration

The term curriculum integration is mentioned frequently in education literature, but its interpretation and use is not applied consistently. Not only are there numerous definitions for curriculum integration, but the extent with which curriculum integration is applied varies greatly. Before the benefits and challenges of curriculum integration can be discussed, the diversity of definitions and uses of curriculum integration must be examined.

Definitions of curriculum integration. The literature on curriculum integration revealed a large number of different definitions and a great variety of detail contained by these definitions. They ranged from broad definitions to specific details of curriculum integration levels on a continuum. Moss and Noden (1995) used one of the most straightforward definitions. Curriculum integration "generally refers to making connections between and among the various subject areas" (p. 358). Martin-Kniep et al. (1995) proposed that integration "generally refers to any putting together or relating of things, either conceptually or organizationally" (p. 228). They suggested that there were four types: "(1) integration of content; (2) integration of skills/processes; (3) integration of school and self; and (4) holistic integration" (p.230). Gehrke's (1998) definition was more descriptive:

> Curriculum integration is a collective term for those forms of curriculum in which student learning activities are built, less with concern for delineating disciplinary boundaries around kinds of learning, and more with the notion of helping students recognize or create their own learning. (p. 248)

Lake (1994) and Harris and Alexander (1998) discussed the term interdisciplinary curriculum as being equivalent to the term integrated curriculum. Harris and Alexander made an interesting distinction between intradisciplinary and interdisciplinary curriculum. They proposed that intradisciplinary integration referred to integration of closely associated subject matter, such as language arts and social studies, both classified as topics in humanities. On the other hand, interdisciplinary integration was seen as the integration of subject areas from different disciplines, such as language arts and mathematics. In Lake's (1994) summary of integrated curriculum, she listed a number of definitions from a number of different educators. She concluded that the definitions indicated that the purpose of an integrated curriculum was to prepare students for a life of learning, which required obtaining skills, which would not be found in discrete, fragmented subject matter. Dressel (1958) did not envision curriculum integration as just connecting different subjects. He believed that the purpose of curriculum integration was to provide students with a framework that would enable them to create new conceptual structures for understanding the world. He stressed the importance of students being able to perceive new relationships.

Though the various definitions of curriculum integration differed from each other, there was a common theme, relationship. Based on these definitions, it was inferred that the purpose of curriculum integration is to provide opportunities for students to make connections between skills, knowledge, concepts, environment and themselves, and to use these connections to relate to the real world and solve complex and interconnected problems. It was also evident that the implementation of curriculum integration occurs at various levels. Drake (1993) distinguished between multidisciplinary, interdisciplinary and transdisciplinary integration. Multidisciplinary integration involved looking at the same topic from a number of different disciplines, but remaining aware of each discipline. Interdisciplinary integration was defined as recognizing specific skills and ideas, which were common to different disciplines, and developing those skills and ideas. The purpose of transdisciplinary integration was to investigate knowledge as it related to the real world. Jacobs (1989) identified six curriculum options: discipline-based content, parallel disciplines, multidisciplinary, interdisciplinary, integrated day and complete integration. Together these six options formed a continuum from discipline-based content, which contained no attempt at integration to complete integration in which the curriculum was created out of the students' day-to-day lives. Jacobs also discussed the value of combining some of the options to meet the specific needs of the students and environment. Bullough (1999) summarized the five designs developed by Alberty in the 1940s. They ranged from type one, based on separate subjects to type five, based on integrated curriculum emerging from the cooperative planning by both teacher and student, without the use of any traditional structure. One of the most thorough and detailed integration continuums distinguished between ten levels of integration (Fogarty, 1991b). The extreme on one side of the continuum was the fragmented model, which was described as the traditional model of separate and distinct disciplines. The degree and depth of integration increased as the continuum moved from the fragmented model to the networked model, in which the learner creates a network of internal connections which lead to external networks of associations.

It is apparent that a single definition and a single specific level of curriculum integration would not be practical, considering the reality of teaching in different environments, classes, subjects and schools. Deciding to use one broad and simple definition, such as the one by Moss and Noden (1995), and using one of the suggested continuums, such as developed by Fogarty (1991b), would allow both simplicity and complexity when needed, as long as the essence and spirit of curriculum integration was retained.

> The ‘new language’ of curriculum is descriptive of ways to plan and organize the curriculum in order to bring meaning to the curriculum – a means of making the curriculum more connected to what is happening in the real world. For the curriculum to become more meaningful to learners, they need to see a connection between what they are learning in school and what information, skills and knowledge they use in real life situations. Since in real life content is not segregated into its respective pieces, ‘integrationists’ contend that the way in which students should learn content in school is not in segregated, unrelated bits and pieces, but as a whole body of related information which is then utilized appropriately in daily life activities. (Kysilka, 1998, p. 203)

A brief history of curriculum integration. There were a number of short outlines of the history of curriculum integration in the literature. Some sources stated that the origins of integrated curriculum were over 2000 years old. Martin-Kniep et al. (1995) mentioned Plato as the earliest advocate of curriculum integration and Henson (2003) described Confucius and Socrates as the first to emphasize the learner. However, according to Henson, no further development was observed until the 17th century. During that time, John Locke developed experiential education based on his belief that the only way learning occurred was through experience. Henson continued the historical outline by describing that a few years later Jean Rousseau broadened this concept to include the aspect of child-centered education. During the next one hundred years, a number of educators further developed the idea of child-centered and experiential education. One of the most influential of these educators was John Dewey. “John Dewey (1859 – 1952) used his very long life (92 years) to exert more influence on education and philosophy than any other American, before or since" (Henson, 2003, p. 8).

Gehrke (1998) summarized the 20th century history of curriculum integration by identifying two periods in which integrating curriculum was very popular: the Progressive Era of the 1920s and 1930s, and the Open Education period of the 1960s and early 1970s. One of the reasons that the movement of curriculum integration was slowed down during the 20th century was the launching of Sputnik in October 1957. This scientific feat by the Russians was seen as a sign that America had fallen behind in scientific and technological progress. The learner-centered education of the time was blamed for this event. Consequently curriculum integration was neglected as "back to the basics" and other traditional structures came to the forefront in school reform during the 1970s and 1980s (Beane, 1997; Henson 2003). However, during the 1990s, renewed interest in this approach of teaching was stimulated by the need to respond to the rapid changes in the workplace and in career choices (Hargreaves & Moore, 2000). Therefore, curriculum integration is currently receiving a lot of attention, its third peak in the 20th century.

The encouragement to explore and implement curriculum integration in the 20th century was based to a large extent on John Dewey and his thinking about knowledge, learning, and schooling. John Dewey was a very influential and renowned educator. In the introduction of their book *John Dewey: Master educator*, Brickman and Lehrer (1959) said:

> During 1959, intellectuals in various parts of the world are observing the 100th anniversary of the birth of one of the best-known thinkers of the present century,

> one of the most influential educators, and one of the most modest of modern men – John Dewey. (p. 9)

Fifty years later, John Dewey is still influencing education. His name appeared in the literature repeatedly as one of the essential contributors to the development of curriculum integration (Beane, 1997; Gehrke, 1998; Hargreaves & Moore, 2000; Harris & Alexander, 1998; Henson, 2003; Taylor, 2003). John Dewey was born in Vermont, on October 20th, 1859, graduated from high school at the age of 16 and attended the University of Vermont (Brickman & Lehrer, 1959). In 1882, at the age of 23, he published his first writings. Seventy years later, John Dewey left a legacy of 50 books, 750 articles, and numerous addresses and reviews (Fishman & McCarthy, 1998). His passion and enthusiasm for philosophy and education was boundless. Dewey created the nation's first laboratory school at the University of Chicago in 1896 (Handlin, 1959). This has been often given as the date that progressive education was born. However, Handlin maintained that though the progressive ideas were being explored at this time, it was not until after the first world war, that these new theories were widely accepted.

John Dewey's philosophy of education initiated many discussions, reforms and inspired many followers. His philosophy is described as influencing four areas of education; learning through experience, learning and evaluating through reflection, awareness of the learning environment and the importance of democracy (Smith, 2001). In his own words, Dewey's (1902) arguments for experience were compelling:

> Nothing can be developed from nothing; nothing but the crude can be developed out of the crude – and this is what surely happens when we throw the child back upon his achieved self as a finality, and invite him to spin new truths of nature or

> of conduct out of that. It is certainly futile to expect a child to evolve a universe out of his own mere mind as it is for a philosopher to attempt that task. Development does not mean just getting something out of the mind. It is a development of experience and into experience that is really wanted. And this is impossible save as just that educative medium is provided which will enable the powers and interests that have been selected as valuable to function. (p. 18)

Dewey had the foresight to realize the value of an education that was problem-based and fun (Henson, 2003). His vision of education, which integrated curriculum, community, education and schooling into one entity, was instrumental in establishing the current movement of curriculum integration (Doll & Gough, 2002).

The movement of curriculum integration that John Dewey affected so greatly during his lifetime advanced only slowly during the late 1970s and 80s after the Open Education Period. Nevertheless, it was not forgotten and evidence of this can be found in the standards documents published since 1989. The teaching standards for grades K – 12 published by the National Science Teachers' Association (1998) reveals the influence of integrated curriculum instruction. Teachers are asked to "structure the time available so that students are able to engage in extended investigation, identify and use resources outside the school and engage students in designing the learning environment" (p. 10). Gehrke (1998) pointed out that "beginning with the 1989 publication of the mathematics curriculum standards by the National Council of Teachers of Mathematics (Commission on Standards for School Mathematics, 1989), curriculum integration of some kind has found its way into most national level standards documents" (p. 249). This conclusion was also made by Ford, Yore and Anthony (1997), who conducted a document analysis of five of the major reform documents. They discovered that every one of the documents promoted constructivist teaching approaches. These requests to include the teaching of connections reflected that for the third time in the 20^{th} century, interest in the benefits and methods of curriculum integration flourished (Basista & Mathews, 2002).

Significance of Curriculum Integration

The developing appreciation of the value of curriculum integration was reflected in the literature. Without claiming perfect accuracy, Gehrke (1998) illustrated the growing interest in curriculum integration during the 1990s by pointing out the difference in the number of books printed and journal articles published during different decades. Seventeen books on curriculum integration were published from 1974 – 1989, 82 books were published from 1990 – 1997. The number of journal listings for curriculum integration was 24 for 1970 – 1989 and 75 for 1990 – 1997. Gehrke cautiously concluded that curriculum integration was in the midst of an upward trend, when compared to the 1970s and 1980s. The interest in curriculum integration from various sources developed because of a growing awareness of the importance and advantages of curriculum integration in educational reform. Jacobs (1989) reported that a poll conducted by the Association for Supervision and Curriculum Development (ASCD) in 1988, indicated that curriculum integration was the most crucial concern of educational reform in North America.

Advantages of curriculum integration. Hargreaves and Moore (2000) argued “that [curriculum integration] allows teachers to address important issues that cannot always be neatly packaged into subjects, that it develops wider views of subjects among students, that it reflects the ‘seamless web’ of knowledge and that it reduces redundancy of content" (p. 91). Basista and Mathews (2002) were convinced that "science provides rich contexts and concrete phenomena demonstrating mathematical patterns and relationships. Mathematics provides the language and tools necessary for deeper analysis of science concepts and applications" (p. 359). Saeki et al.'s (2001) report for the Curriculum Council of Japan, stated "that cross-curricular, integrated learning helps students cultivate a 'zest for living', to make discoveries and to solve problems independently" (p. 418). The phrase "zest for living" is an important reminder that John Dewey believed that education should be fun. Erickson (2001) listed a number of assets of an integrated curriculum:

> The benefits of concept-based integrated curriculum: reduces curricular fragmentation; provides depth to teaching and learning; provides teaching and learning focus; engages students in active learning; challenges higher levels of thinking; helps students connect knowledge; addresses significant problems, issues, concepts; forces an answer to the relevancy question, "Why study these facts?"; draws on multiple styles of learning. (p. 70)

Beane (1997) summarized some of the advantages of using curriculum integration, "With its emphasis on participatory planning, contextual knowledge, real-life issues, and unified organization, curriculum integration provides broad access to knowledge for diverse young people and thus opens the way for more success for more of them" (p. xi). Not only were the benefits of curriculum integration discussed in the literature, but there were also descriptions of successful implementations of this method of teaching.

Examples of successful integration. Aschbacher (1991) reported on the Humanitas Program in Los Angeles Unified School District. This "interdisciplinary, thematic, team-based approach to teaching the humanities" (p. 16) was started in 1986 in several regular high schools in Los Angeles. It is presently used at 29 of 49 high schools and involves 3 500 students. The Humanitas project has two goals; to encourage professional development of teachers and to assist average students develop higher level thinking skills and a sense of control in the learning process. Teachers who volunteered for the program formed teams and developed a set of core courses, such as language arts, social studies and art. The courses were organized around five or six conceptual themes. Teacher collaboration and professional development was considered essential and flexible timetabling was provided.

Aschbacher is a Project Director at UCLA's Center for the Study of Education (CSE) and was the head evaluator of the Humanitas Program for three years. The evaluation of the program was very detailed and involved a number of different methods. A performance-based assessment of 500 grade 11 students was conducted, comparing students' writing skills and history content knowledge. Students, teachers and administrators were interviewed and asked to complete surveys; lessons and classrooms were observed; assignments, exams and portfolios were studied; and records of attendance and discipline issues were analyzed. The results of the evaluation were very encouraging. "Regression analysis of students' essay performance indicated that . . . the program had a statistically significant effect on students' writing and content knowledge over a year's time" (Aschbacher, 1991, p. 18) when contrasted with the achievements of comparison students. Another affirming result was the attendance record. "The overall school attendance rate is 76 per cent, compared to 86 percent for students after their first quarter in the program and 94 percent for students in their third year of the program" (p. 18). Not only students responded positively to Humanitas, but teachers did too. Despite the heavy workload, the teachers "almost unanimously report that participating in Humanitas is one of the most renewing experiences they have had" (p. 19). Aschbacher concluded her report by pointing out three contributing factors to the success of the program. First, there was funding for fieldtrips and teacher release time. Second, the teachers were willing to put in a lot of extra effort to prepare materials and courses. Third, the program created a community within the larger school, which Aschbacher considered critical.

Another success story came from Lafayette Parish, Louisiana. Cain (2002) conducted "a formative internal program evaluation of the Connected Mathematics Project (CMP), a middle school reform mathematics curriculum used in Lafayette Parish, Louisiana" (p. 224). Cain explained that the CMP program started as a National Science Foundation grant project in response to strong criticism of the mathematics curriculum in the United States. The results of the Third International Mathematics and Science Study (TIMSS) were disappointing. At grades 7, 8 and 12, U.S. students performed poorly as compared to most of the rest of the world. TIMSS also analyzed the curriculum and pointed out that the school mathematics curriculum was unfocused, excessively repetitive and that much of the teaching did not promote higher-level thinking (Silver, 1998). The purpose of the evaluation of the CMP program was to determine the effectiveness of this course "in improving achievement and meeting the standards in the area of mathematics in the middle schools" (p. 224). A second goal was to gather information so that the program could be improved. The author taught CMP for a number of years in Lafayette Parish and had the responsibilities of a lead teacher to provide instructional classroom support to other teachers on a weekly basis. A number of measures were used to complete the evaluation. The author compared Louisiana Educational Assessment Program (LEAP) scores and Iowa Test of Basic Skills (ITBS) scores of all students who were in the CMP program (approximately 3500) with all other students who were not in the CMP program. These data were used in a quantitative comparison. The author also collected qualitative data. She interviewed the superintendent, the supervisor and all 34 participating teachers. She visited each CMP classroom and observed or participated in the program. Furthermore, the author gave questionnaires dealing with attitudes towards CMP to 28 mathematics teachers and 300 students participating in the program.

The comparisons of the LEAP scores and ITBS scores demonstrated that students in CMP schools consistently outperformed students from non-CMP schools. The results of the questionnaires surprised the author by being exceedingly positive and supportive of the CMP program. “The results of the teacher surveys showed that an overwhelming majority of the teachers liked the program” (Cain, 2002, p. 231). At the same time, the interviews and observations revealed that there were some concerns regarding basic skills. Teachers felt that “the program needed more basic skills review/drill because these skills had not yet been mastered by the students” (p. 230). The support, in-services and training contributions by the lead teachers were highly valued. This component of the CMP program was seen as an “integral part of this curriculum, as recommended by the authors of connected mathematics and from opinions of the teachers involved” (p. 231). The author concluded that the quantitative and qualitative data indicated that the CMP was successfully implemented in Lafayette Parish and that “given enough time, one can reasonably expect that CMP will make a difference in the mathematical reasoning ability and conceptual understanding of many students" (p. 232).

Saeki et al. (2001) described the success of a cross-curricular course in physics and mathematics at Kanazawa Technical College, which has been taught since April 1996. The objectives of this course were to help students discover the connections between mathematics and physics through hands-on activities. The students used graphing calculators and the Computer Based Laboratory to explore six physical phenomena such as the motion of a walking person. The students worked in groups of three to four students and three teachers team-taught the classes. Using pre and posttest results, Saeki et al. discovered that students' "naïve assumptions regarding the laws of physics were replaced with scientific concepts" (p. 490). It was also shown that interest in physical phenomena increased in 26% of the students and that 48% of the participants agreed that their appreciation of the importance of mathematics had increased. Though these results were supportive of curriculum integration and the authors were pleased with the outcome, the impact of the findings would have been larger if there had been a control group.

Hargreaves and Moore (2000) studied "the relationship between curriculum integration and classroom relevance in the practices of 29 grade 7 and 8 teachers who were actively committed to curriculum integration and wanted it to succeed in their classrooms" (p. 89). The 29 teachers were selected from four school districts in Ontario, Canada and had been pointed out by their principals as being very interested in curriculum integration. The teachers were interviewed for one to two hours on their understanding and use of curriculum integration, the difficulties they had encountered and the support they had received. Four teachers were observed up to ten days each and a number of teachers met together to discuss their experiences. After analyzing the interview transcripts and observation notes, the authors perceived a common theme:

> Relevance was a powerful and consistent organizing principle underlying the integrated units that teachers had designed. Many integrated lessons and units developed by teachers emphasized learning activities that were connected with something or someone in their community or beyond, with issues and ideas that had concrete, personal, and emotional relevance for students. (p. 95)

The teachers used fieldtrips, role-plays and simulations to provide opportunities for their students to deepen their awareness of connections. Hargreaves and Moore identified three recurring kinds of relevance: "relevance to work, relevance to personal development and relationships, and relevance to social and political contexts" (p. 95). The authors provided a number of examples from the transcripts to illustrate their observations of relevance. In their conclusion, Hargreaves and Moore expressed admiration for the accomplishments of the 29 teachers:

> Much of what the study's teachers were able to create in integrated units of study developed forms of knowledge and learning that are increasingly valued in today's rapidly changing and complex postmodern society – the use of higher-order thinking skills, the exercise of problem-solving capacities, the application of knowledge to real problems, the valuing of creativity and invention, the embedding of learning in real time and real life, and the importance of learning collaboratively as well as individually. (p. 111)

These four reports and studies illustrate the advantages of using curriculum integration convincingly. At the same time, the literature also established that to implement curriculum integration successfully, a number of requirements need to be fulfilled.

Requirements of Curriculum Integration

Hargreaves and Moore (2000) stressed that though the teachers found curriculum integration very worthwhile, they described how difficult and challenging it was. The demands on the teachers who wanted to implement curriculum integration successfully were substantial. Time for planning and collaboration was a huge requirement, but also an awareness of other curricula was necessary. These observations were consistent with findings by a number of promoters of integration, making it apparent that to develop a successful program using an integrated curriculum, a number of resources are needed.

