GENDER AND PHYSICS: THE RELATIONSHIP BETWEEN LEARNING ORIENTATION, SELF-CONFIDENCE, AND ACHIEVEMENT

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Gender and Physics: The Relationship between Learning Orientation, Self-Confidence, and Achievement

by

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Abstract

This study explored the relationship between gender, learning orientation, self-confidence and achievement in high school physics students. A sample of 131 physics students in six rural communities throughout Newfoundland were examined to determine a) whether there were any gender differences in learning orientation, self-confidence, and achievement, b) whether learning orientation influenced self-confidence, c) whether learning orientation and self-confidence influenced achievement, and d) whether students' self-confidence changed due to perceived achievement. A one-group pretest-posttest experimental design with all students receiving the same treatment, was used to observe the interaction between these variables. The results of correlations, analyses of variance, and multiple regressions indicated that more differences in achievement were accounted for by learning orientation and self-confidence than by gender. Meaningful learners had higher achievement and higher self-confidence than rote learners. Gender was not significant in predicting learning orientation or achievement. However, males were more confident than females. Learning orientation was most important in influencing pretest levels of self-confidence, which remained stable regardless of actual test performance. These results imply that once established, levels of self-confidence may be difficult to change. A meaningful learning orientation may be important in increasing self-confidence and subsequent understanding of physics concepts. The discussion addresses the importance of promoting a meaningful learning orientation to conceptual understanding and career choices.

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Chapter One

Introduction

In the past two decades, women have traded their vacuum cleaners for briefcases, and have entered the workforce in increasing numbers. These women though have systematically avoided the 'nontraditional' sectors of construction trades, technical fields, and science and engineering. Most women have concentrated in more traditional areas such as social work, teaching, nursing or secretarial work. Even within traditional areas like teaching, women have concentrated in the nursery/primary sector. Acker (1990) reports that women make up only forty-six percent of secondary teachers in England and Wales. Unfortunately for these women, graduates from engineering earn more than those from nursing and plumbers earn more than secretaries. Similarly, because 'women's work' is now being reorganized by technological advances, many traditional women's areas are becoming obsolete. Thus it is increasingly important that women enter those nontraditional areas which are most rewarded and which exercise the most power in our society.

It has been argued that women avoid nontraditional areas because they are biologically incapable of succeeding (Geary, 1989). 'Sex' has been viewed as a limiting factor for success. Acker (1990) however, distinguishes between 'sex' and 'gender': "the former (sex) referring to biological characteristics of males and females, the latter (gender) to culturally specific assignments of traits and roles to each sex" (p. 91). Research has strongly supported a 'gender' explanation of career choice. From birth, children are influenced to exhibit a specific set of behaviours deemed socially appropriate. While these 'acceptable' behaviours may differ between cultures, they are socially mediated.

Nontraditional career choice has been influenced by societal expectations manifested in both schools and families. Family influence is mainly determined by parental roles and expectations. Traditionally, these roles would entail the mother in the home, caring for the children and carrying out domestic duties, while the father would work outside of the home to provide for the family. In the last two decades though, a contemporary ideology has emerged where mothers and fathers share household and financial responsibilities. In an analysis of Statistics Canada surveys for 1973-74 and 1983-84, it was shown that women in Canadian colleges and universities choosing nontraditional careers typically had well educated parents (Guppy & Pendakur, 1989). Mothers' and fathers' education correlated at $r=0.54$ in 1975 and $r=0.58$ in 1984. These surveys had 60% ($N=60257$) and 82.5% ($N=45181$) response rates respectively from a nationally representative stratified random sample of Canadians. These same women perceived their fathers as more supportive of nontraditional career aspirations than their mothers. However, Eccles, Jacobs and Harold (1990) found that both parents were more likely to encourage their sons to take advanced math, chemistry and physics. This study showed that parental advice and encouragement is one of the most important influences on high school course enrollment decisions. Lower parental expectations and encouragement may lead to feelings of inferiority for girls.

These feelings have also been influenced by schooling experiences. By the time children begin first grade they already have a strong sense of traditional male and female roles. Brophy (1985) indicates that "schools are inherently conservative institutions passing on accepted societal values" (p. 14). "If the dominant culture or gender regards as male occupations such as science and mathematics, and as female occupations such as hairdressing and homemaking, its schools will be likely to channel students, in a manner approaching uninformed consent, into their societally sanctioned directions" (Riddell, as cited in Greenfield, 1996, p. 928). By the time students reach high school, they have already undergone a process of socialization that has helped form their gender identities: "...children are classified as 'girls' or 'boys' repeatedly in school, from nurseries on up, as when teachers routinely divide the sexes within a mixed class..." (Acker, 1990, p. 95). These identities can be difficult to change especially if the problem is perpetuated at the high school level, where identities are extremely important in terms of career choice: "...if efforts to decrease occupational sex segregation are to be successful, they must include encouraging both men and women to break sex stereotypic work career boundaries" (Galbraith, 1992, p. 246). To implement this change requires an understanding of where gender role identities originated and how they are being transformed.

During the 1960's a major concern of parents regarding their child's education was in preparing girls and boys for their different roles in society. Hence, the curriculum was consciously designed to meet these 'different needs'. Girls were required to take home economics courses to fulfill their roles as wives and mothers. Boys would take courses in vocational training to prepare them for the labour force. This was not viewed as gender inequality. Educators and parents alike believed that they were adequately educating their children for their life roles. Girls did not receive the technical or scientific training needed to succeed in a 'man's world'. The skills they did receive were viewed as inferior and unimportant. When a debate arose on schools or education it was out of concern for boys. It was a grave concern that the elementary school was too 'feminine'. In an elementary school "teachers were often women, school was too much a woman's world, governed by women's rules and standards" (Sexton, 1965, p. 57). The entire educational foundation was based on the belief that boys and girls must be educated differently.

By the late 1960's and early 1970's there was dissatisfaction in the education system, especially amongst women: "But education had also seemed resistant to change, as it is so large, so multi-faceted, so closely tied to the local community, and at the same time protected at the centre from those who would have an impact" (Gaskell, McLaren & Novogrodsky, 1989, p.1). However, the stage had been set for change. In 1964 the Civil Rights Act included provisions against sex discrimination. In 1970 the Royal Commission on The Status of Women paid attention to education (Gaskell & McLaren, 1987). Publishers jumped on the bandwagon as well, and developed guidelines to achieve production of more equitable texts. "Scott-Foresman (1972) was the first company to issue guidelines to improve the image of women in textbooks. Other companies followed suit; Ginn (1973), McGraw-Hill (1974), Macmillan (1975), Houghton-Mifflin (1975) and Holt, Rinehart and Winston (1975)" (Sadker, Sadker & Klein, 1991, p. 274).

At this time it was generally believed that girls and women had caused the problem themselves: "As a result, much of the research and political struggle of feminists in the 1960's and 1970's tried to pinpoint women's problems, and to suggest how schools could address them" (Gaskell, et. al., 1989, p. 12). However, "by the late 1970's other issues - excellence, multiculturalism or vocational preparation - were replacing the issue of gender inequality on the agenda of school boards" (Gaskell & McLaren, 1987, p. 9). Changes were written into reports and companies included guidelines to rid texts of subliminal messages. There was an air of complacency in that the problem had been solved, even though women still earned less than men and girls still aspired to traditional occupations. Since that time gains have been made especially in raising consciousness: "Change, we now understand involves the less glamorous day-to-day issues that every teacher, student and parent must confront" (Gaskell, et. al., 1989, p.2). Still, research through the 1980's and 1990's has shown only gradual improvement for women within the education system, specifically in the classroom as a microcosm of this system.

This situation is especially pronounced in science classrooms. Throughout elementary school equal numbers of boys and girls want to be scientists, but by the time they reach high school these ambitions have changed drastically. "At both the high school and college levels, it often has been found that girls are less likely to enroll in advanced science and mathematics courses or to pursue majors in these areas than are boys" (Greenfield, 1996, p. 901). In fact, among seniors who have taken physics and calculus, 64% of males and only 18.6% of females were planning on majoring in science in college (AAUW, 1992). Because a solid high school mathematics and science background is so important to career possibilities, failure to obtain this background can represent limits on career opportunities. Thus, even though jobs for scientists and engineers are increasing at a rate of 5-7% per year, women are not selecting these careers at the same rate as males (National Science Board, 1989). This situation is reflected in current employment statistics: out of a 45% female national workforce, only 16% are employed as scientists and engineers (Alper, 1993). Of these women, the majority are employed in fields related to the life sciences. For the physical sciences, only 10.7% were employed in chemistry fields, 3.1% in engineering, and 4.7% in physics and astronomy (Brush, as cited in Greenfield, 1996). Brush believes that this circumstance is not improving: "fewer women received bachelor's degrees in physics in 1990 than in 1984, and although the number of science and engineering doctorate degrees awarded to women has been increasing since the 1960's, the rate of increase has slowed over the past 10 years" (Greenfield, 1996, p. 902). These figures may be largely attributed to the science experiences of girls at the high school level.

It has been demonstrated that boys and girls have received differential treatment even when enrolled in the same classes (Whyte, 1984; Kahle & Lakes, 1983; Alper, 1993). Boys demand and receive more attention and are more likely to use science equipment than girls. These factors may partially explain the lower achievement of girls in science: "National Assessment of Educational Progress studies over the last 20 years have shown a gender gap favouring boys ... for overall science achievement...; interestingly, the gap is small or absent at the fourth-grade level but grows steadily through secondary school" (Greenfield, 1996, p. 902). At the secondary level, the largest areas of male advantage are in physics, chemistry, earth science and space science (Mullis & Jenkins, 1988). Why might girls avoid science and experience lower achievement in these areas? Rennie (1987) has indicated that there are differences in boys' and girls' out-of-school science experiences in 'tinkering' and exploration. Because such experiences can influence science achievement, lesser exposure to them could mean lesser success with science: "For girls, this can translate into lowered academic achievement as well as less interest in science" (Greenfield, 1996, p. 902). Furthermore, less exposure to science experiences could increase misconceptions about the way the world works. Halloun (1996) argues that high school students possess an array of "folk conceptions" about the physical world which do not agree with physics theory. If girls have not had a chance to 'tinker' and explore a physics idea, then they can have no way of verifying or falsifying their beliefs. Moreover, if girls have no prior conception, they may understand scientific concepts in a rote manner only, by committing text and notes to memory. "Rote learning is thought to impede the learning of new science ideas and interfere with students' formulation of sound scientific understandings" (Cavallo, 1996, p. 626). Halloun (1996) believes that because of this approach, physics instruction suffers from short term retention, high attrition rates, and low efficacy. The purpose of this study is to extend these ideas to examine the relationship between gender, learning approach, self-confidence and achievement in physics.

Chapter Two

Literature Review

Gender and Science

Research suggests that there are significant disparities in the science achievement of males and females, with males generally outperforming females, especially in the physical sciences. (Levin, Sabar & Libman, 1991; Kelly, 1988; Kahle & Meece, 1994; Simpson & Oliver, 1990; Erickson & Erickson, 1984). Erickson & Erickson (1984) reported on a survey of grades 4, 8 and 12 students participating in the 1978 British Columbia Science Assessment undertaken by the provincial Department of Education. Response rates for the survey were listed as 95.2% (70187 students), 90.7% (51012 students), and 78.6% (6328 students) for the grades 4, 8 and 12 populations respectively. The lower response rate by grade 12's can be explained by higher absentee rates at that level on the day of the test, and to the fact that not all grade 12's were enrolled in the course during which the test was administered. In this way, several candidates from the grade 12 population were excluded. Science test items were extensively pilot tested and revised accordingly, with efforts made to design nonsexist questions. Results of differences in mean p-values between males and females showed that at all three grade levels, boys outscored girls in the areas requiring specialized content knowledge, with the greatest differences found in grade 12. It is possible that these results may be a product of the testing instrument. Tests can be better or worse depending on how well they are matched to specific curricula. If the NAEP is not matched to a particular curriculum, it is probably measuring only a portion of what students have been taught in school. As well, it may draw upon students' experiences outside of school, and in some cases material the student may not have seen before. A test designed for a specific curriculum however should be based on objectives that all students have been taught. Thus NAEP results might be indicative of differential out-of-school experiences for males and females. On tests designed for specific curricula however the test-curriculum consistency set should be high, and males and females should be on more equal footing. Consideration of the testing instrument may therefore be critical to the interpretation of gender differences in science achievement.

Differential enrollment patterns in the sciences have also been suggested as an explanation for achievement differences. In a 10% random sample of the assessment population, Erickson and Erickson (1984) found that while male-female enrollment patterns were similar for biology, they were not for physics. Among students who had taken the same number of physics courses though, males still scored substantially higher than females. Mullis and Jenkins (1988) analysed data taken from the 1985-86 National Assessment of Educational Progress (NAEP). This data was collected from 9-, 13- and 17-year olds, with questionnaire response rates being 92.9%, 89.2% and 78.9% respectively. These NAEP assessments were based on a stratified three stage sampling procedure (randomly selected counties, schools and students) designed to be nationally representative. Data was recorded by readers trained in scoring the open ended questions, and then weighted in accordance with the population structure and adjusted for nonresponse. Results indicated that gender differences in achievement could not be explained by differential course enrollment for boys and girls. For example, gender differences on the life sciences subscale were the same for students who had or had not taken a biology course. Kahle, Parker, Rennie and Riley (1993) support these findings: "Analyses of the results of both the 1986 and 1990 science surveys from the National Assessment of Educational Progress (NAEP) indicate that gender differences in achievement persist in subjects with similar enrollment patterns for girls and boys" (p. 382). Mullis and Jenkins (1988) further comment that even though females enroll in fewer physics courses, course enrollment patterns could not account for the magnitude of gender differences observed in achievement on the physics subscale of the survey. Evidence against enrollment effects necessitates a consideration of other factors contributing to the observed gender differences in science achievement.