Necessities for implementing curriculum integration. The literature on curriculum integration identified a number of essential requirements for the successful implementation of integrated curricula. A vital necessity often raised was the need for professional development of teachers (Aschbacher, 1991; Basista & Mathews, 2002; Cain, 2002). There were two main reasons for this. First, teachers have difficulty using a method effectively if they have not encountered it themselves as learners (Meier, 1996). “If teachers have not experienced this integration of science and mathematics, they are unlikely to teach integrated curricula in their classrooms” (Basista & Mathews, p. 359). The second reason was the lack of background knowledge of the teachers. “Teachers who participate in the program must learn a portion of one another’s subjects in order to create an interdisciplinary program” (Aschbacher, 1991, p. 19). Martin-Kniep et al. (1995)

maintained that the background knowledge of teachers was essential for the success of integration:

> A strong knowledge base and a firm grounding in schools' substantive content are vital if integration is to succeed. The criteria for evaluating the merit of integrated curriculums become meaningless if the teachers themselves are not soundly grounded in their subject fields. No amount of creative activities, no matter how coherent or relevant, can compensate for teachers' erroneous or superficial understanding of content. (p. 248)

This evident need for professional development was addressed successfully by Wright State University. Considering the needs for implementing an integrated curriculum and the call for all science and mathematics teachers to provide their students with the opportunity to make connections, an integrated science and mathematics professional development program was established at Wright State University in 1997. Basista and Mathews (2002) reported on the goals, design and results of this program, which was developed for middle school teachers (grades 4 – 10). The program "consisted of an administrators' workshop, a four week intensive summer institute and academic year follow-up seminars, classroom visitation and support" (Basista, Tomlin, Pennington & Pugh, 2001, p. 615). The program was itself completely integrated and team-taught by both science and mathematics education faculty. The goal of this course was to improve both the content and the pedagogical knowledge of the participating teachers.

During 1999, the program was rigorously evaluated. There were 22 participating teachers. "Teachers' content understanding, pedagogical preparation, confidence and classroom implementation were evaluated, as well as the effectiveness of the administrators' workshop. The teachers' content understanding was evaluated through pre-post institute exams" (Basista & Mathews, 2002, p. 364). Teachers' attitudes towards science, mathematics and teaching were monitored with a questionnaire. "The teachers showed excellent gains in content understanding" (Basista & Mathews, 2002, p. 365). The normalized gain in integrated physics and mathematics was 0.896. The normalized gain in mathematical modeling was 0.850. Teachers also indicated that they had grown in confidence and the ability to see connections in science and mathematics and teachers felt more confident about using cooperative learning and inquiry teaching practices. The administrators' workshops were also well received and the administrators' support for the teachers making changes in their classrooms showed growth during the year. Basista and Mathews concluded that the program "ha[d] been successful in increasing science and mathematics teacher content and integration knowledge, increasing teacher pedagogical knowledge and implementation, increasing administrator awareness of the science and mathematics standards, and supporting teachers' implementing new teaching practices in their classrooms" (p. 367). At the same time, it also demonstrated that teachers needed to be committed and willing to devote time and energy to this program.

A second requirement for the successful implementation of curriculum integration was flexibility in the structure and organization of school timetables and building use. "This type of curriculum design calls for changes in the organization of middle and secondary schools. Two such changes are the implementation of block programming and the provision of common preparatory periods for teachers involved in the curriculum design" (Martin-Kniep et al., 1995, p. 235). The need for common preparatory periods for teachers was mentioned by a number of sources, as the collaboration of teachers is considered essential for the success of curriculum integration (Aschbacher, 1991).

Another factor that influenced the effective implementation of curriculum integration was the attitude of administrators. Whyte (1999) stated:

> Research on effective schools has recognized the school principal as the key to change and has affirmed the importance of [administrative] support . . . It was noted that in the schools where management actively supported teachers' ongoing professional development and valued participation in the curriculum project, most professional growth occurred. (p. 6)

Aschbacher (1991) also mentioned that principals who supported the teachers enthusiastically and were willing to take risks promoted the success of curriculum integration.

Finally, one crucial requirement was time. Time for teachers to reflect on their teaching and the needs of their students; time to talk to other teachers; time to develop materials and courses; time to evaluate and assess; time to prepare relevant themes and problems; and time to learn and experience (Kysilka, 1998; Lake, 1994; Martin-Kniep et al., 1995; Meier, 1996; Taylor, 2003). Given this necessity, it is obvious that financial support is also a fundamental requirement of curriculum integration. Professional development, teacher release time, administrator workshops, all, require financial support (Meier, 1996).

Obstacles to curriculum integration. Given the current interest in curriculum integration and the recognition of the necessary requirements for using this method, one could assume that the implementation of this approach to teaching would be spreading through North America. However, after enthusiastically reporting on the increase of publications on curriculum integration, Gehrke (1998) was disappointed when she looked for examples of curriculum integration in practice:

> Evidence of integrated curriculum in use rather than in advocacy is somewhat depressing – if one supports curriculum integration. Though all these books may be having a salubrious effect on beginning teachers' use as the decade ends, the research evidence on general teacher use is not as healthy, especially at the middle and high school levels. Arredondo and Rucinski (1995) surveyed principals of middle schools in the state of Missouri about their schools' curriculum integration and discovered that only about 37 per cent claimed *any* level of use in their schools. (p. 253)

Kysilka (1998) also expressed her awareness that there were only a few classrooms using curriculum integration. She stated, "The integrated curriculum movement in the United States is currently more rhetoric than activity" (p. 207). In Canada, advocates of Science-Technology-Society-Environment (STSE) education have also been frustrated with the lack of response from teachers and administrators. The purpose of STSE education is to provide students with the opportunities to build connections between their studies in science and technology, and society and the environment. However, Bencze et al. (2003) discovered that instead of promoting STSE issues, most official curricula is pro-business, promoting industrial production and consumption. The observations of Gehrke, Kysilka and Bencze et al. point to a number of obstacles faced by supporters of integration. Not surprisingly, these obstacles mirror the necessities described in the literature for successful curriculum integration.

A common concern was the substantial time required by teachers to prepare and collaborate (Meier, 1996). Kysilka (1998) discussed the reluctance of teachers to get involved with curriculum integration because of the huge time commitment. The lack of content knowledge was another issue. The success of using curriculum integration depends on the strength of the teacher’s background (Martin-Kniep et al., 1995). The financial support necessary to implement interdisciplinary courses successfully is another factor (Meier, 1996). A final area of consideration was the organizational structure needed for curriculum integration. Martin-Kniep et al. (1995) determined that a major hindrance for some teachers was the lack of organizational support in establishing common preparation periods since teacher collaboration is imperative.

In addition to these obstacles, another common concern in senior level courses was the substantial content of the course. “The content-packed nature of some syllabuses severely restrict opportunities for meaningful discourse on learning and problem solving because teachers simply can not make room for it to happen” (Kirkwood, 2000, p. 533). The content coverage concern was connected to assessment. As long as teachers are held responsible for the achievement of students on standardized tests, they will resort to familiar methods of teaching and be careful about using curriculum integration, as they cannot control the learning environment in an integrated program as they do in chalk and talk classes (Kysilka, 1998; Fishman & Krajcik, 2003).

Summary

The literature is full of examples of the beneficial outcomes of curriculum integration. There are a number of success stories in which integrated curriculum has made a positive difference in both students’ and teachers’ experiences of education.

Nevertheless, at the same time, there are considerable hurdles to overcome, funding, professional development and assessment pressures. Considering the lack of consistent use of curriculum integration in North America, it would be easy to say that this teaching method is just another reform of the month. However, the richness and relevant education that curriculum integration offers cannot be ignored. Meier (1996) predicted that:

> Society will eventually demand it. Needs of business, industry, and society, as well as needs of the individual, all require us to see the big picture, and to understand the connections and relationships around us. At the current rate of information growth, any attempt to learn everything there is to know about any one subject proves a fruitless endeavor. To gain a wealth of knowledge about a variety of subjects separately and later call on that information for use has also proven problematic. . . What better way to make connections and increase the relevance of all subjects than to teach them as interrelated topics through interdisciplinary efforts? (p. 230)

The literature has made it apparent, that no matter what obstacles stand in the way, devoted advocates of curriculum integration will pursue the advancement of their cause to the best of their ability. As society continues to evolve and consequently requires changes in education, curriculum integration might become a necessity and not only an ideal. In the early 1990s, the chair of the Key House Committee, George E. Brown Jr., pointed out repeatedly that science and technology could no longer be expected to solve the world’s problems. He was convinced that only by developing awareness of the environmental concerns, the needs for equity and justice and the impact of changes on the quality of life for all, could science and technology be used to serve humanity. Brown saw the integration of social sciences with science and technology as the key to developing this awareness and allowing this appreciation to help solve the crucial problems of the 21st century (Cordes, 1993). Considering the visions of Meier and Brown, it is important to determine whether integration is possible without considerable funding, time resources and with little or no professional development. It is also advisable to discover whether content demanding courses such as Physics 11 can be integrated successfully with language arts and social studies, without obstructing the completion of the prescribed curriculum.

The intent of this study was to explore curriculum integration in a Physics 11 classroom without the benefits of extra funding and a flexible timetable. In the study, attendance, test marks and attitude questionnaires were used to document the relationship between the teacher action and the student academic achievement and increased awareness of connections in this complex world. At the same time curriculum integration was explored using field notes, reflections, interviews, student class work and journals. This study aimed to address the following research questions:

1) Does curriculum integration allow the current academic achievement of high school students in a Physics 11 class to be retained?

2) Is it possible to provide integration with limited resources and simple tools within the normal timetable and structure of the current high school in a Physics 11 class?

3) Do students become more aware of the complexity of the world they live in and the connections between different bodies of knowledge after experiencing a simple model of integration in a Physics 11 class?

Chapter 3

Methodology

Introduction

This study addressed three research questions focused on integrating social studies and language arts themes into Physics 11 within the context of the school schedule, available resources and learning expectations. Analysis of the problem space, research questions and the potential data sources to inform these questions revealed variations in the type of data and development of issues. Therefore, it was judged that a mixed-methods comparison case study methodology was most appropriate. The chosen research design of mixed methods was judged the best fit given the research foci and the contextual limitations by combining quantitative and qualitative data collected as part of the normal instructional program. The research design, sampling, Physics 11 course, treatment, data collection, instruments and data analysis are outlined in the following pages.

Research Design

There are three general approaches to research: quantitative, qualitative and mixed methods (Creswell, 2003). Using a mixed methods approach allows the researcher to supplement benefits of the quantitative approach with benefits of the qualitative approach and in so doing produce a more in-depth analysis of the studied phenomena. The mixed methods are considered a recent development, but this approach does have a fifty-year history. Creswell suggested that the idea of using different methods probably began in 1959 with the validity study of psychological traits by Campbell and Fiske (1959). Both quantitative and qualitative methods have advantages and disadvantages.

Weaknesses, such as the lack of depth in quantitative approaches and the inability to generalize when using qualitative approaches (McMillan & Schumacher, 2001), can be decreased by using the strength in one approach to compensate for the deficiency in the other approach. Consequently, the mixed methods can provide findings that are more complete (Creswell).

The mixed methods approach was chosen for this particular study since quantitative data were required to compare academic achievement of the treatment group with the comparison group. Qualitative data were collected for three reasons, to gain insight into the practicality of using curriculum integration from the teachers' perspective within the contextual limitations, to establish whether the work of the students indicated that some degree of integration had taken place and to discover whether a simple model of integration can help to increase the awareness of students of the complexity of the real world.

The concurrent triangulation strategy is one of six major mixed methods models (Creswell, 2003). It was chosen as the most appropriate research design for this study as it allowed collection of qualitative and quantitative data at the same time. Triangulating data sources is a technique for establishing connections within qualitative and quantitative data. It involves a comparison of the two sets of data to determine whether they support or contradict each other (Creswell, 2005). The process of triangulation allows the researcher to test the validity and reliability of results, enabling a more honest and complete picture of the studied phenomena and potential explanations with causal mechanisms to be developed (Creswell 2005; Painter & Rigsby, 2005; Sydenstricker-Neto, 1997).

The research design chosen for the qualitative data was the collective case study. In a collective case study "multiple cases are described and compared to provide insight into an issue" (Creswell, 2005, p. 439). In this study, there were two cases, one Physics 11 class (the comparison group) was taught a unit on special relativity using the traditional approach of presenting the prescribed curriculum as lectures. The other Physics 11 class (the treatment group) was taught a unit on special relativity by integrating the prescribed curriculum with history of science, social studies and English. The two Physics 11 classes were taught by the same teacher and were compared by collecting quantitative data (unit tests, unit marks, attendance) and qualitative data (teacher field notes and reflections, attitude questionnaires). The experiences of the participating teachers and students were further explored by collecting additional qualitative data. These included interviews with two guest speakers and student work and journals.

The quasi-experimental design that was chosen for the quantitative data was the Non-Equivalent Groups design (Trochim, 2002). Though a comparison group was established, many differences existed between the treatment and comparison groups, which could conceivably have influenced the results. The independent variable was the teacher action; the dependent variables were academic achievement and attendance.

Sampling

Two groups of participants were selected through convenience sampling. Both groups were Physics 11 classes taught by the same teacher. The semestered class was assigned the treatment status, since it was more convenient for the colleagues of the action teacher to visit during the block of the semestered class. Table 1 on page 33 provides a summary of the characteristics of the two classes. Participants were students at a Catholic private high school with a population of 400 students from grades eight to twelve. The action teacher had taught Physics 11 for twelve years at this high school. Her education included a B.Ed. with a major in Early Childhood and a B.Sc. with a combined major in Physics and Astronomy. The study on curriculum integration was part of the completion requirements of a MA in Science Education. The action teacher's teaching experience included four years at the intermediate level, one year of high school in Calgary and the twelve years at the host school for this study.

Table 1

Characteristics of Classes used for Comparison and Treatments Groups

Characteristic	Comparison group	Treatment group
Class size	16 students	23 students
Time table	Linear	Semestered
Gender of students	7 male, 9 female	17 male, 6 female
Grade 12 students	one male	two males

Though the high school and corresponding classes were small, the characteristics of the student population provided a more representative sample of the general population than the typical local high school, decreasing the threat to external validity. Since the school is the only catholic high school in the area, it has three feeder schools from very different locations within the city. The first feeder school is located in an upscale area, where many students come from upper middle to high-income families. The second feeder school is located in a downtown area, where a number of families receive bursaries and other financial assistance. The third feeder school is located in a rural area with mostly middle-income families. Therefore, the students who attend the catholic high school represent a larger cross section of socio-economic standing than expected. At the senior level, there is also a large complement of international students. About 10% of the grade 11 and 12 students are international. Most of them are from Japan, Korea, Hong Kong and a few from Europe.

The Physics 11 Course and Special Relativity

Physics 11 is a survey course. It introduces the students to the fundamental principles of physics and a number of different fields within physics. The course consists of eight units: Kinematics (study of motion), Dynamics (study of forces), Momentum, Energy and Work, Waves, Optics, Careers in Physics and Special Relativity. Special relativity is classified as modern physics and all other topics in the course are grouped with classical physics. The unit on special relativity was the topical focus of this study. This unit was chosen specifically in order to minimize threat to internal validity caused when only one group receives treatment. The inequality produced by this method can invalidate the results. The theory of special relativity fascinates students because of the mind-expanding ideas that are presented, such as time dilation. Therefore, studying this unit is perceived by most students as interesting and worthwhile. It was hoped that this attitude would help compensate for the inequality caused by the treatment. The enthusiasm and exhilaration on part of the action teacher, because of presenting the treatment, could also influence the results. It was expected that this would be offset by choosing this particular unit, as it is the teacher’s favourite unit to teach. Other factors might also have decreased the threat to internal validity. The treatment group received two presentations by guest speakers, but the comparison group was aware that they had less homework, as they were able to complete more of the assigned work during class time. Furthermore, the comparison group completed a special project on careers in physics, for which the treatment group did not have time. The lack of time was not due to the treatment during the unit on special relativity, but due to the semestered course having fewer hours of student contact time than the linear course.

Special relativity covers a number of topics. The unit begins with differentiating between modern and classical physics. This is followed by a discussion on inertial frames of reference and Michelson's and Morley's attempt to find evidence of ether as the medium for electromagnetic waves. Einstein's two postulates that summarize his famous paper from 1905 are then presented. The implications of these postulates, time dilation, length contraction and mass increase are not only discussed but also used in calculations. The unit finishes with a discussion of the well-known equation $E = mc^2$ and its implications.

The course evaluation consists of laboratory reports, assignments, homework, quizzes, group work and unit tests. The group work often involves solving a problem or applying a new concept to different situations. Problems are chosen to foster the development of problem solving skills and critical thinking. The unit tests consist of multiple choice and written response questions, which measure both understanding of theory and successful use of equations. A copy of the course overview, including the prescribed learning outcomes set by the BC ministry is provided in Appendix A. Since the topics of special relativity cannot be verified using equipment in a high school laboratory, the typical traditional lessons consist of lecture, question and answer periods and problem sets. The students copy notes from the board and work on problem sets individually or as a group. A scope and sequence chart of the traditional and integrated units that were used to teach the unit on special relativity is provided below in Table 2.

Table 2

Scope and Sequence of the Traditional and Integrated Unit

Traditional unit	Integrated unit
Modern/classical physics	Modern/classical physics
	History of science: Changing perceptions of the physical world due to numerous discoveries***
Michelson and Morley's experiment	Michelson and Morley's experiment
	History of science: Reaction of physics world to failure of Michelson and Morley's experiment
Einstein's postulates	Einstein's postulates
	History of science: Discussion of Einstein's education and 1905 miracle year
Time dilation	Mass increase, $E = mc^2$
	History of science: Development of atomic bomb
Length contraction	***Guest speaker: Political history from 1900 to 1950***
Mass increase	Time dilation, Length contraction
$E = mc^2$	***Introduction to general relativity***
	History of science: 1919 proof and fame of Einstein
Group problems	Group problems
Review class	***Guest speaker: Poems on special relativity***
Unit Test	Unit Test

* Items in ***Italic Bold*** identify activities and concepts presented only to treatment group.

Treatment

Students in the comparison group were taught the regular Physics 11 curriculum for special relativity. The treatment group received the teacher action. This action included integration with language arts, social studies and history of science. Curriculum integration was incorporated using three methods. First, while teaching concepts of special relativity, the action teacher included concepts from history of science. For example, the result of the Michelson-Morley experiment and its possible influence on Albert Einstein is a prescribed curriculum concept. The treatment group was also introduced to the fact that the whole scientific community was very shaken by the result of the Michelson-Morley experiment. At the end of the 19^{th} century, physicists felt that they practically knew all there was to know about the physical world (Falk, 2002). The result of the experiment was completely unexpected and caused the physicists to question their understanding of physical nature. History of science was included in the following discussions: modern/classical physics, Michelson/Morley's experiment, Einstein's postulates and $E = mc^2$. In addition, the historical influence on science by Albert Einstein was explored. An introduction to general relativity, the subsequent fame of Einstein and the influence on the development of technology, cosmology and quantum physics was also included.

The second aspect of the integration involved two guest speakers, colleagues of the action teacher. The first guest speaker taught social studies and presented one class dealing with the history of the world wars WWI and WWII and the influence of the atomic bomb on the outcome of WWII and its implications. The grade 11 curriculum in social studies requires students to study the role of Canada in WWI and WWII. The lesson presented by the social studies teacher was connected to the development of the atomic bomb, starting with Einstein's law $E = mc^2$. This law had been discussed in the context of physics by the treatment group during the previous lesson. As a response to the presentation by the social studies teacher, the students were asked to create concurrent timelines illustrating the developments in physics and in European history for the relevant period, 1850 - 1950.