It has been suggested that these differences can be attributed to biological factors. Geary (1989) suggested that exposure to adrenal gonadal hormones might result in biological gender differences. Others argued that the hemispheres of the brain are specialized for different mental processes, with the left side controlling language skills and the right side controlling spatial relations. Males are said to have greater right brain capabilities which may explain their dominance in the spatial type activities believed to be important in scientific thinking. More recently Linn and Hyde (1989) argue that differences in verbal ability have essentially declined to zero, and those in spatial ability are heterogeneous and declining. This result though, is based on a meta-analytic review containing many other meta-analytic references, and therefore has limited reliability. We cannot depend on effect sizes when we know little about the quality of the original studies. In this case however, Feingold (1988) suggests the same trend. In a historical study, he examined the Differential Aptitude Test (DAT) results from 1947-1980 (N=193844) and the Preliminary Scholastic Aptitude Test/Scholastic

Aptitude Test (PSAT/SAT) results from 1960-1983 (N=99654 for PSAT) to analyse any gender differences in cognitive abilities. Data were analysed from large representative samples to determine effect sizes for verbal and spatial abilities. It was found that by 1980, boys had completely closed the gap of 1947 on PSAT-Verbal, while girls did the same for abstract reasoning and numerical ability. The analyses of DAT and PSAT normative data question the validity of previous findings where girls outperform boys in the verbal domain. The data analysis for the SAT yield contradictory results in showing a smaller gender difference in favour of boys for verbal skills. However, unlike the DAT and PSAT, normative data on the SAT are only available for self-selected high school juniors and seniors who may be slightly different than a more representative sample. In fact, because the SAT and PSAT have been developed and equated to yield equivalent scaled scores, any differences can be ascribed to different types of examinees. Feingold cautions against the possible distortions caused by cohort effects and the 'less than perfect' reliability of the DAT and PSAT scales. Feingold's data suggests that since gender differences in math, verbal and spatial skills have been decreasing over the years, a biological explanation is not appropriate. Though brain lateralization is a potentially valid explanation, it is possible that such lateralization could be the result of socialization (Erickson & Erickson, 1984). Today we place little faith in biological differences as explanations for gender differences. Most researchers do not attribute underachievement to some deficiency among females to understand science, but rather to other more situational variables: "...the most effective approach to the problem of girls and science is not to regard girls as a special (and inferior) species of learner in science, but to acknowledge the role of experience in learning in science classrooms..." (Erickson & Erickson, 1984, p. 87).

It has been suggested that gender differences in science achievement could be related to inequalities in the science-related experiences of girls and boys. Whyte (1984) was involved in an action research project in Northern England called GIST (Girls Into Science and Technology), which entailed both quantitative and qualitative research designed to aid teachers in reducing gender bias in the classroom. She believes that girls may be lacking in scientific experience outside of school - at least the kind of experience that is valued in school science curricula. Thus school may be the only opportunity for girls to "use machines and tools to carry out scientific experiments" (Whyte, 1984, p. 82). Yet in the classroom, Whyte contends that boys demand more resources and teacher attention than girls. For the qualitative component of this study, efforts were made to ensure investigator triangulation, in that no observation was deemed valid unless it was reflected in the accounts of at least two different observers and took place in at least three of the six schools. The result is a 'thick' description of teacher-student and student-student interactions in the classroom. While the quantitative component concurs that boys initiate more classroom interactions, it must be realized that no attempt at interobserver reliability was made and, in fact, three different versions of the GIST were used. As well, 22 teachers were men while only 12 were women, which may have affected the responsiveness of boys or girls in this study. Whyte contends that, while her observational methodology would be tentative for most quantitative research, there was overall agreement on numerical interactions. While Whyte's results appear to be intuitively true, they must be interpreted cautiously.

In most classrooms, females also have less access to hands-on activities and to science equipment. Kahle & Lakes (1983) analysed data from the 1976-77 National Assessment of Educational Progress Survey (NAEP) on 9-, 13- and 17-year olds' attitudes toward science. They found that the number of actual science experiences for boys exceeded that for girls in every area surveyed, including observations and experimental tasks. Girls even reported attending field trips less frequently than boys. The authors contend that differential field trip experiences may be due to boys' membership in the Boy Scouts or other boys' groups, where visits to weather stations and electrical plants may be routine. They believe that a lack of experiences in science leads to a lack of understanding of science, which will ultimately contribute to negative attitudes toward science. Unfortunately, we are not told the sample size and are asked to assume that numbers of males and females are equal. Neither are we given the response rates for the survey results, which are necessary to determine the representativeness of the sample to the target population. The methodology of representing male and female responses as equal numbers of percentage points above or below the national mean is also questionable, especially since it is based on information regarding sample size to which we are not privy. The survey did include similar items in different question sets to assess intraquestionnaire reliability, but we are not given any reliability measures. Despite the problems in this study, similar findings have been reported by Ormerod and Wood (1983). They studied and compared 10- and 11-year old students' attitudes to science, as measured by three different tests - a Likert 5-response attitudes test, a sentence completion test and a projective test. The attitude questionnaire was extensively piloted with frequent member checks made by 10-11 year old students and experienced teachers. The 55 item test was administered to 176 boys and 154 girls from four urban schools in East Anglia. The 55 items were split into space study (r=0.87) and nature study (r=0.73). Reliabilities for the sentence completion test ranged from 0.65 for space study to 0.76 for nature study. In a factor analysis of the data, 'space' and 'nature' emerged as two 'clear-cut clusters'. The authors' attempt at triangulation highlights the importance of using several different instruments to explore students' attitudes. They found fairly low correlations of 0.40 between the scores in each cluster, indicating that different formats may not be measuring exactly the same thing. Ormerod and Wood (1983) found that at ages 10 to 11 years, "the interests of the sexes have already diverged towards 'nature study' in the case of girls and what is essentially physical science in the case of boys..." (p. 85). Science liking has bifurcated even at this age. The sentence completion test showed similar results in that higher male scores may reveal the type of boy later identified as a 'practical enthusiast' or a 'tinkerer'. This is not so for girls, who score lower on this scale.

This situation can be exacerbated by gender bias in classroom instruction. Tobin and Garnett (1987) studied fifteen science teachers' (12 male and 3 female) classes in public and private schools in Australia. The data consisted of field notes from observation of approximately 200 science lessons, written self-report data on student engagement, questionnaire data for teachers, and interview data from teachers and students. Tobin and Garnett assert that males tend to dominate classroom interactions, particularly in the laboratory:

> The male dominance in laboratory investigations was particularly frustrating to a grade eight girl who commented that the two girls in her group were allowed only to collect things that were needed. The two boys completed all other tasks because they thought that they knew best what to do. Although the girl had mentioned her frustration to the teacher he was not sympathetic to the problem and had refused to allow her to change groups. (p. 98)

The authors recognize that their sample is relatively small, and therefore recommend that the results be tentatively accepted. Similarly, results from an Australian culture may not reflect the situation in Newfoundland or even Canada where societal expectations may be different. Nevertheless, the data did show a number of trends indicating gender bias in the classroom coupled with a lack of teacher awareness of such bias. By allowing boys to dominate classroom activities, teachers are sending girls the message that they are not intelligent or capable enough to do the work for themselves. In this way, girls are not encouraged to persist at problem solving.

Sabar & Levin (1989) suggest that the typical feminine profile describes a 'hesitant, dependent, anxious, help-searcher learner'. Through expert non-participant observation over one year, they studied a purposive sample of 18 eleventh grade high achieving math and science Israeli students (11 boys, 7 girls), who had volunteered for a special research class in biology. These students took part in three supplemental hours of biology per week at school, plus one full day per week at the research institute working on individual research projects with a scientist. For different reasons, two girls and three boys dropped out of the study, leaving a sample of only thirteen. The girls were perceived as dropping out due to a lack of support, while the boys supposedly left because of lack of interest. Considering the level of material taught and the time commitment, students remaining in this program were obviously 'seeking a challenge'. Sabar and Levin found that boys were significantly more confident and active in classroom discussions than were girls. Girls answered or commented only when they were certain to be correct, whereas boys would proffer answers whether they were accurate or not. While these results are based on a small self-selected sample, we must remember that generalizability is not a goal of qualitative research. In fact, no attempt is made at tests of significance due to the small numbers involved. Sabar and Levin argue that by utilizing a combination of observations, questionnaires and interviews, they provide a richer understanding beyond 'quantifiable end results'. In addition, a focused interview was carried out with students, scientists, and teachers to cross-validate the information gathered through observations and questionnaires. Through frequent female comments like "I don't understand anything" or "Can you explain again?", they inferred that girls' lack of confidence and need for clarification formed part of their 'feminine profile'. Since attitude measurement depends largely on inferences drawn from results, caution is warranted in accepting this interpretation. Stating "I don't understand" may not necessarily be an indication of a lack of self-confidence. It may be that instead, girls are confident enough to express their concern. What they might really mean is, "I don't understand right now, but I'm confident I will understand if you explain it further". Both of these interpretations must be considered in an attempt to determine learning characteristics.

Linn and Hyde (1989) concur with Sabar and Levin (1989) that males have greater confidence than females, even when both gender groups perform equally. Males also have more positive attitudes toward science and see it as being more useful in their lives. In 1981-82, Simpson and Oliver (1990) studied 12 schools (4 elementary, 4 junior high, 4 high schools), 78 teachers, 178 science classes and 4500 students from grades six to ten in central North Carolina, to examine home, school and individual influences on attitude toward science. Data were collected from self-reported student questionnaires, achievement tests, semester grades, teacher questionnaires and teacher evaluation by a science supervisor. All data were collected by a four person research team and fifteen trained parent volunteers. They determined that boys scored higher than girls on measures of attitudes toward science, and self-concept. In a longitudinal follow-up of a randomly selected subsample of the original eighth through tenth grade samples in 1985-86, a regression of tenth grade science self-concept on eleventh grade science achievement yielded a highly significant relationship ($p<0.0001$). Great care was taken in ensuring instrument validity for the achievement tests, in that six staff members and a professional test writer constructed and edited the items. Also, a total of twelve editions of attitude instruments were piloted and reduced from 180 to 60 items. The only indications of reliability, though are that particular attention was paid to internal consistency and to the Likert-type items comprising the attitude scale, having the 'highest' reliability. The internal validity of the study is increased through the triangulation of data and the random selection on both the original and follow-up studies. Sjoberg and Imsen (1988) attribute these attitudes to the social definition of science as masculine: "For a girl, a choice of science may lead to sanctions from her feminine peer group - and from boys" (p.

224). They reported the results from a self-description scale for 1364 Norwegian students aged 15-17 years. These students were randomly sampled from the eighth and ninth grades of comprehensive schools and the first grade of high school. Girls showed the highest values for 'orientation towards others' and 'empathy', while boys scored highest on 'competitiveness' ($p<0.01$). Kahle and Lakes' (1983) analysis of NAEP data suggests that these attitudinal differences do not exist at the elementary level, but are large and consistent at the high school level: "...at age 9...most of their [girls'] feelings were positive and comparable to 9-year old boys. However, by ages 13 and 17, girls stated that not only did science fail to instill feelings of 'confidence', 'success' or 'curiosity', but that it also made them feel 'stupid'" (p. 135).

These attitudes are manifested in course selection in high school. In their British Columbia Assessment study, Erickson and Erickson (1984) found that females had enrolled disproportionately in biology courses, and had avoided the physical sciences - especially physics: "The proportion of females who had taken *any* senior physics was less than half the proportion of males who had done so, and females made up only 5.6 percent of students who were taking or had completed physics 12" (p. 71). Other research concurs that physics is the most underrepresented science course for girls. "The problem of girls not doing science is really a problem of girls not doing physics" (Kelly, 1988, p. 669). Horn (1990) identified physics as "the great divider between young men and women..." (p. 26). In a summary of data from the Department of Education (1991) and the Task Force on Science and Mathematics (1989) however, Clark (1991) states that the situation in Newfoundland is not quite so grim. While girls still take fewer physics courses the gap is closing: "...almost four times as many females were enrolled in high school physics in 1990 as in 1979" (p. 14). In any case, enrollment has serious implications in that physics is a prerequisite for many jobs in a way that biology is not.

Gender and Physics

Of all the sciences, physics has the lowest enrollment of girls, while biology has the highest. Trends begun in high school enrollments can be predictive of post-secondary course selection. Garratt (1986) administered a questionnaire to 177 first year tertiary college students (89 boys, 88 girls) taking A-level courses, to investigate patterns of subject choice and some of the factors influencing boys and girls when making these choices. She found a significant relationship between sex and subject specialization ($p<0.001$). In her sample, only 29% of the students in the science group were female, as compared to 70% in the arts group. Within the science group 16% of females studied the physical sciences (combined with mathematics, geography or geology), while 44% studied biology (combined with physical sciences, mathematics, geography or geology). For males, these percentages were 84 and 56 respectively. In fact, "biology is perhaps perceived as being relevant to girls of all abilities, but only appropriate for boys of average ability. Conversely, physics may be seen as suitable for a broad ability band of boys, but only for girls of higher ability" (Garratt, 1986, p. 68). No attempts were made to relate measures of reliability or construct validity for this questionnaire. Thus her findings may have limited validity and should be regarded cautiously.

Contrary to these results, girls and boys in Thailand are participating equally in the 'science' course, consisting of physics, chemistry and biology. Klainin, Fensham, and West (1989) studied six schools (2 girls', 2 boys' and 2 co-educational) in Bangkok, where 378 boys and 415 girls from grades 10, 11 and 12 wrote two practical tests and three pencil and paper tests, one of which was a Knowledge Achievement in Physics (KAP) test. The KAP tests were three part multiple choice tests designed to measure knowledge of principles, laws and concepts. The three parts corresponded to year 10, 11, and 12, though the whole test was administered to all students. In a one-way ANOVA between sex and the KAP measures, no significant gender differences were found. They found that girls performed at least as well as boys in physics. On the problem solving scale, assessment was based on independent direct observation by three assessors and written reports from students, to determine that females significantly outperformed males ($p<0.01$). While these results can be confidently accepted due to the large sample size, they are unique to the Thai context where the organizational features of secondary schooling have ensured that girls will participate in the physical sciences. While students can choose between the 'humanities' and 'science', the former still involves at least two years of study of physical science. As well, about fifty percent of physics teachers in Thailand are women. From classroom observations in Thai co-educational schools, it has been noted that girls are active participants in science classes. Reliabilities of test items yielding these results however are low, with test item-total score correlations ranging from 0.35 to 0.67 for year 10, 0.23 to 0.63 for year 11, and 0.40 to 0.76 for year 12. These factors severely limit the external validity or even comparison of these findings to other areas where situations may be quite different. These Thai results lend support to a cultural explanation of gender differences. Trends may be different in Thailand because of different cultural expectations and beliefs. More recently, Greenfield (1996) studied a series of students in grades 3-12, representing four major ethnic groups in Hawai'i - Japanese, Caucasian, Filipino and Hawaiian. Achievement in science was assessed using student scores from the science subtest of the SAT series, while student attitudes were assessed using an abbreviated version of the Student Attitude Questionnaire. The total number of students surveyed exceeded 1000. Data were analysed using analysis of variance and chi-square tests. Greenfield found that the traditional male advantage in science was not supported. In fact females, if not having a definite advantage, displayed at least equity for self-confidence and achievement. This study supports a cultural explanation of gender differences in that the groups studied are culturally diverse. Filipino mothers for instance, have been found to instill high educational aspirations in their daughters. Parents of Asian-American students are believed to hold less gender differentiated expectations of their sons and daughters than do Caucasian parents (Campbell & Connelly, as cited in Greenfield, 1996). Hawaiian mothers have been found to encourage daughters to attend college more than sons (Fricker, as cited in Greenfield, 1996). This is in direct contrast to the results of Guppy and Pendakur (1989) which showed that Canadian girls perceived more support from their fathers than their mothers. Even Caucasians represent an ethnic minority within such a highly heterogeneous environment. It is possible that females in less traditional environments may fare better in pursuing higher education and nontraditional careers. Essentially, "powerful societal forces...affect the members of a society in ways that shape their perceptions of their ultimate places within that society, and those perceptions are reinforced by societal institutions such as schools" (Greenfield, 1996, p. 928).