The second guest speaker taught English and presented one class on poetry at the end of the unit. The grade 11 English curriculum requires students to create a variety of academic, technical and personal communications. Furthermore, students are expected to demonstrate an understanding of the main ideas, events or themes of a variety of increasingly complex novels, short stories and poetry. At the beginning of the 75-minute class the students were introduced to poems by Walt Whitman, Rainer Maria Rilke and others, which explored physics content. Following this introduction, the students were guided in writing their own poetry pertaining to special relativity.

Both guest speakers met with the action teacher before their visits to the treatment group. During their visits, they made a significant effort to refer to the physics content of the unit. For example, the social studies teacher mentioned one of the great contributors to the development of nuclear fission, Lise Meitner. She also brought in pictures of Meitner to show the students. Since the English teacher visited the class at the end of the unit, she referred to a number of concepts such as time dilation, length contraction and mass-energy conversion. During the visits by the social studies and English teachers, the action teacher was present in the classroom. The action teacher introduced the speakers and at times discussed ideas or procedure with the speakers in the presence of the students.

The third component of the curriculum integration consisted of the students in the treatment group keeping a journal during the unit on special relativity that provided them with space, time and opportunity to reflect on the lessons and their significance. This activity was not included in the presentation on special relativity to the comparison group. Every other class the students in the treatment group were asked to respond to a focus question provided by the action teacher. Journals help students integrate concepts through reflection and assist researchers to determine whether students are able to deepen their awareness of connections of different bodies of knowledge.

Journal Stems of the Five Journal Prompts:

1. *During the last 100 years there have been many discoveries in science. Do you think that this will continue during the next 100 years? Why or why not?*
2. *Reflect on what it might have been like for Einstein when the two atomic bombs were dropped on Japan.*
3. *How would the general public have reacted to hearing and reading about time dilation and length contraction?*
4. *Given that in our everyday life we don’t observe relativistic effects, is it still important for scientists to study the special theory of relativity?*
5. *What are your feelings regarding group work? Do you enjoy it? What parts of group work are difficult? Do you think that you will be working in groups when you pursue a career as an adult?*

Data Collection

Before teaching the unit on special relativity and collecting any data, written consent was obtained from the students, their parents or guardians and the two participating teachers. Copies of Ethics approval and the consent forms are provided in Appendix B and C. The consent forms were administered by a third party and were not examined until the school year had finished and the final report cards had been distributed to the students.

The first research question, which was to ascertain whether the teacher action retained academic achievement, was addressed with data from the normal course evaluation. Evaluation of the Physics 11 course included one-hour tests at the end of every one of the seven units. The test results of the unit on special relativity were compared to the average of the other six unit tests in the course. The cumulative mark for special relativity was compared to the average mark of the other six units. The attendance during the teaching of the unit on special relativity (14 hours) was compared to the average attendance of the students during the rest of the course (86 hours). For all three of these data sources, mean scores of the treatment group and comparison group were compared. The quantitative data were supplemented with a number of qualitative data. The action teacher kept a journal of field notes during the teaching of the unit on special relativity where she reflected on the response of the students and her own feelings about the integration to supplement the data by linking classroom events to patterns in the quantitative data. The guest speakers were interviewed by the action teacher to gain insight into their observations of the students' responses and their previous experiences with integration. A list of the interview questions are included in Appendix D.

The second research question, which attempted to decide whether it is realistic to expect teachers to implement curriculum integration with few or no resources, examined two different concerns. First, to determine whether some degree of integration had occurred using such a simple model, qualitative data such as the journal responses, timelines and poetry were studied to confirm that deeper thinking had been initiated and that students could relate more thoroughly to their studies in high school. The historical timelines and poetry were evaluated by the appropriate subject teacher to determine whether outcomes from social studies and English courses had been met. Second, to ascertain whether curriculum integration is feasible in the current school structure, the guest speakers were interviewed regarding their personal growth due to the integration experience, their observations regarding the success of the integration and their views on the time and organization needed for preparing integrated units.

The third research question, which attempted to discover whether the teacher action helped the students develop a deeper understanding of the complexities of the world and become more aware of the relevance of their studies, involved three different data collections. The quantitative record of attendance during the teaching of special relativity was compared to the attendance of the whole course. Improved attendance is an indicator of student involvement in a course and one of the expected outcomes of curriculum integration (Aschbacher, 1991; Jacobs, 1989). Qualitative data were assembled from the journals providing possible confirmation that the curriculum integration initiated greater awareness of the connections between different areas of learning. Third, a questionnaire was distributed to both groups at the beginning and at the end of the unit. The questionnaire consisted of closed-ended questions, such as multiple choice questions and Likert scale questions, and was used to indicate the depth of understanding and awareness the students had regarding the complexity of the world and the relevance of their high school courses to the outside world.

Data Collection Instruments

The unit tests written by the comparison and treatment group were prepared by the action teacher. Each test consisted of both multiple-choice and written responses. The action teacher was confident that the unit tests were reliable for the low-risk purposes of teaching and this study, as she looked for consistency in achievement between the multiple-choice and written responses sections. Furthermore, the action teacher had prepared unit tests for special relativity for ten years and had over the years, eliminated types of questions that the students found confusing or ambiguous. Finally, after every test was completed by the students, the action teacher made a note of any questions that more that half of the class answered incorrectly and either removed them or rewrote the questions to be clearer.

Content validity was considered present since the questions were designed to test the successful completion of each specific learning outcome set by the BC curriculum, (see Appendix A). Support for construct validity was established by the use of these unit tests for a number of years with a variety of classes. Students who completed both quizzes and assignments with high scores, but had difficulty with some of the unit test questions, helped identify questions that were either ambiguous or did not test the specific concepts of special relativity. These types of discrepancies were also noted by the teacher when they occurred between answers on unit test questions and clear and correct verbal responses from the students in class or tutorials.

The questionnaire was prepared by the action teacher, who was aware that she would have a personal bias. Therefore, the first draft of the questionnaire was read by three educators, who were not connected to the study. The readers were asked to look for biases and any ambiguity to help establish validity. According to Anderson and Arsenault (2000), the only form of validity commonly used with questionnaires is face validity. “A measure has face validity if it looks to the subject like it is appropriate for the purposes at hand” (Cone & Foster, 2001, p. 156). The initial readers of the questionnaire pointed out questions that were not clear or could be interpreted in two or more ways. After incorporating the suggested changes by the readers, the action teacher continued to work on establishing face validity by distributing the questionnaire to a group of volunteer grade 12 students, who were only a year older than the students in the treatment and comparison groups. After the students filled out the questionnaire, they were asked to make comments and suggestions about each set of questions. A number of students made very thoughtful and useful suggestions, which included recommendation on how to rewrite statements and questions. Some of the students also proposed different vocabulary, for example instead of “math skills” in question 9, it was suggested to use “arithmetic facts”. Some of the questions that the adult readers had been able to understand were not clear to the grade 12 students. A few questions took too much time to be completed and had to be modified.

Anderson and Arsenault (2000) also recommend using procedures and measures that lead to consistent results no matter who is collecting the data. Therefore, the questionnaires were administered by the same person before and after the treatment, who read out the exact same instructions each time. The questionnaires were collected by a student each time and sealed in an envelope, which was placed in the care of a third party until the end of the school year. While the students filled in the questionnaire, the action teacher did not interpret or assist with any of the questions. Internal consistency of the questionnaire was examined by determining Cronbach's alpha for the Likert Scale questions #1 - 17. A copy of the questionnaire is provided in Appendix E.

Data Analysis

All the data collected for this study were retrieved at the end of the school year. The first step in analyzing these data involved reading through transcripts of teacher interviews, student work (timelines and poetry) and the journals to gain a general sense of the responses to the study. This was followed by a coding process of the journals and teacher observations and comments. The coding process was modeled according to the illustration presented by Creswell (2005) in which he recommended a number of steps that assist the researcher to move from the general to the more specific.

Using the journals as an illustration of this process, the first step involved reading all the journal responses to a specific journal question or prompt without making any notes. Then the responses were read a second time and notes were made of all phrases and words used by the students. After studying these notes, similar responses were identified and the journals were read again, highlighting similar responses with different colours. Following the colour coding, the journal responses were read again and this time notes were made on which responses could be grouped together. For example, all comments relating to technology in response to the first journal question were grouped together. Once the groups of responses were identified, the journals were read again, counting the number of times that a particular group of responses was mentioned in the journals. For example, out of fifteen journals, nine mentioned some kind of technology in response to the first journal question. This step was followed by another reading of the journals, keeping the general themes developed from the grouping of responses in mind and looking for single responses that indicated a different view or understanding. After noting these single ideas, the journals were read through one more time. This time evidence of critical thinking and integration within the identified themes and categories of responses were documented, such as being able to relate to other people and other circumstances.

This process was used for all journal questions and both interview transcripts. The seventh reading used for the journals was not included in the analysis of the interviews, as evidence of critical thinking was not relevant. The timelines and poetry were analyzed using a similar process, however, not as many steps were required. The timelines were grouped into two categories, either the students kept the political and science timelines separate or they integrated them. The poetry was studied by making notes on types of concepts used in the poems. The concepts were grouped into three categories, concepts of special relativity, emotions and other.

The results of the questionnaires were tabulated and averages calculated. The changes between the pretest and posttest responses were determined for both groups. Apart from descriptive statistics, the results of the questionnaires were not analyzed using statistical methods. The results were used to complement qualitative observations and conclusions.

Following these analyses the quantitative data (the attendance records, the test, unit and course marks) were initially interpreted using descriptive statistics. The means, standard deviation and range of scores were calculated for each set of data (see Table F10 in Appendix F). Analysis of covariance (ANCOVA) was used to determine whether the treatment effects were significant for unit tests, unit marks and attendance. Covariance was essential since the Non-Equivalent Groups Design is susceptible to internal validity threat of selection (Trochim, 2002). The ANCOVA is used in order to remove “the obscuring effects of pre-existing individual differences among subjects” (Lowry, 2007, chap. 17, p. 1). It was expected that in all three cases, unit tests, attendance and cumulative marks, that there would be no difference between the treatment group and the comparison group once initial differences were controlled. In other words, it was expected that taking the time to incorporate curriculum integration did not affect the academic achievement negatively. The data analysis was followed by the process of interpreting possible results by integrating the observations, descriptions and statistical results.

Summary

This study used the mixed methods research approach to investigate the effectiveness of curriculum integration in a Physics 11 classroom. Using the concurrent triangulation strategy, quantitative and qualitative data were collected at the same time from a treatment and a comparison group. After the data were analyzed using narrative and statistical descriptions, the results were integrated in order to develop a complete picture of using curriculum integration in the Physics 11 class.

Chapter 4

Results

Introduction

This chapter is a summary of the quantitative and qualitative data collected during and results of the teacher action in June 2006, which consisted of teaching a unit on Einstein's theory of special relativity in Physics 11 using two different methods. Out of 16 students in the comparison group, 11 chose to participate (68.8% participation rate). Out of 23 students in the treatment group, 15 students chose to participate (65.2% participation rate). Of the 13 students who did not consent to be participants, three were international students who struggled with the language; three were absent a lot due to health reasons or sports; and five students were Canadian who were challenged all semester by the content of the course. As a result, the participating students in both groups were slightly above average achievers compared to the typical Physics 11 students at this school. Characteristics of the classes and participants are summarized in Table 3.

Table 3

Characteristics of Classes and Participants of Comparison and Treatment Groups

Characteristic	Comparison group	Treatment group
Mark range of class	35% - 96%	54% - 98%
Time table	Linear	Semestered
Number of participants	11 students	15 students
Gender of participants	three boys, eight girls	nine boys, six girls
Mark range of participants	64% - 96%	78% - 98%
Time spent on unit	13 hours, 45 minutes	13 hours, 50 minutes

The summary is divided into three sections corresponding to the research questions. At the beginning of each section, the research question will be stated, followed by a general assertion and a review of the evidence support.

Research Question 1

Does curriculum integration allow the current academic achievement of high school students in a Physics 11 class to be retained?

Collectively the data suggest that the integration treatment produced similar or significantly higher achievement results compared to the traditional approach.

Three sets of quantitative data, unit tests, unit marks and attendance, were analyzed in response to the first research question. It was expected that there would either be no significant differences between the treatment and comparison groups or that the treatment group would demonstrate a significantly higher achievement. The academic performance on the unit test and unit mark for special relativity was compared to the average of the other six units. The attendance during the teaching of the unit on special relativity was compared to the attendance of the rest of the course. The means for the comparison and treatment groups (see Table 4 on page 49) indicate small differences. Given the expectations, the differences were favourable for the treatment group in every case.

Using the analysis of covariance, "the obscuring effects of pre-existing individual differences" (Lowry, chap. 17, p. 1) were removed and adjusted means indicated larger differences than the raw data (see Table 5 on page 50). Analysis of covariance on the unit test data indicated that there was a significant main effect between the adjusted means

Table 4

Performance Means of Participants of Comparison and Treatment Groups

Unit tests	Average of six units	Special relativity unit	Difference
Comparison group	87.0%	83.4%	-3.6%
Treatment group	83.6%	86.5%	+2.9%
Unit marks	Average of six units	Special relativity unit	Difference
Comparison group	87.6%	84.6%	-3.0%
Treatment group	84.9%	86.9%	+2.0%
Attendance*	Average of course	Special relativity unit	Difference
Comparison group	5.9%	8.0%	+2.1%
Treatment group	8.6%	4.4%	-4.2%

*Attendance is reported in terms of excused or unexcused absence from class.

favoring the treatment group over the comparison group, $F(1, 23) = 5.14$, $p < 0.05$, with an effect size $d = 0.36$. Analysis of covariance on the unit mark data did not indicate a significant main effect between the adjusted means of the treatment and comparison group, $F(1, 23) = 3.45$, $p > 0.05$, with an effect size $d = 0.28$. Analysis of covariance on the absenteeism of the students indicated a significant main effect between the adjusted means favouring the attendance of the treatment group over the comparison group, $F(1, 23) = 4.32$, $p < 0.05$, with an effect size $d = 0.42$. The effect sizes were calculated using Cohen's *d*, which for the analysis of covariance consisted of the difference in the means divided by standard deviation of the comparison group (Cohen, 1988). The results of the analysis of covariance are summarized in Table 6 on page 51.

In addition to these scores, qualitative data were collected during the teaching of the unit on special relativity in order to complement the quantitative data. The qualitative

Table 5

Analysis of Covariance (ANCOVA) Adjusted Means for Special Relativity Unit

Unit tests	Average of six units	Special relativity unit	Difference
Comparison group	87.0%	82.1%	-4.9%
Treatment group	83.6%	87.8%	+4.2%
Unit marks	Average of six units	Special relativity unit	Difference
Comparison group	87.6%	83.4%	-4.2%
Treatment group	84.9%	88.0%	+3.1%
Attendance*	Average of course	Special relativity unit	Difference
Comparison group	5.9%	8.9%	+3.0%
Treatment group	8.6%	3.5%	-5.1%

*Attendance is reported in terms of excused or unexcused absence from class

data consisted of reflections made by the action teacher in a journal during the teaching of the unit of special relativity and interviews of the two guest speakers by the action teacher. These two interviews were conducted after the final marks for the two Physics 11 classes had been submitted to the administration.

A number of informal observations and field notes were made by the action teacher and the teachers who participated in the integration. The action teacher noticed that when teaching the unit of special relativity to the treatment group, a number of students who normally were easily distracted, were more attentive when concepts were presented in the context of science history. She also observed that some of these students were more inclined to participate by asking questions or contributing comments. In the case of two particular students, the difference was so marked that the action teacher was

Table 6

Summary of ANCOVA Results

	ANCOVA			
Category	*df*	*F*	*p*	*d*
Unit tests	23	5.14	0.05	0.36
Unit marks	23	3.45		0.28
Attendance	23	4.32	0.05	0.42

surprised at what an impact this method of introducing new concepts made.

> Action Teacher Reflections*: The students were very receptive and Bill and Jane who often have trouble listening, paid very close attention, unbelievable. I never would have expected this . . . (May 31, 2006)*
>
> *Michelle came in today. It was fabulous. The kids participated so well. (June 8, 2006)*

This increase in attentiveness, brought about by the connection to the stories of people, was mentioned explicitly by the English teacher, who shared her own experiences of learning in high school.

> English Teacher*: Yes, and I think if I had had a teacher who taught that way I would have done better, even with chemistry and mathematics. If I had an emotional reaction to something even if I hated it, I would do better, especially with concepts. For example, I had to know the story of calculus before I could apply it – okay now I can deal with the theories and formulas.*
>
> *(Interview, June 20, 2006)*

While teaching the treatment group, the action teacher noted that the response to the journals was very positive, even from students who normally avoided completing homework. One particular student felt incompetent when asked to finish homework assignments that involved using equations because his math skills were very weak. Consequently, he completed his homework only about 5% of the time during the course. However, when asked to respond to questions in a journal he felt more confidence and completed all five of the journal entries. A further difference pertaining to academic achievement that was noted between the comparison and treatment group, was that two students in the treatment group received their best test mark on the unit test for special relativity. The fact that no one in the comparison group achieved a best test mark was not surprising, since the unit of special relativity was the last unit of the course. Invariably, there is a natural let down of attentiveness by several students as they approach the end of a course, especially at the end of the school year. Furthermore, the concepts of special relativity are more abstract compared to the concepts of any other part of the course, challenging the students to reach beyond their intuitive understanding of the physical world. Nevertheless, in the treatment group, one student got 76% on the unit test for special relativity, which was 6% higher than his next best test. His average of all other tests was 62%. The second student who received a best test mark got 90% on the unit test, 5% higher than his next best test. His average of all other tests was 77%.

The action teacher also became aware that there was a sense of excitement in the treatment group, which she did not observe to the same degree in the comparison group. Moreover, the action teacher did not recall ever experiencing such a marked difference in attitude between the unit of special relativity and the rest of the course in her previous years of teaching this course.

> <u>Action Teacher Reflection</u>: *Today I taught time dilation and the evidence for it. It was a very exciting class. Students Jack and Jim kept on asking questions about different scenarios. There is much more "aliveness" in the treatment group. They have been more fun to teach all year, but their response to the integration has been amazing. (June 6, 2006)*

Certainly, there was enthusiasm in both classes, but in the treatment group, there was a definite difference in the atmosphere of the classroom during the unit on special relativity.

> <u>English Teacher</u>: *. . . I was expecting some faces from particularly some of the boys that are not into poetry. Not the touchy-feely types. And I was really surprised because it wasn't there at all. Well, there was one, Bert, 'you're going to do what?' – but he participated very happily and the whole class had a very good attitude. (Interview, June 20, 2006)*

In conclusion, both quantitative and qualitative data appear to indicate that not only was the current academic achievement retained by the treatment group as expected, but it was actually improved, compared to the results of the comparison group.

Research Question 2

Is it possible to provide integration with limited resources and simple tools within the timetable and structure of the current high school?

Within the context of the host school, supportive colleagues and receptive students, it is possible to enact an integration approach for a Physics 11 unit on special relativity within the timetable and structure of the current high school.

This research question was divided into two parts. First, did some level of integration take place? Second, if it did take place, did the teacher participants feel that adding curriculum integration to the normal school structure was feasible? In order to respond to the first part of this research question, a number of different data sources were considered: the action teacher's reflections, the guest teachers' interview responses, the students' journal responses, the historical timelines, the student poems and their responses to the first section of the questionnaire (questions 1- 17) which dealt specifically with integration.

The action teacher's reflections indicated that assignments designed to cross disciplinary boundaries were reasonably successful in promoting integration of physics, social studies and English. During the lessons that the treatment group received, some activities and presentations were prepared specifically to encourage integration. The action teacher presented a number of the concepts from the theory of special relativity in the context of science history. The students were introduced to the hopes, dreams and failures of the scientists who were instrumental in the emergence of Einstein's tremendous contributions to the current understanding of the universe and the impact of these contributions on the science world.

> <u>Action Teacher Reflection</u>*: My class is so wonderful – they actively listened for an hour. The impact of 1905-1945 was not lost on anyone. I really enjoyed teaching*

the lesson – from now on, I want to incorporate as much history of physics as possible. (June 1, 2006)

The students were presented with connections to other concepts by the two guest speakers. Both speakers were aware of the context of the previous lessons and referred to names, dates, and concepts, consciously building a bridge for the students while presenting their respective material.

> <u>*Action Teacher Reflection*</u>*: Today Amy came in. It was so wonderful to have another teacher in the room. The students were very cooperative. The horror of the atomic bomb really grabbed them. Amy had pictures of Rutherford and Meitner. She referred to their contributions. She asked the students to help her flesh out the political scene as they had covered a lot of this material in their social studies classes. It was a wonderful tie-in. They started on the timelines but couldn't finish since we had a five-block day. We should have explained [the assignment] more thoroughly. But it felt really good – the integration happened. (June 5, 2006)*
>
> *Michelle came in today. . . . She was so enthusiastic and tied it in so beautifully. It really gave the [students] the opportunity to express their feelings about special relativity. (June 8, 2006)*

Furthermore, the visits by the guest speakers gave the students the opportunity of observing teachers from different faculties working together as the action teacher remained in the classroom during the visits by the participating social studies and English teacher.

Social Studies Teacher: I think so, yeah, I think they were interested. One of the girls came up afterwards and said, "That was so cool, that was so neat that you came to our physics class." You don't often see teachers in the other places – only in their own place – which is what we were talking about and so it's somewhat neat to have them suddenly not just here is physics, here is history, here is science; suddenly they are interconnected. When you see the person, even in the room, it makes a difference.

(Interview, June 28, 2006)

Action Teacher: . . . Your coming into the room made a huge difference. I asked the students about group work and their responses were very positive. I think that you and I working together was excellent modeling for the students. . . .

(Interview, June 20, 2006)

As mentioned in chapter three, the students in the treatment group were given the space and time to reflect on some of the classroom discussions in journals by responding to five questions or statements at regular intervals during the unit. These entries also provided verification that integration and critical thinking had taken place. The first question was in response to the history of science lessons dealing with the impact of discoveries.

Journal Question 1: During the last 100 years there have been many discoveries in science. Do you think that this will continue during the next 100 years? Why or why not?

Students' journal responses suggested that they were able to connect and project history of science successes into the future and identify potential supports and barriers for continued progress. The majority of responding students, 73%, felt that there was a lot more to discover and that the rate of discoveries during the last 100 years would continue. Of the fifteen responses, nine (60%) felt that the future discoveries in science were directly related to the advancement in technology.

> <u>Journal Entries</u>*: Yes, I believe that there will be a tremendous amount of discoveries made in the next 100 years. I believe that technology will advance, and previous theories discovered may be proven to be wrong. There is such a vast amount of knowledge and many, many more new discoveries to be learned and made. We will never be able to comprehend everything, as there is so much wonder and grandness on this earth. (Student Journal #15)*
>
> *Yes, I do think that this will continue, because science is improving every day and as we get more and more technology, I think that we will be able to make more advances in science. (Student Journal #18)*
>
> *I personally think that it will continue and more discoveries will be made, because technology is continuously advancing a great deal. Scientists will discover many interesting things like perhaps [] extra terrestrial life! (Student Journal #1)*

There was awareness among the students that advances in science and technology would affect the environment (27%) or medical progress (27%). Among the responses to this first question, there was some discussion about new discoveries depending on attitude and ability *to think outside the box*. Two students (13%) were concerned that people did not question what they were taught. One student (7%) mentioned the impact of curiosity and another the impact of politics and economy. Another student believed that a conservative shift in politics might hinder developments in science. Finally, one student felt that the complexity of current knowledge might itself slow down the development. The students' responses to the first journal question indicated that they had made connections such as between technology and science and were aware of implications on their world by further developments in science.

The second journal question was given to the students after both the political history and the science history of the atomic bomb were presented to the treatment group.

> Journal Question 2: *Reflect on what it might have been like for Einstein, when the two atomic bombs were dropped on Japan*.

Students' responses demonstrated that they were able to take multiple perspectives on the science and social impact of Einstein's discovery and the resulting technical application. Without exception, the students had great empathy for Einstein and put effort into imagining what it would have been like for him in August of 1945.

> Journal Entries: *The thought of knowing you helped to create the atomic bomb would be amazing. To know that you've made such an advancement in science would have been a rewarding feeling for Einstein. But, seeing the aftermath of the two atomic bombs that Einstein helped to create must have created a feeling that is incomprehensible. Einstein must have been deeply effected by what happened, probably so much so to look on life in a new way. (Student Journal #3)*
>
> *I don't think Einstein thought about building bombs when he wrote his books and introduced $E = mc^2$. I'm sure he was sure of what his formula was about; and he wanted to use it for good reasons. When Einstein heard of the drop of the first atomic bomb on Hiroshima, he must've felt terrible. I can't imagine being him*

during that time. I bet he felt guilty for what happened. And I feel sorry for Einstein, too. (Student Journal #12)

It would have been devastating for Einstein when the atomic bombs dropped on Japan. The very fact that Einstein wrote to President Roosevelt in order to warn him, shows he opposed the bomb greatly. The discovery that advances in technology that you discovered was the reason for so many deaths would overwhelm you immensely. Personally, I would feel betrayed if the technology that I created was used against my every motive for creating the advances in technology. I would feel very guilty and question my career choice and every sense of my reality. (Student Journal #19)

A number of students expressed that Einstein would have had conflicting feelings. Every student mentioned that Einstein probably would have experienced abhorrence for the dropping of the bombs. Four students (27%) mentioned remorse, three (20%) a possible depression and five students (33%) used the word horror. There was a strong sense of destruction of property and of life. Nine of the fifteen (60%) responses used the word *destruction*. Nevertheless, a number of the participants were aware that the science would have been fascinating. Five students (33%) mentioned the emotions *amazement* or *fascination* that would have been part of Einstein's response. Four students (27%) looked beyond the immediate impact and discussed how this event possibly influenced the rest of Einstein's life. Two (13%) felt that this event could have been instrumental in motivating Einstein to become a peace activist. Two other students felt that in the future Einstein might have felt compelled to hide his discoveries and not share them. There was also a sense of defending Einstein; almost half of the students (47%) stated that Einstein expected his discoveries to be used for the good of humankind. The students' responses to the second journal question demonstrated their ability to envision the viewpoint of another person and imagine the far-reaching effects of such a devastating event, evidence of critical thinking.

About half way through the unit on special relativity, the students were asked to respond for the third time in their journals regarding the reaction of the public to Einstein's theories.

<u>Journal Question 3</u>: *How would the general public have reacted to hearing and reading about time dilation and length contraction?*

Students were able to relate to the public reaction to major paradigm shifts in science and how such news might be unsettling to most people. Many of the responses at first reflected the students' own experiences of confusion and difficulty accepting such unfamiliar theories. Seven students (47%) used some form of the word *confusion* and six (40%) mentioned how difficult it was to grasp these theories. Three students (20%) mentioned fear, whereas five (33%) discussed amazement or excitement. The majority (73%) of the students expressed that the theories would have been difficult to accept and that there would have been resistance. Some of the responses demonstrated the ability of some of the students to relate to a world, which they themselves had not experienced.

> <u>Journal Entries</u>: *Einstein's concepts and ideas were truly revolutionary. To comprehend his ideas fifty years later is even difficult after all the technological developments. I cannot imagine trying to grasp this concept back then. (Student Journal #8)*

I think that for example, science teachers must have felt impressed with the new discoveries. They probably wanted to meet Einstein personally and ask him a lot of questions. I also think that some people must have felt confused, because they never thought about this before. (Student Journal #12)

A few of the students thought of factors that possibly could have influenced how members of the general public reacted to Einstein's theories. A couple of students (13%) felt that the backgrounds of the members of the public would have influenced their ability to understand and accept the theories of Einstein. They discussed the need for education, an open mind and time. One student (7%) challenged education by questioning the policy to teach concepts that are not correct. Overall, the reflections on this question illustrated the students' ability to recognize that different emotions, such as confusion and amazement can exist at the same time.

<u>Journal Entries</u>: *I think that the general public would have reacted in an amazed way but also in an afraid way. I would feel confused yet astonished that we are only beginning to learn about our universe. At first it would be difficult to accept the idea that time, length, mass can change when, to us, we have always thought that those things didn't change. I think that the general public would become more curious about our world and question ideas that we already thought were true. (Student Journal #16)*

The general public would probably have had mixed reactions, interested, confused or in disbelief. Many would find it interesting about the time dilation and length contraction, but would not fully understand how. They would most likely question it or pass it off as irrelevant. . . . (Student Journal #20)

The responses to the third journal question illustrated the students' ability to use their own experiences to understand and imagine how people in different but similar circumstances would feel. Towards the end of the unit on special relativity, the students were asked to reflect on the fourth journal question.

> <u>Journal Question 4</u>: *Given that in our everyday life we do not observe relativistic effects, is it still important for scientists to study the special theory of relativity?*

Students were aware that the impact of science discoveries may not be immediate or result in common technologies and that sometimes just being aware of how the universe operates is beneficial. Two students were absent; therefore, there were only thirteen participants for this reflection. With only one exception, every student felt it was important to continue studying the special theory of relativity.

> <u>Journal Entries</u>: *Yes, it is still very important for scientists to study and research the special theory of relativity. It helps us understand our world and the universe much better. It can help us discover how our world came to be and its workings. Just because we don't see it or use it doesn't mean that we shouldn't understand what it is. Who knows, it could lead to a huge discovery. (Student Journal #20)*
>
> *I think it is important to study the special theory of relativity. If it furthers technologies and helps us understand the universe then I think it is important. If science continues to grow at an exponential rate, then at some point in time, the understanding of special relativity is going to be crucial in man's exploration of the universe. Even though we don't observe relativity in our everyday life, studying and learning about it will further man's ability to comprehend our universe. (Student Journal #11)*

The one student that did not respond affirmatively to this question expressed that finding a cure for cancer and dealing with poverty was more pressing.

> Journal Entry: *If we don't observe relativistic effects in our daily life, then no, I don't think it's as important as other things. I mean I love physics, but if the money spent on studying special relativity doesn't help mankind in any way, but satisfying curiosity, [I would] rather have the money spent on finding a cure to cancer or donating [it] to help world poverty. (Student Journal #14)*

There was still concern for the environment as in the first journal question responses. Four students (31%) mentioned the possibility of finding a new energy source. Many of the students discussed how important it was to understand the universe and its unique relation to humanity. Many felt that questions should not be left unanswered. Ten of the thirteen participants (77%) wanted to know what is really happening in the world, even if it is not intuitive and easy to understand. Seven students (54%) felt that eventually this research would lead to other amazing discoveries or progress, possibly answer more questions and discern more of the *mystery of life.*

> Journal Entries: *Yes, I feel it is very important for scientists to study the special theory of relativity because it is valuable to understand what is going on rather than taking things for granted. Also, by studying we can learn how to improve our lives (for example a new energy source). I feel we can always benefit from learning more. (Student Journal #3)*
>
> *Yes, I think that it is important for it to be studied because it may lead to some new discoveries to how we observe our world. It is valuable to learn about the special theory of relativity, because it would answer many unanswered questions.*

However, maybe it was meant for us as humans not to learn how our universe was created. Personally, I think that we will never know. But the fact that we tried [and] are trying is a good start because we can never know what we will learn about the mystery of life. (Student Journal #16)

One interesting comment from one of the students compared understanding science with understanding political issues.

Journal Entry*: Yes, it is still important for scientists to study the special theory of relativity. You never know when there will be technological advances that will require taking this theory into account whether it be for safety reasons or data taking. If we choose to completely forget about the special theory of relativity, it may be unknown to them in the future, so they will have to discover it themselves when making advanced technology. It is always good to know about what is happening about the things happening around us, just like it is good to know what is happening in other countries/cities. (Student Journal #21)*

The responses to this question were extensive and thought provoking. It was apparent that some of the students were becoming aware of the importance of making connections and that they were able to consider the implications of research.

Journal Entries: *Yes, even though we don't observe relativistic effects, it is important for scientists to study special relativity. It's extremely important to ensure that people, in particular scientists, understand the theories of special relativity because it impacts all aspects of our existence. Without the concepts of how mass, time and distance are not absolute, how can we fully comprehend when they are absolutes? If we don't try to understand how our world operates in* *all aspects, how can we make progress? The universe, as it has been demonstrated in this subject, is all connected. English and socials are connected to physics, therefore, physics is also connected to biology, cosmology, math and earth science. Those who understand a variety of concepts will excel in their specialty. (Student Journal #19)*

Of course, it is important. It is not only interesting but it is important to know how our universe functions. Something especially important is cold fusion. Though no one has been able to produce it, it is important to put money into research on the chance that we discover something that could provide everyone with cheap energy. I think it is important to study special relativity so that we do not remain ignorant of the truth. (Student Journal #23)

Yes. I believe firmly that scientists should deepen and research their idea of special relativity. Just because the every day person may not feel the profound effects discussed in Einstein's theories, there is no reason to not discover what we cannot perceive in a normal day. I truly believe that Einstein's theories were a gift to science to be critically thought through. Einstein may have found the key to time travel and other tremendous activities. If we follow his findings and theories, we may one day travel 99% of the speed of light and discover many new things about our universe. (Students Journal #8)

At the end of the unit on special relativity, the students were asked to reflect on group work, which is a valuable method of promoting integration.

> <u>Journal Question 5</u>*: What are your feelings regarding group work? Do you enjoy it? What parts of group work are difficult? Do you think that you will be working in groups when you pursue a career as an adult?*

Student responses demonstrated their awareness of the value and challenges of group work. Out of fourteen responses, thirteen students (93%) declared that they enjoyed group work and actually preferred it to many other methods of learning. A number of different reasons for this positive view were mentioned in the journal entries. Some students had experienced the exchange of thoughts and ideas (43% mentioned *ideas*). They were aware that in group work, communication skills and cooperation were developed and that creativity was stimulated. Another advantage mentioned by the students was the opportunity of receiving feedback on their ideas and opinions, at times clearing up misunderstandings. A number of students also discussed the value of group work in problem solving. In general, the journal responses indicated that group work was greatly appreciated by the students.

> <u>Journal Entries</u>*: Group work is awesome! I enjoy it because I get to interact with other people and get their take on things. However, group work can be bad, when some members do not participate. It is a lot of fun when everyone works together and contributes. I hope that in my future career I can work in groups. After all, part of being alive is interacting with other people. (Student Journal #23)*
>
> *I enjoy group work sessions because they allow me to exchange thoughts and ideas with others. As well, to practice my communications skills, as they are very important in everyday life, including careers involving sciences (Physics). Group work is also necessary whenever you must work and cooperate with individuals in*

the work force, so having this training earlier on in life prepares us for the future. Group work is often difficult when individuals are closed-minded and do not cooperate. (Student Journal #15)

One quiet and shy boy mentioned how wonderful it was to work with friends and that the group work during the whole course was his favourite part of Physics 11.

<u>Journal Entry</u>*: I think group work is really enjoyable; you get to work with your friends and get a lot of hard work done. The best part about Physics besides movies is the work sheets done in groups and labs. Working in groups when I am in a career is almost[unavoidable]. Either in person or by computer, people are always connected in groups to get a job done because it is the easiest way to do it. (Student Journal #7)*

The students discussed the difficulties of group work and shared their insights and experiences. Four students (29%) discussed the problems that arise when a person in the group is too controlling. In the same way, closed-minded and stubborn people were seen as a hindrance. Lack of listening, agreement, cooperation and participation were mentioned as impediments to the success of group work. Four students (29%) referred to situations where one person in the group can end up completing all the work.

<u>Journal Entries</u>*: I think group work is a very effective method of sharing and solving problems. I enjoy discussing ideas and even if there are differences of opinions, it is enjoyable debating your point of view. But, I find it difficult if members of the group are controlling or choose to be isolated from the [others]. I do think I will be working in groups when I pursue a career as an adult because it is a method that can be used in almost every situation. (Student Journal #19)*

I enjoy group work, but a lot of it depends on whom you are working with. I overall have trouble with my group who I am paired with, because Joe[an international student] never understands anything. However, it also brings up my self-discipline because it pushes me to concentrate harder and to finish the work. This summer, I probably will be working together with other people cooperatively because I will be working construction and people usually work together. (Student Journal #1)

I enjoy working with a group. When working with a group it is usually more difficult to have a unanimous decision that everyone can agree on. It is an excellent opportunity to share your ideas and learn about what other classmates think. In the future, I think that every career involves some aspect of teamwork. When in a group it is sometimes difficult to be listened to if one person is controlling over the group. However, there ha[ve] to be some flaws with teamwork. Not everything is perfect. Overall, teamwork is beneficial. (Student Journal #16)

When asked about group work in the future, eight students (57%) felt it was very likely that group work would be part of their job description and two of these students (14%) looked forward to working in groups in the future. There was a sense of the necessity for cooperation and that the jobs themselves would influence the need for group work. The reflections on the fifth focus question were surprisingly detailed and gave the action teacher tremendous insight into the students' experiences with group work.

The assignments given by the guest speakers were also examined for indications that integration had taken place at some level. The historical timelines prepared by the treatment group indicated that the students were aware of the connections between the scientific and political development of the atomic bomb. After the students were introduced to the political and science history concerning the building of the atomic bomb, the students were asked to prepare timelines incorporating both histories. The students worked in pairs and had about fifteen minutes to complete the task. Nine timelines from 1900 to 1950 were constructed. Every single one illustrated a connection between the political and science events, but five groups (56%) kept events separated. Four (44%) of the nine groups intertwined the political and physics timelines. The social studies teacher made the following comments about the timelines during the post action interview.

> Social Studies Teacher: *Maybe we should have suggested webs. This activity is not hard to do, but the process is certainly worthwhile in order to help students become aware of the integration. (Interview, June 28, 2006)*

The writing of poems on the theory of special relativity, demonstrated that students integrated concepts, feelings and reflections. At the end of the unit, before the unit test, the English teacher was a guest speaker in the Physics 11 class. She invited the students to express concepts, ideas and feelings relating to the unit on special relativity in poetry form. One of the participants was absent, but everyone else took part. Of the fourteen poems that were written, nine (64%) incorporated or mentioned one or more concepts of special relativity, such as the following two poems.

> *His theories are so confusing,*
> *could drive a man to boozing.*
> *Time can slow, Distance can grow,*
> *My entire mind I think I am losing.*

There once was a girl named Kate,

Who was late for her very first date,

She ran without sight,

The speed of the light,

And ended up having to wait!

All fourteen poems expressed an emotional reaction. Six (43%) of the poems expressed the challenge of understanding and accepting Einstein's theories, such as the following two poems.

The speed of light is absolute

Though this statement I wish to mute

Time, mass, and distance shouldn't be changed

Einstein's theory is so deranged

But I'm compelled by physics and this is its root.

Special Relativity,
This concept's really new to me.
I can't perceive,
I won't believe,
I'd rather plead insanity.

Seven (50%) of the poems expressed some form of amazement or admiration for Einstein, such as the following two poems.

Hard to understand, Special Relativity,

Interesting, Einstein's view of light,

Seems crazy and outrageous,

Brilliant, yet odd.

A man in 1905

made physics jump alive

with time dilation

and length migration

he started up a jive.

Three of the poems (21%) demonstrated that some of the concepts were being integrated with other subjects. The following poem pulled together science, mathematics, communication and emotions in the diamond form of poetry.