Levin, Sabar and Libman (1991) analysed data from the 1983-84 Israeli IEA (International Association for the Evaluation of Educational Achievement) science study, to explore gender-related differences in science learning. The study involved measures of science learning, ten attitudinal measures, and items and errors classification. While these measures are adapted from an international study, no reports of instrument reliability or evidence of pilot testing are given for this analysis. For a random sample of 1934 ninth grade students, a two-tailed t-test revealed that boys consistently outperformed girls. In physics, achievement differences of more than one half of a standard deviation were found. A W^2 estimate showed that gender accounted for about 10% of the variance in physics. This finding, while specific to the Israeli context and of limited reliability and external validity, does resemble typical patterns demonstrated in national and international surveys of science achievement (Erickson & Erickson, 1984). Kelly (1988) surveyed 1472 children participating in a Girls Into Science and Technology (GIST) project in ten co-educational comprehensive schools in Greater Manchester. She found that even though boys were doing better in physics, observed differences were less than one quarter of a standard deviation ($p<0.10$). These results though, were based on in-school end-of-third-year examination results. Each school had its own method of tabulating science subject scores. Kelly recognizes the problems these differing assessments create in comparing results across schools. She also indicated that since her sample is not random, tests of statistical significance are really not applicable, though they do give some indication of how much reliance can be placed on observed differences. Her in-school test results differ substantially from results obtained on standardized tests.

Bateson and Parsons-Chatman (1989) have shown that gender differences in science achievement may be due to specific test items used in the assessment instrument. In 1986 they examined a province wide science assessment in British Columbia which surveyed over 100,000 students in grades 4, 7 and 10 on science achievement. Each grade level was assessed using background questions, affective measures, and 120 multiple choice knowledge items chosen to reflect the content of the entire elementary and junior secondary curricula. All test items were subjected to extensive review by teachers, psychometricians, and reading specialists, and were piloted on the target populations. These items were multiple matrix sampled on three forms for administration to students. Teachers rated the test items to show that five out of seven items were more difficult for females than males. Those items causing the most difficulty were from physics: "Electricity has been well documented as an area of physical science where the greatest sex related differences have been reported" (Bateson & Parsons-Chatman, 1989, p. 380). This bias involved item characteristics relating to differential out-of-school experiences, particularly in electricity and circuitry. They advocate the importance of item analysis to producing gender equitable assessment instruments. Linn, DeBenedicts, Delucchi, Harris and Stage (1987) advocate that there are no significant gender differences on scientific inquiry, and that as long as test items do not depend on specific science content, no gender differences exist. They analysed data from the 1976-77 NAEP science assessment for 17-year olds to determine the frequency of 'I don't know' responses for females. This assessment employs a deeply stratified sample design with oversampling in extreme rural and in low income areas. Odd-even split half correlations adjusted back to full test length by the Spearman-Brown Prophecy formula, averaged 0.83 for total test score and 0.89 for the 'I don't know' response. They found that large male-female differences in 'I don't know' responses occurred on physical science items. They suggest that when given the option, females choose this response because they either lack content knowledge, or are uncertain of that knowledge and do not want to risk 'guessing'. For males, the 'I don't know' response has less value because males are expected to take risks.

This situation may indicate that boys have more confidence in their own ability in physical science, particularly physics. Guzetti and Williams (1996) did a case study of a purposive sample of 55 students in two high school physics classes (one physics and one honours physics class) in the southwest US to examine gender differences in participation in learning counterintuitive science concepts. These classes were chosen because of the teachers' goals and instructional methods, and his willingness to participate. Over the course of the study, the students focused observer attention towards an explanation of gender differences in classroom interactions. Over an eight month period, daily observations were made by highly qualified individuals trained in naturalistic inquiry. As well, data were triangulated from direct observations, questionnaires, interviews and lesson plans. Member checks were conducted with both the teacher and student informants. Data analysis using the computer program Ethnograph version 4.0, revealed that girls were characterized by self-doubt and a lack of self-confidence: "I don't know enough about physics to debate about it" (p. 13). While 47% of males said they would argue points in physics, 60% of females said they would not. The fact that this difference is small may be indicative of the small sample size used in the case study approach. Nevertheless this method allowed Guzetti and Williams to provide a 'thick' description of what they saw as gender bias in the classroom. Similarly, in Kelly's (1988) study boys estimated their performance to be approximately the same in chemistry, biology and physics, while girls estimated that they were doing much better in biology than in physics. While boys thought they were excelling in physics, girls thought they were excelling in biology. However, these estimated differences were much greater than any actual differences. Girls were especially likely to underestimate their performance in physics, reflecting their lack of self-confidence in this area.

Boys' and girls' views also differ on attribution of success. Boys are more likely to attribute success to ability and failure to lack of effort. Girls are more likely to reverse this trend by attributing success to luck or effort and failure to lack of ability. Ryckman and Peckham (1987) studied 165 girls and 160 boys, randomly sampled by classrooms, from grades 4-12 in the Seattle public school system. The sample was considered to be representative of the Seattle district. The students responded to a Survey of Achievement Responsibility (SOAR) designed to measure their attributions of success and failure. Reliabilities for this instrument were much higher for the language attributions to effort in failure situations ($r=0.75$) than for math/science attributions to luck in failure situations ($r=0.39$). Test-retest correlations ranged from 0.75 to 0.44 for these same respective areas. Though the reliabilities for math/science seem low, the authors contend that they compare favourably with reliabilities reported for other similar scales. Data were analysed by using repeated-measures analyses of variance. It was shown that on the mathematics/science items, girls tended to attribute their successes to effort and their failures to ability. The authors suggest that effort and ability are both internal attributions, where effort is unstable and ability is stable. When girls attribute their successes to unstable factors, they see those successes as being out of their control. It is then less likely that they will take pride in their achievements: "To attribute success to an unstable attribution and failure to a stable one is a characteristic of a learned-helplessness orientation" (Ryckman & Peckham, 1987, p. 123). While this study covers attributions in science in a broad sense, we can reasonably conclude that feelings of 'helplessness' in any specific area will impact on students' attitudes toward those areas.