Physics
Intense, Magical
Confusing, Enjoyable, Fast-moving
Numbers, Symbols, Languages, Arithmetic
Constructing, Maneuvering, Growing
Learning, Loving
Life

One of the participants worked on the poem outside of class time and integrated physics and philosophy.

Length to length,

Do you see that strength?

Time to time,

Can you see the dime

drop?

Mass to mass,

Can you measure glass?

It's amazing how everything can change, *how strange.*

Our universe, our cosmos.

It's so huge, full of the unknown.

We are part of our earth

so small, so minuscule

What are we made up of?

Atoms that are made of space?

How mysterious, it's such a blizzard . . .

will we ever discover our Creator's puzzle?

One of the two students, who received a personal best test mark for the unit on special relativity, wrote this short poem connecting the physics of time dilation with its implication of humanity's understanding of time.

The faster the speed

Immortality is near

Time will slow for you.

The poems were discussed in the post action interview with the English teacher, who was very enthusiastic and supportive of the project.

> Action Teacher: *I've taught Special Relativity for six years and I have never been so aware of how much the students struggle with the concepts of Special Relativity, even though I did myself and you said you did. It really came out in their poetry – so now looking at what they wrote, keeping in mind that we gave them only a little time and didn't ask for revisions, these are unpolished first ideas – so what do you think?*

> <u>English Teacher</u>: *I think they're fantastic, it looks to me like they have real ideas, as if they are really trying to put down thoughts and ideas in poetry form and I think some of them are very successful as poetry. They work very well and are very clever and some are very funny and many are very descriptive. Yes, I think they work well and it is clear to me that every single one of these students had something that they wanted to say about this theory – I think that maybe poetry worked after all. (Interview, June 20, 2006)*

One of the students enjoyed writing poetry so much that she completed a bonus project for her English course.

> <u>English Teacher</u>: *One of the girls really enjoyed this and wrote me a number of poems after this [integration experience] as a bonus project – she really took this on and some of her poems dealt with concepts in physics such as gravity. (Interview, June 20, 2006)*

On the whole, the students and teachers responded positively to the poem writing exercise and the participants took advantage of the opportunity to express their feelings about the theory of special relativity.

One final activity that was examined in relation to the second research question in order to establish whether the treatment group had experienced integration, was the difference in response to the first part of the questionnaire. A complete copy of the questionnaire is provided in Appendix E on page 143. The first section of the questionnaire consisted of seventeen Likert scale questions, which dealt with awareness of the value of integration. Cronbach's alpha coefficient, determined for the pre treatment responses for both the treatment and comparison groups, was 0.856. For the post treatment responses, the alpha coefficient was calculated to be 0.911 for the treatment and comparison groups. These values indicated an acceptable level of internal consistency. Of the 17 statements that the students responded to, only six demonstrated a notable (> 7.0%) difference between the comparison and treatment groups when comparing the change between pre and post treatment means.

Questionnaire Stems of the Six Statements:

3. Like Social Studies 11 and English 12, Physics 11 should be a required course for graduation from high school.

4. Students who are good at writing essays and interpreting literature should not have to bother with science and mathematics courses, if they would rather not study those subjects.

5. In a professional setting, astronomers and geophysicists rarely interact with people from other fields.

11. History is very interesting as a story of the past, but is very rarely relevant to the problems and challenges of today's world.

13. Scientists who are completing serious and important studies that will affect the world population, should be aware of the possible political outcome of their research.

17. Interpersonal skills are essential for any job or career in order to ensure success and fulfillment.

Table 7 (see page 75) provides a summary of the difference in mean responses of these six questions. The data for all 17 questions can be found in Appendix G. In general, the data indicated that after the treatment, the students in the treatment group were more likely to consider some type of integration a necessary and rewarding element of education. The largest difference in response was to the fourth statement. The mean response of the comparison group in favour of integration decreased by 8.4% after the unit on special relativity, whereas the treatment group's response in favour of integration increased by 10.2%. Statements 13 and 17 also showed large differences between the pre and post treatment responses of the treatment and comparison groups. The mean response of the comparison group in favour of integration for question 13 decreased by 3.6%; however, the treatment group's response increased by 6.6% after the unit on special relativity. In contrast, both groups' responses showed a decrease in favour of integration for question 17. However, the comparison group decreased by 14.2%, whereas the treatment group only decreased by 1.2%. In the other three cases, each difference between the pre and post change in responses of the comparison and treatment groups, indicated an increase in awareness of the importance of integration by the treatment

Table 7

Summary of Questionnaire Responses (Means) to Statements 3, 4, 5, 11, 13 and 17

Statement	Comparison			Treatment			Difference
	Pre	Post	Change	Pre	Post	Change	(Treat – Comp)
3	3.53	3.83	6.0%	2.42	3.09	13.4%	7.4%
4	2.67	2.25	-8.4%	2.27	2.78	10.2%	18.6%
5	2.87	2.58	-5.8%	2.05	2.30	5.0%	10.8%
11	2.67	2.42	-5.0%	2.95	3.10	3.0%	8.0%
13	3.93	3.75	-3.6%	3.63	3.96	6.6%	12.0%
17	4.13	3.42	-14.2%	4.26	4.20	-1.2%	13.0%

group. Considering all these data sources, the reflections, interviews, journals, timelines, poems and questionnaire responses, it can be inferred that integration took place during the treatment.

The second part of this research question concerned the possibility of providing integration in simple ways in the current structure of the school. Both the action teacher's journal reflections and the transcripts of the interviews with the guest speakers were studied in order to respond to this question. The response of the action and guest teachers to the experience with integration indicated that it is feasible to provide integration in the current school structure, given that the teachers support each other and are willing to collaborate. Five main different impediments to curriculum integration were discussed in chapters one and two: time required by teachers to prepare and collaborate, the organizational structure, funding, lack of content knowledge and lack of integration experience by teachers. None of these impediments was seen as insurmountable if teachers were willing to be flexible and receptive to new ideas.

Preparing for an integrated presentation to a class demanded extra time by the teachers. Nevertheless, it was observed that the extra work, like any other teacher preparation, could be used the following year and then be developed through the years of practice.

> *Action Teacher: May I ask you, for this hour and 15 minutes, how much time did you spend planning and preparing for it?*
>
> *English Teacher: Oh, I did do some research on these poems, so maybe two to three hours and then maybe another hour putting the lesson together, so maybe*

four, more than I would normally use for planning my own lessons, but that's because I was planning something new.

Action Teacher: Exactly and next time, if you came in to do the poetry . . .

English Teacher: I've got this done!

Action Teacher: You have the poetry, so it is something that can be built on just like anything else.

English Teacher: Yeah, absolutely.

(Interview, June 20, 2006)

Concerning the time required to plan, one teacher met with the action teacher at lunchtime. The other teacher was only able to meet over the phone because of other commitments. None of the teachers involved in the curriculum integration had preparation blocks during the same period.

Action Teacher Reflection: . . . Meeting with Amy was wonderful – she is excited about [curriculum integration] and mentioned our collaboration in her interview for next year. . . Michelle and I could only meet over the phone – at school we had no overlapping free time. But it went very well. I think we are clear on what we want to see happen in the class when she visits. (June 1, 2006)

The classes of the two teachers who came into the Physics 11 classroom as guest speakers, were supervised by other staff, who volunteered to support the teacher action. The action teacher reciprocated and covered the volunteers' classes on other occasions. The coverage was an important issue since the current school structure was not modified to provide the teachers involved in the integration with preparation time during the Physics 11 block. If integration was adopted and used to a greater extent, the problem of coverage would have to be addressed. Funding would be required if teachers on call were needed. In fact, the only requirement for funding using this simple method of integration that was noted, was for teachers on call.

A further hindrance to integration discussed in the literature review was the lack of content knowledge. All three teachers, the action teacher and the two guest speakers, required time for research to supplement their content knowledge. However, during the interviews, it was discovered that both guest speakers had a larger background in mathematics and science than expected by the action teacher. The English teacher had a substantial science background.

> English Teacher: *University was worse, I could choose between a science and an art program, but I couldn't do both and I wanted to do both. I loved Biology and did well, but I also loved literature and would plead that they would let me take more credits, because I wanted more lit courses – eventually they would let me. In my third year, I moved completely into literature, but before that I always found connections between my science and lit courses. (Interview, June 20, 2006)*

The social studies teacher had taken Physics 11 with the action teacher, was an accomplished diver, and had rowed for the University of Victoria, which demanded a comfort with mathematics.

> Social Studies Teacher: *You use math in diving. And in sports! There are rowing books on how to get the perfect stroke, not just physical, they have equations, many books in the UVic library. A boatman who builds the boat uses math, angles and figures out how to bend the wood perfectly.*
>
> *(Interview, June 28, 2006)*

Therefore, it is very likely, that both guest teachers were more inclined to participate in the integration because they had some positive experiences with sciences in the past. This possibly would not be the case for every teacher that considered using integration. It was also noted that in working together knowledge was shared, which was greatly appreciated by the teachers.

> *Action Teacher: You've given me such an insight. I enjoy mathematics just for the satisfaction of seeing the pattern and solving the problem. That was enough for me, when I studied physics the concepts blew my mind, those emotional responses were huge. I think many students are more like you, Michelle. When I taught the history of science leading up to the atomic bomb, people responded, everyone was paying attention. There was such an emotional response. There were a few that were not as affected, but by far the majority was. You could feel it in the room. (Interview, June 20, 2006)*

An important requirement described in the literature for integration is teacher collaboration. In this situation the three teachers enjoyed the collaboration very much and were stimulated and enriched by the opportunity to work together.

> *Action Teacher Reflection: Today Amy came in. It was so wonderful to have another teacher in the room. The students were very cooperative. (June 5, 2006)*
>
> *Action Teacher: . . . I really wanted to see how the children responded and I felt it was good for them so see us communicating and enjoying each other's contributions.*
>
> *English Teacher: And I really wanted you to be there when I was trying to talk about science. I loved having you in the room. . . (Interview, June 20, 2006)*

The lack of their own experience of integration can be a large hindrance for teachers. This was discussed and pondered at length by the three teachers involved in the teacher action. The teachers realized that each one of them had had very different experiences with integration during their high school and university education. The action teacher experienced curriculum integration once in grade 12. Her English teacher asked the art teacher to be a guest speaker in the English 12 class. The art teacher discussed a number of paintings and asked the students to respond to them with poetry. The action teacher composed a song that she imagined a woman in a painting was singing. The response of the class was very positive. However, that was her only experience with curriculum integration.

> Action Teacher: *Amy, I was taught linearly, even at University. I really feel that I should have had a course that integrated everything in my 4th year of my Physics degree. (Interview, June 28, 2006)*

The social studies teacher did not have any experiences with curriculum integration in high school. However, at university while studying history, she began to make connections on her own.

> Social Studies Teacher: *Of course, I didn't realize until university that you always think of these things on linear paths, you don't think that they intermingle.*
>
> Action Teacher: *And it happened to you at university?*
>
> Social Studies Teacher: *Yeah, it happened at university when I was taking courses and stuff and I realized, hey, 1500, that was the same time this was happening and I thought maybe those have some interconnected thing going on there, technology and history.*

Action Teacher: Wow, now was this technology and history, or was it two different histories or what was it that you noticed?

Social Studies Teacher: Hm, it was both, it was like Canadian history and then history in Europe. I would take these two separate courses and I wouldn't even realize, you don't even think about it, hey, that's happening at the same time, that's interesting. You wonder if they had something to do with each other until you take a world history and then you realize that, oh, wow, this is all going on at the same time, you can't learn it all at once though, but you realize the connections. (Interview, June 20, 2006)

On the other hand, the English teacher realized when she was a high school student that she learned through making connections. She discovered that when she was able to connect ideas from different subject areas that she retained and understood the material much better. Furthermore, if there was an emotional response connected to the situation, she was much more involved in the learning.

Action Teacher: Did you ever experience integration through high school?

English Teacher: No, not at all and I really believe that that is how I learn. I was focused on sciences in high school because I thought I was going into sciences but I took as many literature courses as possible because I loved them and I remember going from English to Biology 12 and saying, oh, that's a metaphor – isn't that weird.

Action Teacher: You made connections.

English Teacher: Yes.

(Interview, June 20, 2006)

Lack of experience with integration, especially at the high school level contributed to all three teachers feeling apprehensive about participating in the treatment.

<u>Action Teacher</u>*: My first question is, would you do this again? Would you come I into the Physics 11 class again and do poetry?*

<u>English Teacher</u>*: My answer is definitely yes. And I would do it with less fear and trepidation, I would do it with more – I wouldn't be as nervous.*

(Interview, June 20, 2006)

<u>Action Teacher</u>*: Do you think it would have been easier if we had brought the class to your room?*

<u>Social Studies Teacher</u>*: Yeah, I'm comfortable with that area. I probably wouldn't have been as nervous, I probably wouldn't have forgotten as many things.*

(Interview, June 28, 2006)

<u>Action Teacher Reflection</u>*: I can't believe it! I was so nervous about the whole thing and now I feel so good about it. I really want to do more of this. It was fun, it was exciting, I think it was really worthwhile! (June 13, 2006)*

In summary, the action teacher and her two colleagues had a positive experience being involved in the integration unit and felt that it was possible to adopt this teaching method to some degree within the limitations of the current school structure. It was discovered that the time required by the teachers to prepare, collaborate and research generated numerous benefits. The prepared integration lessons and research of content could be used for future instruction and the collaboration provided professional development. The lack of integration experience certainly played a role, but one single experience appeared to be enough to decrease the apprehension of using integration and developing enthusiasm for this method of teaching.

Research Question 3

Do students become more aware of the complexity of the world they live in and the connections between different bodies of knowledge after experiencing integration?

The attendance data, journal responses and differences between the pre and post responses to the questionnaire indicate that students in the treatment group became relatively more aware of the importance of integration and the complexity of the world when compared to the comparison group.

The attendance of the treatment group was significantly higher during the teaching of the unit on special relativity than the comparison group, indicating that possibly the students were more involved in the course, a predicted outcome of using curriculum integration. In addition, the journal reflections demonstrated that the participants were aware of connections between their learning and the real world. Finally, the questions #18 – #24, #26, #30 and #31 of the questionnaire, which related directly to the third research question, indicated that the treatment group became comparatively more aware of the complexity of the world than the comparison group.

Questions #18 – #24 involved choosing from one to twelve high school subjects that the students felt were mandatory for the education of seven different professions to ensure success in the particular profession. The results are summarized in Table 8 on page 84.

The average difference between pre and post results for the comparison group was a decrease of 0.027, which was 0.23% of the 12 options. This negligible difference

Table 8

Summary of Questionnaire Responses (Means) to Questions #18 - #24

	Comparison			Treatment		
Profession	Pre	Post	Change	Pre	Post	Change
artist	5.17	4.67	-0.50	4.11	4.35	0.24
business person	4.60	4.67	0.07	4.47	5.04	0.57
carpenter	3.80	4.00	0.20	2.79	3.74	0.95
philosopher	7.10	6.75	-0.35	6.00	6.74	0.74
politician	5.67	5.50	-0.17	5.53	5.91	0.38
reporter	5.80	5.58	-0.22	4.00	5.09	1.09
scientist	6.80	7.58	0.78	7.32	7.22	-0.10

indicates that there was relatively no change in the responses of the comparison group between before and after studying the unit of special relativity. On the other hand, the average difference between the pre and post results for the treatment group was 0.55, which was an increase of 4.6%. In other words, after the unit on special relativity, the students in the treatment group identified on average a larger number of high school subjects that they felt were necessary for the success of a variety of professions. Of the seven professions, the comparison group selected a larger number of required high school courses for three (43%) of the professions. The treatment group selected a greater number of required high school courses for six (86%) of the seven professions. The eighth profession, *teacher*, (question #25), was not included in the analysis. A number of questionnaires contained comments that indicated that the students were not sure if the *teacher* was at an elementary school, high school or college. Therefore, they were not sure how to respond and were hesitant to be definite.

For question #26, participants were asked to choose how many of sixteen professions or jobs should have both science and humanities as part of their education. The comparison group had an average increase of 0.7% between their pre and post responses. The average increase for the treatment group was 8.3%. These differing results indicated again almost no change in the comparison group and a decisive increase in the treatment group (see Table 9 on page 86).

For question #30, students were asked to choose how many of sixteen different professions would be required to solve the world problem of global warming. For the comparison group the average increase was 2.2% between their pre and post unit responses. The average increase for the treatment group was 6.0%. For question #31, students were asked to choose how many of sixteen different professions would be required to solve the world problems of war and terrorism. For the comparison group the average increase was 0.4% between their pre and post unit responses. The average increase for the treatment group was 6.0%. These small but clear differences between the comparison and treatment groups confirm, that though these STSE issues were not directly presented to the students, participating in the treatment encouraged students to become more aware of the global aspect of environmental and political concerns.

Summary

During the fourteen hours of teaching the unit on special relativity, different data were collected in order to respond to the three research questions. There were differences in achievement and attendance. Both quantitative and qualitative data indicated that

Table 9

Summary of Questionnaire Responses (Means) to Question #26

	Comparison			Treatment		
Category	Pre	Post	Change	Pre	Post	Change
artist	13.3	25.0	11.7%	10.5	13.6	3.1%
athlete	0	8.3	8.3%	15.8	4.6	-11.2%
business person	46.7	25.0	-21.7%	31.6	50.0	18.4%
carpenter	20.0	33.3	13. 3%	5.3	9.1	3.8%
childcare worker	20.0	41.7	21.7%	21.1	31.8	10.8%
engineer	73.0	50.0	-23.0%	47.4	63.6	16.3%
farmer	20.0	41.7	21.7%	21.1	31.8	10.8%
lawyer	33.3	41.7	8.3%	47.4	45.5	-1.9%
mechanic	40.0	25.0	-15.0%	10.5	27.3	16.7%
nurse	46.7	66.7	20.0%	42.1	27.3	-14.8%
philosopher	73.3	66.7	-6.7%	52.6	50.0	-2.6%
politician	46.7	25.0	-21.7%	68.4	45.5	-23.0%
reporter	33.3	33.3	0%	21.1	50.0	29.0%
scientist	86.7	75.0	-11.7%	94.7	86.4	-8.4%
secretary	6.7	8.3	1.7%	0	13.6	13.6%
teacher	100	100	0%	73.7	86.4	12.7%

curriculum integration allowed the academic achievement to be retained by the treatment group. The guest speakers and action teacher expressed enthusiasm for the treatment and thoroughly enjoyed the collaboration. Qualitative data implied that it was possible to provide curriculum integration within the current timetable and structure of the high school. The poetry and journal entries provided insights into the participants' experiences with the theory of special relativity and the experiences with integration. Differences in responses to the questionnaire pointed to an increase in appreciation of the complexity of the world by the treatment group and, furthermore, a clear increase in awareness of the value of integration. The integration was intense and valuable for both teachers and students. The next chapter will outline conclusions drawn from the data, list a number of recommendations for further study and explore ways that teachers can incorporate curriculum integration using simple tools within the current school structure.

Chapter 5

Discussion and Conclusions

Introduction

Literature has repeatedly shown that curriculum integration can contribute many valuable benefits to education and is becoming essential for preparing students for this new century of rapid technological, political and environmental change (Burton, 2001; Czerniak, Weber, Sandmann & Ahern, 1999; Ellis & Fouts, 2001; Gaff, 1989; Gehrke 1998; Hargreaves & Moore, 2000). Yet, there are a number of requirements described in the literature that appear to make integration a challenge for classroom teachers in the present school structure (Aschbacher, 1991; Basista & Mathews, 2002; Gaff, 1989). The purpose of this study was to determine whether it is possible to provide integration in a typical school setting with few resources and whether a simple model of integrating physics with humanities can have a positive influence on academic achievement and attitudes of students. Furthermore, it attempted to determine whether a simple model of integration could contribute to increasing students' awareness of the value of integration and the complexity of the real world. This chapter discusses the conclusions drawn from the results of this study. Each of the three research questions will be discussed separately, followed by a summary of limitations of the study and a description of unexpected outcomes of the treatment. Suggestions for further studies of integrating sciences and humanities are outlined, followed by recommendations for educational professionals, who are interested in using integration in their teaching.