Female attitudes toward physics are generally negative. Girls consider physics to be boring and as having no connection to the real world: "The courses may be dull and largely irrelevant to their concerns" (Linn, et al., 1987, p. 277). Staberg (1994) investigated Swedish students' perceptions of chemistry, technology and physics in grades 7-9. Thirty-two students were followed from the start of grade seven in compulsory school until they made their choice of study program in grade nine. Data were collected by the author in the 'ethnographic tradition'. Through semi-structured classroom observations, questionnaires and interviews, she found that boys and girls construe their lives differently: "...girls prefer knowledge connected with their own and others' lives, while boys are interested in apparatus, things, and in making things." (Staberg, 1994, p. 40). Eva, a grade seven student, offers a telling comment: "I don't really know what resistance is and all these peculiar things...all these words" and "you know it's only in biology I understand something" (Staberg, 1994, p. 40). In contrast, Baker and Leary (1995) state that "both physical and biological science are interesting to study in school" (p. 24), and that girls are highly self-confident about science. They decided on a semistructured protocol interview study, as a better way to gauge female feelings toward science. They contend that more quantitative studies do not accurately reflect the fact that attitudinal differences toward science between school age boys and girls are actually small. Their study however, was based on a 'volunteer' sample of forty girls in grades 2, 5, 8 and 11 - those students who volunteered are most likely students who have an interest in science to begin with. We are not told where these girls go to school or anything about their academic backgrounds. Also, there is no consideration given to the construct validity of interview questions, and there is no attempt at triangulation of data. Faith in these findings could result in minimizing attitudinal differences between males and females in physics. These attitudes may be important in relation to learning physics.

Gender and Physics Learning

The discipline of physics is structured around the learning of concepts, rules and laws. While knowledge of rules and laws are important to 'using' physics, it is a meaningful understanding of concepts which is required for 'knowing' physics, and having a confidence in that 'knowing'. A student may for instance, remember that Newton's second law is mathematically formulated as F=ma, but remembering that rule will not help the student understand the concept of net forces in various situations. Students must be able to apply the concept of Newton's second law in sometimes novel situations. If students feel they do not really understand the concepts beyond memorization of rules and definitions, they cannot be confident in their ability to apply those concepts. Halloun (1996) states that students tend to view solving physics problems as tasks for "selecting mathematical formulas to relate variables in the problem" (p. 1020) instead of as tasks for understanding concepts.

Novak and Gowin (1984) define a concept as "a regularity in events or objects designated by some label" (p. 4). In the past, behaviourist research has indicated that students should 'discover' and accept concepts as absolute truths. Much of present day educational research however, advocates an approach where conceptual knowledge is constructed. Such construction invariably recognizes the prior experiences and knowledge of individuals. However, the same experience can have very different meanings depending on one's background.

In learning physical concepts, Vygotsky (1982) distinguishes between 'everyday' and 'scientific' concepts. The former are based on students' everyday experiences, while the latter are learned at school. These two do not always coincide. Halloun (1996) indicates that major deficiencies in students' knowledge can persist even after instruction. Gilbert, Osborne and Fensham (1982) did in-depth interviews with 43 New Zealand school children ranging in age from 10-17 years, to determine their views of scientific concepts. Unfortunately, we are not given any indication of interviewer training or of any pilot testing. These students were selected by their teachers as being of 'average attainment' in science. Through individual discussions with these children, the authors were able to conclude that children used many 'scientific' words differently in everyday language: "The word particle is commonly used in science classes to mean atom, molecule or ion. In everyday use it refers to a small, but visible, piece of solid substance" (Gilbert, et al., 1982, p. 625). Despite the limited reliability and external validity, these results support the notion that in order to attain a scientific concept, a related everyday concept has to be addressed and sometimes refined. This is not always an easy task, especially when a 'scientific' concept to be learned involves contradiction of one's prior knowledge structure. This can lead to a situation where old and new concepts co-exist, with new knowledge used to solve physical problems in school, and old concepts reverted to for use in solving everyday problems:

> It is possible for the student to basically reject the teacher's science as something that can be accepted in terms of how to view the world, but to consider it as something that must be learned, eg. for examination purposes. The student, therefore, has two views, but the learned science viewpoint is not the one that has been adopted for use outside the formal learning situation. (Gilbert, et al., 1982, p. 629).

In a discussion paper based on Finnish research, Rasenen (1992) suggests that females have more difficulty in working with cognitive contradictions than do males. In physics, where concept attainment is such an integral part of learning, this is especially important. Learning a physical concept can be defined as a conceptualizing process: "It is recognizing and naming forms in the surrounding nature. The whole knowledge of physics is based on total integration development, whose nucleus is recognizing ever bigger structural forms and, in this way, creating ever more general and absolute combining concepts" (Rasanen, 1992, p. 87). In physics, a concept can only become viable for students as part of a system. Because females may lack prior knowledge and experience in physics, they may also have difficulty in attaining individual physical concepts. This difficulty then translates to learning systems of concepts. Novak (1988) emphasizes that, when students do not possess relevant concepts new information must be learned by rote: "In rote learning, new information is not associated with existing concepts in cognitive structure, and therefore little or no interaction occurs between newly acquired information and information already stored" (p. 77).

Rote learning and its antithesis, meaningful learning, are primary concepts in Ausubel's (1963) learning theory. Ausubel defines meaningful learning as the ability to relate new knowledge and concepts to existing knowledge. In fact, according to Ausubel, three conditions must be fulfilled for meaningful learning to take place: 1) the concepts presented must have meaning for the learner, 2) the learner must possess prior knowledge to which the concepts can be related, and 3) the learner must possess a 'meaningful learning set' in which one actively tries to relate prior knowledge to new conceptual ideas, and in which one has a desire to make these connections. Novak (1988) also indicates that new knowledge should be acquired through the construction of relationships between concepts and ideas. In rote learning however, knowledge can be attained through memorization. Knowledge gained in this way does not have to interact with prior knowledge structures, has little functional value, and is ineffective in producing lasting significance (Novak, 1988). "Students who learn meaningfully acquire, retain and use knowledge better than those who learn by rote, although the latter may achieve well on some school tasks" (Novak, 1988, p. 89). Entwistle and Ramsden (1983) indicate that meaningful learners respond to 'novel problems' by connecting and expanding ideas, while rote learners state definitions and cannot elaborate concepts. Thus, students who predominantly utilize rote learning are at a disadvantage in physics, where the integration of concepts in problem solving is so critical.

Cavallo and Schafer (1994) studied 70 males and 70 females attending a public suburban high school in central New York state, to determine how students' meaningful learning orientations related to their understanding of meiosis, genetics, and the relationship between these topics. The implementation of questionnaires, tests, and instruction took place over a period of approximately one week. The Cronbach alpha internal consistency coefficient for a 24 item subscale of a Learning Approach Questionnaire to determine this learning orientation, was $r=0.54$ ($r=0.77$ for the whole instrument). In light of this fairly low value, a more reliable determination of learning orientation as rote, midrange or meaningful, was obtained by using the LAQ self-reports *and* trained teacher observation of students. Also, of the 140 participating biology students, data were used only from the 94 students whose own ratings matched the teacher ratings. A mental modelling assessment technique was used to reveal the extent and nature of student understanding. The authors argue the virtue of this technique in that traditional testing procedures may not detect differences in conceptual understanding, because many students can obtain correct answers with only rote-level knowledge. Content accuracy of explanations was determined by the researcher and two genetics professors. A regression analysis of meaningful learning orientation x prior knowledge explained 18% of the variance in Punnett Square method posttest scores ($p<0.0001$). With this interaction for procedural relationships between meiosis and Punnett Squares, Cavallo and Schafer found that mid-range learners experienced an increase in meaningful understanding with an increase in prior knowledge. However, with low prior knowledge their level of meaningful understanding was about the same as for rote learners. Their study supports the contention of Entwistle and Ramsden (1983) that students may need to use both rote and meaningful learning approaches in order to attain complete conceptual understanding. Cavallo and Schafer (1994) concluded that a meaningful learning approach was at least as important as aptitude and achievement motivation in attaining conceptual understanding.