An initial cursory look at the results described in chapter four clearly demonstrates that the findings support positive responses to all three research questions.

The differences in the achievement scores between the comparison and treatment groups and in the responses to the questionnaires point to a more effective teaching of physics by using integration, and to an increased awareness of the importance of integration. The student products of poetry, historical timelines and journals all demonstrated that the goal of encouraging deeper and more critical thinking was met. Not only did the students relate their studies to the real world, but they also became more mindful of the complexity of the world. Finally, and possibly most importantly, reflections and discussions with the three participating teachers indicated that integration can be developed within the present school structure. Though the system is not ideal, there is no reason to let existing impediments to integration become unmanageable obstacles.

At the same time, some aspects of the study must be carefully considered. The unwillingness of the less successful students of both classes to participate and the bias of the action teacher require a thorough scrutiny of all results. Are the outcomes relevant? Do the quantitative and qualitative results support each other? Moreover, can the results of this study be used to make recommendations for other schools in different circumstances?

Research Question 1

Does curriculum integration allow the current academic achievement of high school students in a Physics 11 class to be retained?

The results of this study demonstrated that the academic achievement was retained by the treatment group and in the case of unit tests; it was improved. This outcome was determined by comparing the unit mark and test for special relativity of a treatment group and a comparison group with the average of the other unit marks and unit tests. The results of the ANCOVA analysis on the results of the two groups revealed that the treatment group significantly outperformed the comparison group on the unit test on special relativity.

The expectation that the academic achievement would be retained, was based in part on a report that “young people tend to do as well, and often better, on traditional measures of school achievement when the curriculum moves further in the direction of integration” (Beane, 1995, p. 618). Positive achievement results of using curriculum integration were reported by Aschbacher (1991) and Cain (2002). Aschbacher ascertained that the Humanitas Program significantly affected the students’ writing and content knowledge and, furthermore, dramatically improved the attendance of the students. Cain determined that students who participated in the Connected Mathematics Project (CMP) regularly outperformed students who did not take part in this program. These results encouraged expectations that the treatment group would retain the academic achievement expected for the Physics 11 class, even though some of the instructional time was used for integration with subjects from the humanities.

The positive achievement results on the unit tests were supported by the difference in attendance during the teaching of the unit on special relativity. Attendance is considered a measure of possible academic success. A longitudinal study in Britain conducted by Petrides, Chamorro-Premuzic, Frederickson and Furnham (2005) indicated that “attendance levels are positively correlated with academic performance, even after partialling out verbal ability and personality scores” (p. 250) of the students. Aschbacher (1991) had noticed a sizable increase in attendance of students involved in the Humanitas project. Therefore, it was predicted that there would be no decrease in attendance of the treatment group in this study and if there was a difference that it would be in favor of the treatment. This was the case! The absentee rate for the comparison group increased during the unit of study, and decreased for the treatment group. Similar results were found during an interdisciplinary unit at Running Creek Elementary School, where the attendance went up from the usual 85% to 98% during the integrated unit (Jacobs, 1989). Therefore, it can be concluded, that the quantitative data collected during this study supports an affirmative answer to the first research question.

The qualitative data gathered during the investigation consisted in part of reflections and observations by the action teacher and interviews with the two participating teachers. These data not only confirmed the results of the quantitative data, but also indicated a possible reason that the academic achievement of the treatment group was higher than that of the comparison group. The action teacher's observations that the students were more attentive, participated more, completed homework more willingly, and were more excited about the material, could account for the improvement in attendance. The improved attendance and the greater participation could in turn have contributed to the improved academic achievement. This is consistent with previous findings discussed by Jacobs (1989) who observed that integration is associated with higher attendance, improved homework completion and overall better attitude towards school. The response of the English teacher supports this claim, as she was very aware that an emotional connection to a subject was necessary for her to learn the material well. A number of educators have observed how an integrated curriculum can enhance students' focus and engagement (Hargreaves & Moore, 2000). One of the premises that supporters of integration claim, is that "when curriculum and instruction engage the personal intellect of the students, they are more motivated and interested in the study, and students exhibit a greater degree of retention and understanding" (Erickson, 2001, p. x). Therefore, the positive attitudes of the students in the treatment group, as observed by the action and participating teachers, were in keeping with other findings and may have contributed to improving academic achievement.

This research question is important, since in this study a science subject was integrated with disciplines from the humanities. In the Humanitas project (Aschbacher, 1991) courses from humanities were integrated, such as language arts, social studies and art. The purpose of the CMP (Cain, 2002) was to provide mathematics to students that was thoroughly connected to other mathematical concepts and to real-world applications. The GTECH project (James, 2000), another example of successful integration, prepared teams of mathematics, science and technology teachers with the goal of integrating science, mathematics and technology at the middle school. None of these three successful examples of integration involved both areas of humanities and sciences. The examples of integration that involved physics that were mentioned in the literature included physics and mathematics or physical education. For example, a cross-curricular course in physics and mathematics was taught in Japan at Kanazawa Technical College (Saeki et al., 2001). The purpose of this course was to present connections between mathematics and physics. The program was successful, but, it also did not provide integration of subjects from both science and humanities. In contrast, the results of this study demonstrate that integrating subjects from science and humanity disciplines can make a positive impact on the academic achievement of students in a Physics 11 class. Providing students with the opportunity to integrate areas from both sciences and humanities is an important preparation for their successful integration into today's rapidly changing world after they graduate from high school. R. C. Taft, an electrical engineer with National Semi Conductor, currently designs integrated circuits that will be used in communication satellites. He has pointed out on numerous occasions that the most important skill for engineers is communication and is convinced that without his reporting and writing skills, he would not be the successful manager of his research group that he is (personal communication, July 2005, July 2006).

Research Question 2

Is it possible to provide integration with limited resources and simple tools within the timetable and structure of the current high school?

The results supported a favourable answer to the second research question. It was shown that it is possible to provide integration in the current high school structure and; furthermore, that a simple model of integration can be effective. Given that a simple model was used and the action and participating teachers had little experience with curriculum integration, it was first necessary to establish whether integration had occurred during the treatment. The quantitative results demonstrated that the treatment group experienced improved academic achievement. However, it was possible that the result was due to the students' awareness that they were part of a study and that the novel lessons generated greater interest and participation. Examination of the integrated unit and the work of the students suggested that integration had successfully been provided, and, therefore, contributed to the improved scores of the treatment group.

The integration was provided to the treatment group by the action and participating teachers. The three teachers modeled both the making of connections and the importance of these connections between different concepts in teaching the unit on the special theory of relativity and its historical and cultural context. Teaching connections was a key principle for integrated units (Humphreys, Post & Ellis 1981):

> It is taken for granted, apparently, that in time students will see for themselves how things fit together. Unfortunately, the reality of the situation is that they tend to learn what we teach. If we teach connectedness and integration, they learn that. If we teach separation and discontinuity, that is what they learn. To suppose otherwise would be incongruous (p. xi).

Kysilka (1998) described the importance of students observing their teachers making connections between content areas. Aschbacher (1991) noted that the students enjoyed seeing their teachers have intellectual disagreements. Students in this investigation were positively affected by seeing teachers working together. They enjoyed it, which probably contributed to their positive attitude toward the integrated unit. The reflections of the action teacher and interviews with the guest teachers mentioned the positive attitudes of the students towards the teacher collaboration a number of times.

During the treatment, the students were given the opportunity to integrate concepts at a deeper level by reflecting in journals on five questions. The depth of integration naturally varied from student to student; but all five of the journal questions gave the students opportunities to strengthen connections between different concepts and areas. Each journal question related the students' learning to the real world, real people, or real experiences. Kysilka (1998) stated that the purpose of an integrated curriculum is to "bring meaning to curriculum, a means of making the curriculum more connected to what is happening in the real world" (p. 203). One of the two students, who received a personal best test mark on the unit of special relativity, wrote journal reflections demonstrating both creative thought and critical thinking to an unexpected depth as compared to his previous class work. His reflections were often unique in the class. Here is his response to the first journal question concerning whether discoveries in science will continue.

> Journal Question 1*: During the last 100 years there have been many discoveries in science. Do you think that this will continue during the next 100 years? Why or why not?*
>
> Journal Entry*: Yes, but I believe the rate of advancement will decrease due to the complexity of finding answers to the present questions and concepts which engineers and [physicists] wonder about. I believe that learning is a gift but can lead to absolute mayhem. The atomic bomb for example is a prime example of this. (Student Journal #8)*

The analysis of the journals indicated that these learning activities provided the students with space and time to reflect and ponder the concepts during the teaching of the unit on special relativity. The analysis of the journals contained evidence that students made connections, were capable of critical thinking and perceptive insights, and produced thought provoking reflections and comments. These observations are consistent with statements made by Tchudi and Lafer (1996), who suggested that writing is one of the best ways of “synthesizing and exploring learning” (p. 169).

The students also participated in two activities that gave them further opportunity to integrate different subjects, creating historical timelines and writing poetry. The activity of putting together a historical timeline that reflected important dates in both the political and the science history was cut short by a change in the timetable of that day. The integration that took place was quite superficial compared to the reflections in the journal; however, it contributed to the experience and awareness of integration and connections. In terms of providing an exercise that promoted integration of subjects, the poetry assignment was much more successful. The poems allowed the students to express their awe and bewilderment, as they connected concepts, feelings and observations. Some of the participating students had fun with the poems; others were able to express strong emotions. The action teacher was reminded how challenging and non-intuitive the concepts of special relativity are when first introduced to students.

One other piece of data supported the existence of integration in the treatment group classes. The first part of the questionnaire had 17 statements that related to curriculum integration. There were noticeable differences for six of the statements. In every case, the treatment group indicated an increased awareness of the importance of integration, whereas the comparison group did not. Considering these data sources, the reflections, interviews, journals, timelines, poems and questionnaires, it can be concluded that integration was provided during the teaching of the theory of special relativity. Consequently, since it has been shown that integration leads to improved attitudes and increased achievement (Beane, 1997; Drake, 1993; Erickson, 2001; Hargreaves & Moore, 2000), it can be inferred that the integration played a role in the significantly higher achievement of the treatment group.

The second part of the second research question concerned the feasibility of integration being used in the current school structure. The literature review suggested that there were five main impediments to using integration: time required by teachers to prepare and collaborate, the organizational structure, funding, lack of content knowledge and lack of integration experience by teachers (Kirkwood, 2000; Kysilka 1998; Martin-Kniep et al., 1995; Meier, 1996). A concern that was discussed in the literature by a number of educators was the time required by teachers to plan and prepare for curriculum integration. Interdisciplinary studies take a tremendous amount of time, especially during the design stage (Stolpa, 2004). The three participating teachers in the investigation agreed that time was a critical requirement. However, this demand was not seen as an obstacle, but as a normal prerequisite of teaching new material or using a new method to teach the prescribed curriculum. It was suggested by the participating teachers that the time was well worth it and that if expectations were kept reasonable as an integration program was built up slowly, the time requirements would not be overwhelming. The guest speakers emphasized that newly researched material and prepared lessons could be used in future integrated lessons.

A possible substantial impediment to using curriculum integration is the current organizational structure of high schools. Clearly, teacher collaboration for the teaching of the unit on special relativity would have been easier if the participating teachers had had preparation blocks during the same period. At a school with one or two thousand students and supportive administrators, arranging for preparation blocks at the same time could certainly be accommodated. But what about smaller schools? The participating teachers felt that the obstacles created by the existing timetable and teaching assignments could be overcome, keeping in mind the proposed simple model of curriculum integration. Both the English teacher and the action teacher were satisfied with the meeting they had using the telephone. The meeting of the social studies and action teacher after school was easily arranged. It was evident that creativity, flexibility and a willingness to accommodate people and circumstances played a larger role than the school structure in making curriculum integration a success in this study.

The current high school structure also creates the need for classroom supervision when using curriculum integration. One of the outcomes of the treatment was the discovery of how beneficial it was for students and teachers when guest speakers and action teacher were in the classroom at the same time. This had been possible because a third party supervised the guest speakers' classes. In the study's limited application of curriculum integration, there were only two classes that required supervision from a third party. This demand would become much more extensive if curriculum integration was incorporated more thoroughly and by more teachers. Additional supervision would in turn require budgeting for teachers on call to provide class coverage. However, surprisingly, this was the only extra cost that was noted by the action teacher at the conclusion of the treatment. Funding has been discussed as a substantial impediment to curriculum integration becoming more widespread (Meier, 1996). However, as demonstrated in the study, a simple model can be adopted with no extra funding and still have an impact on the learning of the students. Furthermore, if a school has serious financial needs, curriculum integration can still be possible without funding for teachers on call. As the guest speakers and the action teacher discussed, lack of money should not prevent the use of curriculum integration.

> Action Teacher: *. . . – and if no one could cover our classes, would you be comfortable coming into my class, while I went into your class.*

English Teacher: That would be really fun, really fun. And if I wasn't doing a whole novel that dealt with science, you could come in and talk about science in a poem or a short story, oh, there [are] a lot of possibilities.

(Interview, June 20, 2006)

The second guest speaker was also willing to avoid the cost of teachers on call.

Social Studies Teacher: Yes, and maybe we could put both classes together so we didn't have to get coverage, but maybe that would have been too many.

Action Teacher: I was thinking even, if we did this regularly, I could take just your class and you come in here.

Social Studies Teacher: That's true, that would work.

Action Teacher: And actually, maybe we could exchange, you could come and bring the history here. I could bring the physics to your social's class.

(Interview, June 28, 2006)

This solution would not allow teachers to work together in the classroom, but at the start of building up a curriculum integration program, it might be necessary to do without that particular benefit. The willingness to accommodate the school structure speaks favorably of how the three teachers felt about their experience with curriculum integration.

The success of curriculum integration depends without question largely on the content knowledge of the participating teachers (Martin-Kniep et al., 1995). All three contributing teachers to the study spent considerable time researching content in preparation for the curriculum integration. The comfort with which the two guest speakers related the physics content to their own subject area increased the effectiveness of the integration. As mentioned previously, the preparation could be used the following years and would not have to be repeated. There is an added benefit of teachers continuously increasing content knowledge and extending their own connections between concepts, and that is the value of modeling what it is to be a lifelong learner. When students observe teachers struggling with new ideas and enthusiastically approaching a different subject area, they will internalize that learning is a lifelong process (Stolpa, 2004). Helping students to become aware that knowledge and understanding is continuously adapted and modified as new information becomes available is an essential aspect of education, especially science education (Good, Shymansky & Yore, 1999).

One of the largest hindrances to curriculum integration is the lack of teacher experience, which was evident in the small study. Though the action teacher was persuaded after reading about the benefits of curriculum integration that it was worthwhile to include this method of teaching, she felt unprepared and unsure about the treatment. Both the guest speakers expressed that they were nervous. Drake (1993) concluded from her discussions with numerous teachers and teams who were attempting to use curriculum integration that most teachers felt overwhelmed, unsure and challenged when beginning to use curriculum integration. Nevertheless, after the completion of the treatment, before any data were analyzed, the action teacher felt convinced that curriculum integration was very valuable, due to her own positive experience and the enthusiasm of the students and guest teachers.

> *<u>Action Teacher Reflection:</u> Michelle [English teacher] came in today. It was fabulous. The kids participated so well. She was so enthusiastic and tied it in beautifully. It really gave the kids the opportunity to express their feelings about*

special relativity. And they had such strong feelings of which I was really unaware. I believe in [curriculum integration] totally! (June 8, 2006)

This encouraging experience gave the action teacher the desire to increase her own use of curriculum integration in the future. Drake observed similar outcomes, “I was fascinated to discover that the ‘impossible nightmares’ faded and were replaced by much more positive interpretations once a writing team actually began to implement integrated curriculum” (p. 2).

Many examples of successful integration in the literature implied that restructuring, professional development and funding were necessities for the successful implementation of curriculum integration (Basista & Mathews, 2002; Cain, 2002; Meier, 1996). The results of this study suggest that if these requirements are not met, it is still possible to provide integration to students. The most important requirements for a successful integration program are enthusiastic teachers, willing to take risks, work together and learn from colleagues and students. These qualities are found in any healthy, effective school, no matter how small or poor.

Research Question 3

Do students become more aware of the complexity of the world they live in and the connections between different bodies of knowledge after experiencing integration?

The consistent differences between the pre and post responses for the comparison and treatment groups to the questionnaire indicated that by participating in the integration, the treatment group became more aware of the importance of developing skills in both sciences and humanities, of the relevance of high school education and that the problems of the world can only be solved by people working together. It is actually remarkable that with such a relatively small and simple treatment, there was a noticeable change in attitude of students in the treatment group.

Harris and Alexander (1998) pointed out that two of the consequences of a disciplined and fragmented approach were “boredom and lack of relevance of school to students’ lives” (p. 117). The survey questions #18 – #24 directly related to this issue. There were slight shifts in the mean responses to these questions in the comparison group, averaging less than half a percent. However, the results of the treatment group were quite different. Six of the seven questions showed an increase, for an overall increase of 4.6%. This increase implied that these students became more aware of the relevance of high school studies after the treatment. Given the short treatment of 14 hours, these results were encouraging.

Martin-Kniep et al. (1995) stated that effectively developed integration would help students appreciate connections between diverse concepts and ideas and become more aware of the complexity of the world. These issues were addressed by questions #26, #30 and #31. Question #26 reflected the connections between science and humanities. There were some shifts in the pre and post responses for the comparison group, but again the overall change was less than one percent. On the other hand, the overall increase for the treatment group was 8.3%. These results implied that after participating in the units on special relativity, students in the treatment group felt that a greater number of the 16 listed professions required both studies in humanities and science to complete their education. Questions #30 and #31 dealt with the concern of increasing awareness of the complexity of the world. The questions dealt with serious issues that had repeatedly been in the news, global warming and terrorism. For both these questions, the students were asked to choose how many of 16 listed professions would be required to solve the specific problem. The responses to the question dealing with global warming showed an increase in both the comparison group (2.2%) and the treatment group (6.0%). The responses to the question dealing with terrorism showed almost no change for the comparison group (0.4%) and a noticeable change for the treatment group (6.0%). The changes observed between the pre and post responses of the students, indicated that there was a definite shift in the attitude of the treatment group, whereas there was little or no change in the comparison group. Again, these results indicated increased awareness of the complexity of the world and the need for people of many professions to work together to solve complex world issues.

Students in both the comparison and treatment groups were aware of the purpose of the study since it was described briefly in the recruitment information. During the teaching of the unit on special relativity, the students in both groups were not explicitly reminded of this purpose. However, it is very likely that by participating in the activities and receiving the integrated lessons, the students in the treatment group were alerted to the purpose of the study. It is very probable that these implicit reminders influenced the responses of the participants when filling out the questionnaire. It is impossible to determine how much of the changed attitude of the treatment group was due to the integration activities and how much was due to the awareness of the topic of study. It would be a natural outcome in any classroom that the activities chosen by the teacher would reveal the teacher’s ideals. Choosing to include integrated lessons would logically promote awareness of the importance of integration.

The third research question contributed to the study by showing that a simple model of integration does not only improve the academic achievement of the students, but also encourages students to become more aware of the complexity of the world and the value of interdisciplinary approaches. Though the differences in responses to the questionnaire questions relevant to the third research question were not large, they indicated that the simple model of integration was effective in transforming attitudes.

Limitations of Study

The results and implications of this study indicate favourable answers to all the research questions. However, there is an important limitation to the study. Unfortunately, in both the comparison and treatment groups, the lower achieving students chose not to participate in the study. The mark range missing from the comparison group because of non-participation was 34% - 64%. The mark range missing from the treatment group because of non-participation was 54% - 78%. At the same time, it is advantageous that this choice was made by students in both groups, since, if the lower achieving students of only one group had participated, the results of the comparison between the two groups might have been biased. Any reform in education is geared in large part to the lower achieving students as it is hoped that the reform will be beneficial for all students, especially if they are not experiencing success in the current system. However, though it can be concluded that the middle and high achievers in this physics class benefited from the curriculum integration, the same claim cannot be made of the lower achieving students.

Nevertheless, observations by the action teacher indicated that the lower achieving students enjoyed and participated in the integration. The action teacher was surprised at what a difference integration made in attentiveness for some of the students. One of the lowest achievers completed all journal entries and began participating in the class, which had not happened before. On the other hand, comments made by a few of the lower achieving students, demonstrated that they were embarrassed by their marks and that they did not see how their marks could possibly help the action teacher. There appeared to be a fear that their low marks would ruin the results for the action teacher. Given the outline approved by Ethics, the action teacher did not encourage or reassure these students, as their participation had to be voluntary. If this or a similar study were completed in the future by the action teacher, she would specifically address this issue in the recruitment information used to introduce the students to the research. It is apparent that promising anonymity was not enough for these students. It should have been stressed that the lower marks were every bit as important for the research as the higher marks. In conclusion, though some observations implied that the lower achieving students benefited from the curriculum integration, there was no quantitative data to corroborate these observations.

A second limitation of this study is that though the data showed that a simple model of integration in the current school structure is possible, this positive outcome was in part influenced by the background of the guest speakers. Both the English teacher and the social studies teacher had had positive experiences with science. Their experiences helped them be more comfortable in the Physics 11 class and ultimately more willing to participate. This would not necessarily be the case with every teacher who wanted to contribute to establishing a program of integration. Therefore, it must be considered that given different circumstances and teachers, the preparation for an integrated unit might be more time consuming and more daunting. In the same way, the influence of the action teacher must be considered. Naturally, she was aware that her enthusiasm for the integrated classes with the treatment group could influence the outcome of the study. Therefore, she made an effort to bring passion and excitement to her classes with the comparison group. She continuously reminded herself that her actions could play a role in both Physics 11 classes. Nevertheless, it is very likely that her interest in the integrated curriculum design contributed in part to the positive results of this study.

Unexpected Benefits of Curriculum Integration

The descriptions of curriculum integration in the literature consistently mentioned the importance of teacher collaboration. Aschbacher (1991) maintained that teacher collaboration was essential for the success of integration and pointed out that frequent meetings, sharing feedback and revising plans were necessary ingredients for teachers working together on curriculum integration. It had been expected that the action teacher and participating guest teachers would have to meet to plan and evaluate the treatment. However, the rich, stimulating and professional sharing that was generated by the preparation and discussion of results was an unexpected and valued benefit.

The planning and evaluation of the experience brought about an exchange of ideas that would not have happened otherwise. The three teachers gained insight into connections that their colleagues had made, which they themselves had not experienced or developed. The English teacher had made connections between biology and literature, the social studies teacher had made connections between American and European history and the action teacher had made connections between physics and history. Sharing these perceptions increased the participating teachers' awareness of connections. Though this was an unexpected outcome by the participating teachers, it is consistent with findings by Gaff (1989) who realized that one of the principal means of professional development for teachers in curriculum integration is team teaching. Furthermore, the revelation of the English teacher's need for connection in order to learn and the experience of the social studies teacher connecting historical dates from different parts of the world, provided the action teacher with a greater awareness of different styles of learning. Recent brain research has demonstrated that humans look for connections to make meaning and, therefore, teaching through connections would appear to be vital (Czerniak et al., 1999; Drake 1993). Curriculum integration is seen foremost as a teaching method that will benefit students. Nevertheless, promoters of curriculum integration point out that the nature of this method leads to professional sharing among teachers, which can be of great benefit (Hargreaves & Moore, 2000). The professional enrichment that the participating teachers in this study experienced was greatly appreciated and valued.

Another unexpected outcome for the action teacher was the tremendous insight she gained from the fifth journal question on group work. She had no concept of how thoroughly the students understood the value and challenges of group work. Group work is used by many advocates of curriculum integration as a way of allowing collaborative learning to take place. "Cooperative learning encourages sharing of ideas, provides modeling of learning processes, and develops student bonding. Through participation, students learn how to listen actively, integrate the opinions of others into their views, practice negotiation and persuasion, and draw logical conclusions" (Mallery, 2000, p. 20). The students' responses made the action teacher aware of how important well thought out and implemented group work is for the development of higher-level thinking and integration. This increased awareness is a documented outcome when using curriculum integration. “Interdisciplinary curriculum provides opportunities for ongoing professional growth. As teachers design instruction, their research leads to broader and broader schema and in-depth content understandings. As [teachers] observe children, read their papers, and listen to their reports, [they] grow as educators” (Mallery, p. 9).

Recommendations for Further Study

An essential aspect of further studies in curriculum integration is the inclusion of the lower achieving students in a secondary science class. The concerns of poorly achieving student need to be addressed directly in the recruitment information to prevent their lack of participation due to feelings of inadequacy. Furthermore, being aware of these probable feelings, the ethics proposal should be prepared with this in mind, allowing the action teacher to use one or two specified phrases of reassurance. The value of the study would be greatly enhanced if the lower achieving students also responded positively to curriculum integration.

It is suggested that this study be repeated with two or three units. A positive result would hopefully demonstrate that the enthusiasm of both teachers and students was not entirely due to the novelty of the treatment. Furthermore, given that the students would be involved with curriculum integration for a longer period, the gain from this method of teaching might be more pronounced. Two units in Physics 11 could be easily added to the theory of special relativity for use with curriculum integration, optics and kinematics. In optics, students use ray diagrams to identify the positions and characteristics of different images. These activities could be connected to biology with physiology and anatomy of the eye, with psychology and the influences on human perception and with pop culture of super beings with x-ray vision. In kinematics, students use linear and curved graphs to understand the concepts of displacement, velocity and acceleration. These concepts could be connected to the graphing learned in previous mathematics classes. At the end of the kinematics unit, the students are introduced to accident reconstruction and forensic science by using given variables to determine how the accident might have occurred. This could be integrated with English for writing reports on the accident after calculations were completed. The history of science could be presented to the students throughout the units of optics and kinematics, as it was with the special theory of relativity. These suggested connections involve both science and humanities. The connections to humanities (psychology and English) engage and promote interdisciplinary skills needed by the students in the future to complement one another, as previously discussed. The connections to science and mathematics are also indispensable. “Science is no longer characterized by pure disciplinary lines, such as biology, chemistry, geology, and physics. Rather, divisionary lines between the sciences are blurred” (Czerniak et al., 1999, p. 424), making it imperative that students be exposed to the integration of sciences to prepare them to live in today's developed world.

The weakest response to this study was to the third research question. Though the differences between the pre and post responses on the questionnaire by the treatment group indicated a favourable change, this outcome would have been more convincing if statistical tests had been made on the data. Therefore, in combination with a longer study, the questionnaire could be used again to collect pre and post treatment responses. These responses could be coded so that an analysis of variance could be completed to test for significance.

If further studies on curriculum integration between physics and subjects from the humanities were conducted, it would be advisable not to administer the treatment at the end of the school year. The action and participating teachers realized that conducting the study in June had a number of disadvantages. The action teacher observed that some students had given up on school in general, as they were so close to finishing the school year. This could have biased the results of the study. Furthermore, the guest teachers and action teacher discovered that interruptions by the school routine at that time of year interfered with the treatment. For example, the day the social studies teacher visited the physics class, a schedule change decreased the class time from the expected 75 minutes to 60 minutes, not giving students enough time to finish the historical outlines.

Recommendations for Teachers

The results of this study suggest that using a simple model of curriculum integration in a Physics 11 class in the normal school structure is not only possible, but also that it will favourably influence the academic achievement, attendance and attitudes of participating students. Successful examples of curriculum integration described in the literature involved professional development, restructuring of the school organization and considerable funding. This study clearly demonstrated that though these features would be very helpful, curriculum integration can be incorporated to some degree without them.

The treatment used in the study did not involve a completely integrated unit, but rather a traditional physics class that was supplemented with lessons and activities that promoted integration. It was hoped that taking the time for these activities would not hinder the treatment group from understanding the physics' concepts. The opposite occurred. The simple integration model that was used actually appeared to improve the academic achievement of the students and at the same time help students become more aware of connections and complexities in the real world. Therefore, it can be conjectured that even a small amount of integration is better than no integration at all. Consequently, if a teacher would like to incorporate curriculum integration in his or her teaching it is possible to do so, without waiting for extensive professional development and reorganization.

The first activity that is recommended is the use of journals. Perkins (1991) emphasized that "coaching understanding performances" will enhance the quality of thinking. This included writing across the curriculum such as in journals. The more the writing goes beyond description to include "interpretation, generalization, argument, analogy [and] transformation" (p. 7), the more that thinking at a deeper level is encouraged to develop. Journal writing can be incorporated in any class without the need to collaborate with colleagues and administrators. Structured-entry journals give students the opportunity to reflect, integrate and develop critical thinking. If questions and statements are chosen carefully, responding to them will encourage students to relate their learning to their own experiences and the real world.

An additional activity that will promote integration and does not require any collegial teamwork is group work. This activity can be simple, such as completing a laboratory exercise or problem set as a group. On the other hand, this activity can be challenging such as presenting the students with an ill structured or STSE problem and encouraging them to use as many resources as possible to develop a solution. The deeper and more challenging the group work, the more extensive the integration developed by the students and the deeper the awareness of connections established by the students.

If colleagues are willing to collaborate and exchange lessons in their subject area, the integration will benefit both the students and participating teachers. If two or three teachers begin to develop a curriculum integration program, it would be important to have reasonable expectations at the beginning. Since a great deal of time is required to research, plan and evaluate integrated units, the whole endeavor could very quickly become overwhelming and cause teachers to abandon the attempt if too much is expected. For example, Physics 11 consists of eight units. If every year, two units were adapted to include integration, the course would have integrated activities for every unit in only four years. If small steps are taken, successful implementation of curriculum integration is far more likely.

A supportive administrator would also contribute substantially to the success of curriculum integration. Preparation blocks and budgeting for teachers on call are two matters overseen by administrators. Teachers involved in curriculum integration would certainly appreciate being assigned preparation blocks during the same period, as this would facilitate their collaboration greatly. One of the significant experiences that influenced the success of the study was the presence of both the action and guest teachers in the classroom at the same time. If the budget would allow funds for supervision of classes when teachers worked together in a classroom, the curriculum integration would evolve even more.

Given these recommendations and suggestions, it is evident that the process of incorporating curriculum integration into the current school structure at the secondary level would be very slow. However, any far reaching and grass root level change in education will only become securely incorporated, if the change is brought about carefully and thoughtfully. There have been repeated attempts during the last one hundred years to promote curriculum integration (Drake, 1993; Gehrke, 1998; Henson, 2003). However, in this new century, curriculum integration is becoming a necessity to prepare students for the changing world that is evolving. “A curriculum form, meant to promote democratic practice, critical analysis of social issues, collaborative problem solving, and democratic social integration” (Beane, 1997, p. 100) demands profound change from the grass roots. This change will not happen within a school year, but it is so essential to education that it is worth taking small continuous steps to help implement this needed transformation. If a teacher feels discouraged, it is worthwhile to remember, that modeling behavior can be a powerful creator of change. By implementing small changes, even though they might appear insignificant, both students and colleagues will become aware of integration. Colleagues will observe the use of journals, group work and teams of teachers. Students will not only develop connections and critical thinking, but those that go on to become teachers themselves will have experienced curriculum integration in their high school education.

Conclusion

Curriculum integration has been shown to be a significant aspect of school reform with the specific purpose of preparing students for the rapidly changing world of the 21st century. Given the complicated demands of successful integration models, this collective case study hoped to demonstrate that a simple model in the present school system could be effective. The data comparing the two Physics 11 classes, suggest that a simple model is certainly possible in the current school structure and that it is valuable. The academic achievement, attendance and attitudes of the students in the treatment group improved.

Journals, timelines and poetry showed evidence of critical thinking and integration by students. Questionnaire responses consistently indicated that students in the treatment group became more aware of the importance of integration and the complexity of the world. Furthermore, the participating teachers were enthusiastic about continuing with integration in the future and valued the collaboration. Individually, these outcomes would have been interesting, but taken together the results provide compelling support for this simple integration model combining physics with humanities.

These results are noteworthy as empirical research on integration is both difficult (Ellis & Fouts, 2001) and rare (Czerniak et al., 1999). The relevance of this study is augmented by the fact that science was integrated with humanities, an uncommon experience at the senior high school level. Given the expectations of employers in the present work world, integrating these two disciplines will become increasingly more significant. Meier (1996) stated, "Society will eventually demand [curriculum integration]. Needs of business, industry, and society, as well as needs of the individual, all require us to see the big picture, and to understand the connections and relationships around us" (p. 230). Therefore, educators should be encouraged that curriculum integration can be successfully incorporated into the current school system to help prepare students for the complex and challenging life of the 21st century.

Postscript

The previous two paragraphs were the expected finale to the story of integration in the physics classroom. However, this study generated unexpected long-term outcomes that merit mentioning to complete the picture of the investigation. It would appear that the experience in the treatment group influenced both the action teacher and a few of the participating students more than expected. During the month of June 2006, when the action teacher was teaching the unit on special relativity, she was promoting a brand new course called Quantum Physics and Cosmology 12 for the next school year. The purpose of this course was to introduce grade 12 students to the exciting research that was currently taking place in the area of physics. It was designated a Board Authority Course and was developed by the action teacher. Fortunately, nine students registered for the course, making it possible to offer it the following year. It was a linear course, which explored the following topics: Quantum Physics, Standard Model, Special and General Relativity, The Big Bang Theory and String Theory. The action teacher and nine students enjoyed the course immensely. The teacher was informed that a number of the students felt that it was the best high school course they had ever taken. It was only when the action teacher took time to review and evaluate the experience of teaching this course that she realized that curriculum integration had played a very large role.

First, of the nine students that took the course, eight had been participants in the treatment group the previous year, including the two students, who had received their best test mark on the unit test for special relativity during the treatment. Second, the action teacher became aware that she had unwittingly used integration throughout the teaching of this course. The students reflected on quotes in journals, worked as groups on projects, represented the standard model artistically or as a game, discussed numerous articles from *Scientific America* and *Discover* magazines, were read to from physics books, were visited by guest speakers or heard talks at the university and rarely experienced the lecture format. Discussions, readings and content integrated the science concepts with history, social justice, philosophy and theology. During the final evaluation, the students were asked to reflect on how taking this course had changed their vision of the world. The responses were profound – every student had been deeply affected by the course. The content itself was stimulating, but sharing ideas, questions and concerns with their classmates and teacher had a far-reaching effect. Reflecting on the experiences with the treatment group in the Physics 11 class and the nine students in the Quantum Physics and Cosmology 12 class, has convinced the action teacher irrevocably that Tchudi and Lafer (1996) are right in proposing that curriculum integration is the most promising reform movement available to present day teachers.

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Appendix A

Physics 11 | Course Overview | Tanya Taft

The course consists of eight units: Kinematics, Dynamics, Momentum, Energy, Waves – Part I and Part II, Special Theory of Relativity and Physics – the Discipline.

Unit 1 Kinematics

Content

Significant Figures
Displacement, Velocity and Acceleration in one dimension

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Teacher modeling of problem solution write-ups.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.
Labs: Uniform Motion, Changing Velocity
Velocity and Acceleration, Diluting Gravity
Group Work: Interpreting Velocity and Displacement Time Graphs
Two Kinematics Application Problems
Video: Mechanics III: Graphical Analysis of Motion of a Car

Assessment and Evaluation

Informal: individual homework on board and responses to questions in class
Individual comments and questions during class work and tutorials
Formal: group work, completion of homework
quizzes, lab reports, unit assignment, unit test

BC Curriculum Learning Outcomes

Kinematics (Displacement and Velocity in One Dimension)

It is expected that students will demonstrate an understanding of the relationships between time, displacement, velocity and apply these relationships to problems in everyday one-dimensional situations.

It is expected that students will:

define period and frequency, distance, displacement, speed and velocity.
construct displacement-versus-time, velocity-versus-time graphs.
use displacement-versus-time graphs to determine the displacement, average velocity, or instantaneous velocity of objects and use velocity-versus-time graphs to determine the displacement or velocity of objects and solve problems involving: displacement, time and average velocity.

Kinematics (Acceleration in One Dimension)

It is expected that students will demonstrate an understanding of the relationships between time, velocity, displacement, and acceleration and apply these relationships to calculations in common situations.

It is expected that students will:

define acceleration, use velocity-versus-time graphs to determine instantaneous or average acceleration of objects.
solve problems for objects with constant acceleration, involving: displacement, initial velocity, final velocity, acceleration and time.

Unit 2 Dynamics

Content

Vectors and Scalars
Force of Gravity
Force of Friction
Newton's Laws
Elastic Forces

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Brainstorm scalars and vectors in real world.
Compare and contrast gravitational field strength on different planets and the sun.
Teacher modeling of two and more step problems.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.

<u>Demonstrations</u>: Beliefs of Greeks - rolling ball
Galileo - stopper on car
Newton's 1st Law - coin on card
Newton's 2nd Law - two balls with different masses
Newton's 3rd Law - pushing off a wall

<u>Labs</u>: Mass and the Force of Gravity
Sliding Friction
Stretching a Rubber Band

<u>Group Work</u>: Two Dynamics Application Problems

<u>Video</u>: Mechanics III: Vector Addition of an object travelling on a moving surface
Mechanics III: Newton's first Law: Rest Inertia of Bursting Water Balloon, Shattering Flask and Concrete Block
Mechanics III: Newton's First Law: Motion Inertia of Steel Wedge, Ketchup Cart
James Bond: two minute clip (airplane over cliff)

Assessment and Evaluation

Informal: individual homework on board and responses to questions in class
individual comments and questions during class work and tutorials

Formal: group work
quizzes
lab reports
unit assignment
unit test

BC Curriculum Learning Outcomes

<u>Dynamics in One Dimension</u> (Force of Gravity)

It is expected that students will demonstrate an ability to apply in a variety of situations concepts related to the force of gravity.

It is expected that students will:

- differentiate between scalar and vector quantities(**from Kinematics Unit**)
- define gravitational field strength
- use the gravitational field strength to relate the mass of objects to the force of gravity (weight) acting on them
- demonstrate that the force of gravity between two objects is an inverse square law with respect to distance
- solve problems involving Newton's law of universal gravitation for: force, mass, distance of separation and universal gravitational constant

Dynamics in One Dimension (Force of Friction)

It is expected that students will demonstrate an ability to describe and apply the concept of friction to everyday situations and determine the factors that affect it.

It is expected that students will:

- distinguish between static and kinetic friction
- compare the effects of the normal force, materials involved, surface area, and speed on the force of friction and define coefficient of friction
- solve problems involving objects sliding on horizontal surfaces for: force of friction
- coefficient of friction and normal force

Dynamics in One Dimension (Elastic Forces)

It is expected that students will demonstrate an ability to describe and apply Hooke's law to everyday situations.

It is expected that students will:

- use appropriate materials to verify Hooke's law
- solve problems using Hooke's law that involve: force, spring constant, distortion
- relate Hooke's law to situations in their homes and community

Dynamics in One Dimension (Newton's Laws)

It is expected that students will demonstrate knowledge of Newton's laws and apply them to common situations.