It is sometimes believed however, that females have a greater tendency than males to learn by rote. Haggerty (1987) examined science achievement in a ninth grade class in a Canadian urban upper middle class neighbourhood. The sample consisted of 14 female and 9 male students who were given achievement tests to assess their understanding of heat and temperature. Students were given a unit test prepared by the teacher and then a post-test (r=0.90). The unit test measured factual knowledge which could have been learned by rote, whereas the post-test measured understanding of concepts, requiring students to apply knowledge to novel situations. Haggerty found that boys outperformed girls on the post-test with a difference of one standard deviation. School science grades however, were not significantly different for males and females. Haggerty concluded that her findings parallelled the same inconsistencies in female performance on in-school as opposed to standardized tests. In contrast, a recent study by Meece and Jones (1996) focussed on the use of rote or meaningful learning strategies in science. They studied 213 fifth and sixth grade students (108 girls, 105 boys) from predominantly white, middle-to upper-middle class suburban communities, to examine gender differences in learning orientation. To determine strategy use they utilized the Active-Learning Strategy Scale (r=0.79) to measure strategies directed toward making sense of learning material, and the Superficial-Learning Strategy Scale (r=0.85) to assess strategies which minimize effort and thinking. These instruments were checked for construct validity in a prior investigation by Meece. It was found that boys (M=1.44, sd=0.33) reported greater use of effort-minimizing strategies than did girls (M=1.37, sd=0.30). The study did not support the idea that girls learn science by rote. It must be realized however, that the data was collected from self-reports. The extent to which these self-reports match actual strategy use is unknown. As well, the results pertain to elementary aged children in science, and cannot reasonably be generalized to high school students learning physics. It may be that gender differences in learning orientation could appear in later grades or in other classrooms. It has already been demonstrated that gender differences in science achievement are most pronounced in high school (Mullis & Jenkins, 1988; Greenfield, 1996). It may be that the development of a learning approach throughout school culminates in the differences in achievement observed in high school.

Cavallo (1994) suggests that socialization throughout the school years, may contribute to the adoption of a particular learning orientation. In a study of 140 high school biology students in New York State, a determination of learning approach was made by students and teachers. In a 2x2 chi squared analysis, teachers rated the females as being more rote in their learning orientation than males. These teachers were trained for two months according to specific criteria determined from a pilot study. In contrast, there were no significant gender differences in learning orientation on the student self-reported questionnaires. While the results of this study were inconclusive as to which rating was more appropriate, an important issue is raised. Do teachers' perceptions of girls result in differential expectations leading to rote learning for females? After all, females are typically socialized to conform and not to question authority. Males however, are encouraged to challenge authority. This socialization is consistently borne out in the science classroom, where teachers view boys as more rewarding and responsible pupils, even if they do tend to make unsolicited comments, call out in class, and ignore the hands-up rule (Whyte, 1984). Girls are viewed as more docile and conforming. Thus girls may choose rote learning as a way of meeting teacher expectations.

Rote learning may also be preferred because it has served females well in the past. Physics and many other subjects are often taught and assessed in such a way that rote learning is encouraged. "Even in the best schools, the pressures on students to recall numerous items of information or to identify large numbers of objects or items often preclude their feeble efforts to organize this material into frameworks that would be meaningful to them" (Novak, 1988, p. 91). If students perceive that a learning approach is working for them, why change it? It has been shown that on teacher made tests where students have been exposed to relevant information, females do well. However, those qualities which promote high achievement in school might inhibit female performance at other academic levels where different traits might be valued. While rote learning may serve females well in some physics classrooms, a lack of real understanding through meaningful learning will preclude further study of physics, and entry into physics-related careers. This is evidenced in that even at the university level many students have difficulty understanding physics, and often have misconceptions. Piaget (1970) would say that these students have not yet reached the formal reasoning stage of development. However, learning approach may also be an important determinant. Williams and Cavallo (1995) studied 26 males and 15 females enrolled in a first and second level physics course at a small Midwestern university. The same instructor taught both courses. They utilized a test of logical thinking ($r=0.85$), a learning approach questionnaire ($r=0.77$), and a force concept inventory ($r=0.86$ for pretest and $r=0.89$ for posttest), to determine the relationship between students' reasoning ability, meaningful learning approach, and their understanding of physical concepts. They found that students with a meaningful learning approach had greater physics understanding than those with a rote approach. However, a meaningful approach did not explain more than was already explained by reasoning ability. Since meaningful learning and reasoning ability were correlated

(r=0.375, p<0.05), it is possible that each may share similar characteristics. While this study is based on a small sample, it does offer insight into the extension of high school difficulties to higher learning.

In addition to the academic benefits of a meaningful learning approach, Novak (1988) suggested that rote learning was associated with negative feelings toward cognitive involvement, while meaningful learning was associated with more positive feelings. If girls are indeed learning physics by rote, this could account for their attribution of success to luck or hard work, and not to ability (Gilbert, et al., 1982). Females may feel that they do not really 'meaningfully' understand physics, but that hard work 'gets them by'. In this way, self-confidence may be a key ingredient in physics learning.

While none of this research specifically studies the relationship between self-confidence and learning approach in secondary school physics, it does lay the foundation for much needed research in this area - research which may help alleviate the problem of 'girls and physics'. Primarily, the research has indicated that there are gender differences in science achievement, with boys outperforming girls (Kelly, 1988; Erickson & Erickson, 1984; Simpson & Oliver, 1990; Kahle & Meece, 1994). These differences are most pronounced in physics. Secondly, girls have been shown to have lower levels of self-confidence than boys, particularly in physics (Staberg, 1994; Levin, Sabar & Libman, 1991; Ryckman & Peckham, 1987). Even when girls achieve as well as boys, their self-confidence is still lower. Several reasons have been offered for these results, the most viable being a cultural explanation. Studies of different cultures have sometimes shown drastically different results in both achievement and confidence. The fact that different cultures undergo different socialization processes is a strong argument for the role of external factors (eg. family, schools) in influencing gender differences. If culture did not play a role, results in achievement should be the same worldwide. This, coupled with an awareness of the continually changing nature of gender differences, prevents the support of a genetic explanation. Greenfield's (1996) study showed that even Caucasian females have higher achievement when placed in a different cultural environment. A third major idea from the literature is that girls are thought to learn more by rote than males. While the research on this is inconclusive, it is certain that a rote learning style will not encourage the meaningful conceptual understanding required for success in physics. If learning approach is related to self-confidence, than it may also be culturally mediated. As mentioned girls might adopt a rote learning approach to avoid sanctions from teachers, who may reward the conformity associated with rote learning (i.e. submissive, accepting behaviour). An assumption of a cultural argument is an assumption that the situation can be changed. If girls in Thailand and Hawai'i perform as well as or better than boys, why can't they do it in Newfoundland? What features of the socialization process and school system must be changed to help girls succeed in physics? If there is a relationship between learning approach and self-confidence, the nature of this relationship must be deciphered in an attempt to increase the participation and success of 'girls and physics'.

Problem Statement

The purpose of this study was to elucidate further the influences of learning approach on success in physics. Of particular interest was whether learning approaches influenced students' levels of self-confidence in learning physics, and whether there were any gender differences in this area. If learning approach is a determinant of self-confidence it may also determine achievement in physics. The focus of this study is on establishing the existence and describing the nature of the relationship between gender, learning approach, self-confidence and achievement in physics.