It is expected that students will:

- state Newton's laws of motion and illustrate each with practical examples
- solve problems using Newton's second law that involve: net force, mass and acceleration
- apply Newton's laws and the concepts of kinematics to solve problems

Unit 3 Momentum and Impulse

Content

Momentum in One Dimension
Impulse
Conservation of Momentum in Collisions and Explosions

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.
Teacher modelling of notation used in analyzing collisions and explosions.
Brainstorm for real world places where momentum and impulse play a role
Demonstrations: Momentum - compare destructiveness of basket ball to bowling ball
Impulse - proper golf swing
Labs: Transfer of Momentum
Group Work: Worksheet on Mometum(Bus and Bug)
Video: Mechanics V: Impulse and Mometum: Egg Impacting rigid surface or water column

Assessment and Evaluation

Informal: individual homework on board and responses to questions in class
individual comments and questions during class work and tutorials
Formal: group work
quizzes
lab reports
unit assignment
unit test

BC Curriculum Learning Outcomes

Dynamics in One Dimension (Momentum in One Dimension)
It is expected that students will demonstrate an ability to describe and apply the concept of momentum to everyday situations.
It is expected that students will:

use the definition of momentum to calculate the unknown variable, given any two of the following: momentum, mass, velocity
state the law of conservation of momentum for isolated, one-dimensional systems
use the law of conservation of momentum to calculate any of the following from appropriate data: momentum, mass, velocity
identify workplace applications where momentum is measured or controlled

Unit 4 Mechanical Energy

Content

Work, Kinetic and Gravitational Potential Energy
Law of Conservation of Energy, Power and Efficiency

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.
Directed Analysis of Falling Object - Comparing Kinetic, Potential and Total Energy.

Demonstrations: Efficiency - Electrical energy of a Kettle

Labs: Power Running up Stairs, Kinetic Energy in Elastic Collisions
Total Energy of a Toy Car

Group Work: Worksheet on Comparing Energy and Mometum
Comparison of Power of Four Different Cars

Assessment and Evaluation

Informal: individual homework on board and responses to questions in class
individual comments and questions during class work and tutorials

Formal: group work, quizzes, lab reports, unit assignment, unit test

BC Curriculum Learning Outcomes

Energy (Work and Energy)

It is expected that students will demonstrate an understanding of the relationship between work and the different forms of energy. It is expected that students will:

define work in terms of force and displacement
solve problems involving: work, force, displacement
define energy and define gravitational potential energy
solve problems involving: gravitational potential energy, mass, acceleration due to gravity
height above a reference point and define kinetic energy
solve problems involving: kinetic energy, mass, velocity
define temperature, thermal energy, and specific heat capacity
solve problems involving: thermal energy, mass, specific heat capacity and change in temperature

Energy (Law of Conservation of Energy)

It is expected that students will demonstrate an understanding of the law of conservation of energy and the relationships among work, kinetic energy, potential energy, and thermal energy. It is expected that students will:

relate energy transformations to work done and state the law of conservation of energy
solve problems using the law of conservation of energy including changes in gravitational potential energy, kinetic energy, and thermal energy

Energy (Power and Efficiency)

It is expected that students will demonstrate an ability to describe and apply the concepts of power and efficiency to everyday situations. It is expected that students will: define power and solve problems involving: power, work, time, define efficiency and calculate and compare the efficiencies of common devices

Unit 5 Waves - Part I

Content

Properties of Waves
Speed of Light
Pinhole Cameras
Plane Mirrors and Reflection of Light
Ray Diagrams of Plane and Curved Mirrors

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.
Developing skills with Ray Diagrams
Demonstrations: Pinhole Cameras
Pitch and Frequency (Tuning Forks)
Water Table and Wave Phenomena
Labs: Spiral Springs and Waves
Reflection in a Plane Mirror
Reflection in Curved Mirrors
Group Work: Everyday use of Plane and Curved Mirrors

Assessment and Evaluation

Informal: individual homework on board and responses to questions in class
individual comments and questions during class work and tutorials
Formal: group work
quizzes
lab reports
unit assignment
unit test

BC Curriculum Learning Outcomes

Wave Motion and Geometrical Optics (Wave Properties of Light)

It is expected that students will demonstrate an ability to describe and apply the characteristics and properties of waves to light and other everyday phenomena.

It is expected that students will:

describe the properties associated with waves: amplitude, frequency, period, wavelength, phase, speed, types of waves
use the universal wave equation to solve problems involving:
speed, frequency, wavelength
describe and give examples of the following wave phenomena and the conditions that produce them:

reflection, refraction, diffraction,
interference(superposition principle)
describe the image formed by a pinhole camera
draw and analyse a ray diagram for a pinhole camera to determine magnification ratios

Wave Motion and Geometrical Optics (Reflection of Light)

It is expected that students will analyse situations in which light reflects from plane and curved mirrors.

It is expected that students will:

identify any of the following on an appropriate diagram:
incident ray, reflected ray, angle of incidence, angle of reflection, normal
state the law of reflection
draw ray diagrams showing how an image is produced by a plane mirror
describe the characteristics of an image produced by a plane mirror
identify any of the following on appropriate diagrams:
principal axis, vertex, centre of curvature, principal focus, radius of curvature, focal length, focal plane
identify a curved mirror as converging (concave) or diverging (convex)
conduct an experiment to determine the focal length of a concave mirror
draw accurate scale diagrams for both concave and convex mirrors to show how an image is produced
describe the characteristics of images produced by converging and diverging mirrors
describe some of the uses of plane and curved mirrors

Unit 6 Waves - Part II

Content

Refraction of Light and Index of Refraction
Total Internal Reflection and Fiber Optics
Ray Diagrams of Concave and Convex Lenses
Visible Light Spectrum, Colour and Electromagnetic Spectrum
Light Wave Phenomena: Interference, Scattering, Polarization

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.

Demonstrations:
- Colour - Three Lamps with bulbs of different colours
- Visible Light Spectrum - Diffraction Slides
- Scattering - Laser and Chalk Dust
- Diffraction - Observing Light Through two forefingers
- Polarization - Polarized Lenses on Overhead
- Young's Interference Experiment - Laser and Slide
- Total Internal Reflection - Laser and Fiber Optics

Labs: Comparing and Contrasting Concave and Convex Lenses
Group Work: Concept Map of Wave and Light Phenomena

Assessment and Evaluation

Informal:
- individual homework on board and responses to questions in class
- individual comments and questions during class work and tutorials

Formal:
- group work
- quizzes
- lab reports
- unit assignment
- unit test

BC Curriculum Learning Outcomes

Wave Motion and Geometrical Optics (Wave Properties of Light)

It is expected that students will demonstrate an ability to describe and apply the characteristics and properties of waves to light and other everyday phenomena.
It is expected that students will:

describe and give examples of the following wave phenomena and the conditions that produce them: reflection, refraction, diffraction, interference (superposition principle), Doppler shift, polarization, scattering
identify from an appropriate diagram the visible light portion of the electromagnetic spectrum
give examples of common applications involving:
Doppler shift, polarization, diffraction

Wave Motion and Geometrical Optics (Refraction of Light)

It is expected that students will analyse situations in which light is refracted.

It is expected that students will:

define index of refraction
identify any of the following from an appropriate diagram:
incident ray, normal, refracted ray, angle of incidence, angle of reflection
solve problems using Snell's law, involving: index of refraction, angle of incidence
and the angle of reflection
define critical angle and total internal reflection and solve problems involving total internal reflection
identify any of the following from an appropriate diagram:
principal axis, principal focus, focal length focal plane
identify a lens as converging (convex) or diverging (concave)
conduct an experiment to determine the focal length of a convex lens
draw accurate scale diagrams for both convex and concave lenses to show how an image is produced
describe the characteristics of images produced by converging and diverging lenses
give examples of common devices that refract light

Unit 7 Physics - The Discipline

Content

Branches of Physics
Physics-Related Careers

Teaching Strategies/Learning Activities

Note taking and classroom discussion.
Library Research to prepare written report and class presentation on one physics related career.
Video: Why Physics?

Assessment and Evaluation

Informal:	individual comments and questions during class work and tutorials
Formal:	worksheet on technology in B.C.
	worksheet on branches of Physics and Engineering
	written report and class presentation

BC Curriculum Learning Outcomes

Physics (Introduction)

It is expected that students will demonstrate an understanding and appreciation of the role of physics in society and will be encouraged to develop the skills and methods employed by physicists.

It is expected that students will:

describe the major branches of physics that comprise the discipline
compare and contrast physics with other disciplines
identify the unique characteristics of physics
give examples of the continuing development and refining of physics concepts
demonstrate knowledge of physics-related careers in local, regional, and global workplaces
describe some of the tools and activities of physicists, in particular a reliance on mathematics and experimental design

Unit 8 Special Relativity

Content

Modern and Classical Physics
Inertial Frames of Reference
Michelson and Morley's Experiment
Einstein's Postulates
Time Dilation, Length Contraction
Mass Increase, $E = mc^2$

Teaching Strategies/Learning Activities

Note taking, classroom discussion, directed examples, prompted practice.
Written exercises in class and at home.
Explaining to partners or class how to solve homework problems.
Demonstrations: Reference Frames: three students and a chair
Video: Einstein and Special Relativity

Assessment and Evaluation

Informal:	individual homework on board and responses to questions in class
	individual comments and questions during class work and tutorials
Formal:	group work, completion of homework
	quizzes, lab reports
	unit assignment, unit test

BC Curriculum Learning Outcomes

Special Relativity

It is expected that students will demonstrate an understanding and appreciation of the fundamental principles of special relativity.

It is expected that students will:

define inertial reference frame
explain why simultaneous events for one observer may not be simultaneous for another observer
describe the Michelson-Morley experiment and explain the significance of the "null result"
state the two postulates of the special theory of relativity:
the relativity principle
the constancy of the speed of light
describe the relativistic effects of time dilation, length contraction, and mass increase and describe examples of experimental evidence that demonstrate these effects
calculate relativistic time dilation, length contraction, and mass increase
prove by using relativistic mass increase or relativistic addition of velocities that objects cannot exceed the speed of light in a vacuum
describe the equivalence of energy and mass, and solve problems involving:
energy, mass
speed of light

Appendix B

Appendix C

Example of Parent/Guardian Consent Form

Example of Participant Consent Form

Example of Participant Consent Form for Participating Teachers

Appendix D

Interview Questions

1. How much time did you spend planning and preparing for this integrated class?
2. Would you collaborate with curriculum integration again? Why or why not?
3. Did you feel comfortable coming into another room?
4. Were you nervous? Why or why not?
5. How would you evaluate the timelines/poems?
6. Did you ever experience integration in high school?
7. Did you feel that this experience was worthwhile for you as an educator?
8. Did you feel that this collaboration was worthwhile for the students?
9. How could we deal with call coverage in the future?
10. How could we encourage curriculum integration to occur more often?
11. Did you have a sense of the integration being successful?
12. What did you notice to support the previous answer?
13. What do you see as hindrances to curriculum integration?
14. Do you have any other comments that you would like to add?

Appendix E

Questionnaire

Thank you for taking the time to answer these questions. Your opinions and views will be of immense help to me.

Please circle the number in response to reading the following statements, which corresponds the closest to your opinion. (#1 – 17)

1 – I agree completely with the statement.
2 – I agree with the statement.
3 – I am not sure.
4 – I do not agree with the statement.
5 – I do not agree with the statement at all.

1. The skills of writing and reading well are very important for any scientist doing research.

   1 2 3 4 5

2. It is rare that a scientist will be asked to write a report, maybe once every few years.

   1 2 3 4 5

3. Like Social Studies 11 and English 12, Physics 11 should be a required course for graduation from high school.

   1 2 3 4 5

4. Students who are good at writing essays and interpreting literature should not have to bother with science and mathematics courses, if they would rather not study those subjects.

   1 2 3 4 5

5. In a professional setting, astronomers and geophysicists rarely interact with people from other fields.

   1 2 3 4 5

6. The public does not need to understand science concepts, as they do not apply to their everyday life.

   1 2 3 4 5

7. Understanding mathematical concepts is as important as being able to comprehend written material such as newspapers, magazine articles and information on the internet.

   1 2 3 4 5

8. The public is very interested in the latest discoveries in science.

   1 2 3 4 5

9. In today's world, nobody needs to know his or her basic arithmetic facts. This knowledge is an obsolete skill.

   1 2 3 4 5

10. Math courses should be optional starting with grade eight, as they do not apply to everyday life, and even in science, computers can complete the mathematical tasks.

    1 2 3 4 5

11. History is very interesting as a story of the past, but is very rarely relevant to the problems and challenges of today's world.

    1 2 3 4 5

12. Scientists would benefit from learning about literature as it could possibly help them with their research and studies.

    1 2 3 4 5

13. Scientists who are completing serious and important studies, that will affect the world population, should be aware of the possible political outcome of their research.

    1 2 3 4 5

14. If a scientist is asked to publish his findings, he or she can ask a secretary to write the report. The scientist does not need to spend his time writing.

    1 2 3 4 5

15. Historical reflections can provide scientists with insights that enable them to accomplish their research more successfully.

    1 2 3 4 5

16. Scientists spend close to 50% of their working day reading reports and scientific journals.

    1 2 3 4 5

17. Interpersonal skills are essential for any job or career in order to ensure success and fulfillment.

    1 2 3 4 5

Use the following list of high school subjects to answer questions 18 – 25.

Subjects:			
	Art	Biology	Chemistry
	Computers	English	Geography
	History	Literature	Music
	Mathematics	Physics	Religion

18. How many of the above subjects taught in high school should be mandatory for **an artist**, in order to assure success and enjoyment in his or her work.

    artist ________ (# of subjects)

19. How many of the above subjects taught in high school should be mandatory for **a businessperson**, in order to assure success and enjoyment in his or her work.

    businessperson ____________ (# of subjects)

20. How many of the above subjects taught in high school should be mandatory for a **carpenter**, in order to assure success and enjoyment in his or her work.

    carpenter ___________ (# of subjects)

21. How many of the above subjects taught in high school should be mandatory for **a philosopher**, in order to assure success and enjoyment in his or her work.

    philosopher _________ (# of subjects)

22. How many of the above subjects taught in high school should be mandatory for **a politician**, in order to assure success and enjoyment in his or her work.

    politician ___________ (# of subjects)

23. How many of the above subjects taught in high school should be mandatory for **a reporter**, in order to assure success and enjoyment in his or her work.

    reporter ____________ (# of subjects)

24. How many of the above subjects taught in high school should be mandatory for **a scientist**, in order to assure success and enjoyment in his or her work.

    scientist ____________ (# of subjects)

25. How many of the above subjects taught in high school should be mandatory for **a teacher**, in order to assure success and enjoyment in his or her work.

    teacher _____________ (# of subjects)

26. Circle any of the following jobs and/or careers that you think require **both** humanities (such as history and literature) and science (such as biology and geology) as essential to their education.

artist, athlete, businessperson, carpenter, childcare worker,

engineer, farmer, lawyer, mechanic, nurse, philosopher,

politician, reporter, scientist, secretary, teacher

27. Imagine you are working in a research lab in biochemistry. Rank the following six skills in terms of importance to enable you to complete your work successfully. (Rank 1 the most important, 2 the next important skill and so on until you reach 6 for the least important.)

analyzing data ________
goal setting ________
problem solving ________
public speaking ________
teamwork ________
writing reports ________

28. Imagine you are working in a museum in "The Early Settlers of Canada" exhibit. Rank the following six skills in terms of importance for you to be able to complete your work successfully. (Rank 1 the most important, 2 the next important skill and so on, until you reach 6 for the least important.)

analyzing data ________
goal setting ________
problem solving ________
public speaking ________
teamwork ________
writing reports ________

29. On a scale of one to ten how much has the development of science and technology during the last one hundred years changed the following, either positively or negatively:
(one: no change – ten: a huge change)

awareness of social issues ___________
environment ___________
physical health ___________
satisfaction with life ___________
standard of living ___________
view of the world ___________

30. The media is full of news about global warming and environmental change. Circle any of the following individuals who you think are required to work together to solve our world's environmental problems.

    artist, athlete, businessperson, carpenter, childcare worker,

    engineer, farmer, lawyer, mechanic, nurse, philosopher,

    politician, reporter, scientist, secretary, teacher

31. At this time, many wars are being fought around the world, such as in the Middle East and Africa. Circle any of the following individuals who you think are required to work together to solve our world's war and terrorism problems.

    artist, athlete, businessperson, carpenter, childcare worker,

    engineer, farmer, lawyer, mechanic, nurse, philosopher,

    politician, reporter, scientist, secretary, teacher

32. The contrast between the poor and the wealthy in today's world is phenomenal. Circle any of the following individuals who you think are required to work together to solve our current poverty problems.

    artist, athlete, businessperson, carpenter, childcare worker,

    engineer, farmer, lawyer, mechanic, nurse, philosopher,

    politician, reporter, scientist, secretary, teacher

Appendix F

Table F10

Descriptive Statistics of Unit Tests, Unit Marks and Attendance

Special relativity unit test	Mean	Standard deviation	Range
Comparison group	83.4%	8.9%	70% - 100%
Treatment group	86.5%	8.2%	73% - 99%
Average of six unit tests			
Comparison group	87.0%	6.6%	74% - 97%
Treatment group	83.6%	9.4%	62% - 95%
Special relativity unit mark			
Comparison group	84.6%	8.1%	73% - 100%
Treatment group	86.9%	8.8%	73% - 99%
Average mark of six units			
Comparison group	87.6%	5.6%	78% - 98%
Treatment group	84.9%	8.6%	64% - 96%
Attendance during unit*			
Comparison group	8.0%	8.0%	0% - 22%
Treatment group	4.4%	6.0%	0% - 17%
Attendance during course*			
Comparison group	5.9%	5.5%	0% - 22%
Treatment group	8.6%	5.4%	0% - 20%

*Attendance is reported in terms of excused or unexcused absence from class.

Appendix G

Table G11

Summary of Questionnaire Responses (Means) to Statements 1 – 17

Statement	Comparison			Treatment			Difference
	Pre	Post	Change	Pre	Post	Change	(Treat – Comp)
1	4.40	4.25	-3.0%	4.42	4.25	-3.4%	-0.4%
2	2.93	3.00	1.4%	2.79	2.95	3.2%	1.8%
3*	**3.53**	**3.83**	**6.0%**	**2.42**	**3.09**	**13.4%**	**7.4%**
4	**2.67**	**2.25**	**-8.4%**	**2.27**	**2.78**	**10.2%**	**18.6%**
5	**2.87**	**2.58**	**-5.8%**	**2.05**	**2.30**	**5.0%**	**10.8%**
6	3.20	3.00	-4.0%	3.05	3.10	1.0%	5.0%
7	3.27	3.42	3.0%	3.47	3.60	2.6%	-0.4%
8	3.27	3.42	3.0%	3.58	3.65	1.4%	-1.6%
9	3.20	2.83	-7.4%	3.63	3.20	-8.6%	-1.2%
10	3.13	3.08	-1.0%	3.79	3.55	-4.8%	-3.8%
11	**2.67**	**2.42**	**-5.0%**	**2.95**	**3.10**	**3.0%**	**8.0%**
12	3.53	3.33	-4.0%	3.74	3.75	0.2%	4.2%
13	**3.93**	**3.75**	**-3.6%**	**3.63**	**3.96**	**6.6%**	**12.0%**
14	2.67	2.67	0.0%	1.89	1.95	1.2%	1.2%
15	3.60	3.50	-2.0%	4.05	3.75	-6.0%	-4.0%
16	2.93	3.08	3.0%	3.00	3.20	2.4%	-0.6%
17	**4.13**	**3.42**	**-14.2%**	**4.26**	**4.20**	**-1.2%**	**13.0%**

* The data in bold showed a notable (> 7.0%) difference between the comparison and treatment groups between pre and post treatment means (see Table 7 on page 73).