In this study, learning approaches are adopted from Cavallo and Schafer (1994) and will consist of rote and meaningful learning. These approaches can be seen as analogous to different levels of Bloom's (1956) taxonomy. A preference for rote learning corresponds most closely to Bloom's knowledge level objectives. It is defined as preferring recall of information and describes a passive approach towards physics learning. Meaningful learning corresponds to Bloom's higher order objectives of application, analysis, synthesis and evaluation. It indicates a preference for an active approach towards physics learning where students can integrate and apply concepts to novel situations. Self-confidence describes a students' appraisal of their own ability to understand and succeed in physics.

Research Questions

On the basis of the research findings described previously, the main research questions of this study focussed on learning approach, self-confidence and achievement. It is my contention that self-confidence is related to learning approach in physics. Whether a student has adopted a predominantly rote or meaningful learning approach will determine their level of self-confidence. Students learning physics predominantly by rote will have lower self-confidence in their ability than students adopting a more meaningful learning approach. This confidence level should be reflected in their achievement in physics. Students learning by rote should not be able to achieve well on test questions requiring higher order thinking abilities. Meaningful learners however, should be able to achieve well on both rote and meaningful test items. Specific research questions are as follows;

1. Does learning approach predict achievement?

   It is expected that learning approach will explain some of the observed differences in achievement.

   Null hypothesis: learning approach will not explain any observed differences in achievement.

2. Does level of self-confidence predict achievement?

   It is expected that self-confidence will explain some of the observed differences in achievement.

Null hypothesis: level of self-confidence will not explain any observed differences in achievement.

3. Does achievement predict self-confidence?

   It is expected that achievement will explain some of the differences in self-confidence observed after each unit test.

   Null hypothesis: achievement will not explain differences in self-confidence after each unit test.

If these null hypotheses are true, the posited relationship between learning approach and self-confidence is not supported. If my hypotheses are correct however, the nature of this relationship must be further explored.

4. Are there any gender differences in learning approach in physics?

   It is expected that females are more likely to learn physics by rote than males.

   Null hypothesis: there are no gender differences in learning approach in physics. If this null hypothesis is true there should be no differences between male and female scores on the Learning Approach Questionnaire utilized in this study.

5. Are there any gender differences in achievement on the unit tests?

   It is expected that females will experience lower achievement than males on the meaningful portions of the unit tests. On the rote portions however, females are expected to perform at least as well as males.

Null hypothesis: there are no gender differences in achievement on the unit tests.

6. Are there any differences between rote and meaningful learners in achievement?

It is expected that rote learners will have lower achievement on the unit tests than meaningful learners, particularly on the meaningful test portions. Both rote and meaningful learners are expected to do well on the rote sections of the tests.

Null hypothesis: there are no differences between rote and meaningful learners in achievement.

7. Are there any gender differences in self-confidence in physics?

It is expected that females will have lower levels of self-confidence in physics than males.

Null hypothesis: there are no gender differences in levels of self-confidence in physics. If this null hypothesis is true, self-confidence levels as indicated in the confidence questionnaire, should be the same for males and females.

8. Is there a relationship between learning approach and self-confidence in physics?

It is expected that there is a relationship between learning approach and self-confidence in physics. It is expected that rote learners will be less confident than meaningful learners.

Null hypothesis: there is no relationship between learning approach and self-confidence in physics.

9. Are there any differences in self-confidence for rote males and rote females, or for meaningful males and meaningful females?

It is expected that females learning by rote will have the lowest self-confidence, while males learning meaningfully will have the highest self-confidence.

Null hypothesis: there are no gender differences in self-confidence for rote and meaningful learners.

10. Is there a relationship between gender, learning approach, self-confidence before the unit tests, and achievement in physics?

It is expected that if a student is a rote learner, female, and has low prior self-confidence then they will have low achievement in physics. Conversely, if a student is a meaningful learner, male, and has high self-confidence then they will have higher achievement in physics.

Null hypothesis: there is no relationship between gender, learning approach, self-confidence and achievement in physics.

11. Is there a relationship between gender, learning approach, self-confidence before the unit test, achievement, and self-confidence after the unit tests?

It is expected that learning approach will determine self-confidence before the unit test, but that self-confidence after the unit test will be determined by perceived achievement on the unit test.

Null hypothesis: there is no relationship between gender, learning approach, self-confidence prior to writing the unit test, achievement, and self-confidence after writing the unit test.

Chapter Three

Theoretical Framework and Methodology

Theoretical Rationale

A major component of physics education is conceptual knowledge. Students must remember concepts, and be able to meaningfully apply and integrate them into conceptual systems (Rasanen, 1991; Novak, 1988). It may be argued that academic ability is the predictor of meaningful understanding. It may also be argued that students who have meaningful understandings have higher motivation to learn. Dweck (1986) advocates that motivational attributions may be responsible for achievement discrepancies between boys and girls in mathematics. However, in addition to academic ability and motivation, this study suggests that another variable called 'meaningful learning orientation' may contribute to students' meaningful understanding of physics. Cavallo and Schafer (1994) define a meaningful learning orientation as "the extent to which students approach a learning task with the intention of meaningfully understanding the ideas and relationships involved" (p. 394). To address this idea, it is important to ascertain the level of rote or meaningful conceptual understandings that students possess.

Student understanding may not be accurately assessed on traditional tests where mainly rote knowledge is measured (Ridley & Novak, 1983). To overcome this problem, Cavallo and Schafer (1994) used a technique called 'mental modelling' to assess students' rote or meaningful conceptual understanding: "In mental model assessment, students provide a comprehensive written description of their understandings of a particular topic" (p. 398). In this study however, multiple choice questions were used to measure conceptual understanding, with questions classified as rote or meaningful. Rote learning corresponds to Bloom's knowledge objectives, while meaningful learning covers application, analysis, synthesis and evaluation. In past research by the NAEP (1978) it was found that when test items were classified according to Bloom, there were smaller gender differences as one moves from the knowledge level up to the analysis/synthesis level. Levin, et al. (1993) suggest a male advantage for test items on information, comprehension and application. They go on to say that boys also perform better than girls on understanding processes which require scientific reasoning. In the NAEP assessment, a smaller male advantage in science process methods was identified. Linn, DeBenedicts, Delucchi, Harris and Stage (1987) and Erickson and Erickson (1984) however, advocate that there are no significant gender differences on scientific inquiry, and that as long as test items do not depend on specific science content, no gender differences exist. "Thus NAEP assessments reveal gender differences on science content" (Linn, et al., 1987). It is generally believed that these differences are due to differential prior experiences of boys and girls in science. Bateson and Parsons-Chatman (1989) have shown that gender differences in science achievement may be due to specific test items used in the assessment instrument. They advocate the importance of item analysis to producing gender equitable assessment instruments.

To construct a more complete picture of how students learn, it may also be important to consider 'prior achievement'. For physics, achievement in previous physics and math courses may be especially helpful, in that the type of learning and thinking processes required for earlier courses should transfer to later courses. Prior math success may also be influential since so much of physics involves formulation and mathematical operations. In fact, "...competency in mathematics is a prerequisite for entrance and persistence in scientific and technical fields, (and) the study of mathematics was defined early as the 'critical filter'" (Kahle & Meece, 1994, p. 543). Thus, to examine gender differences in learning physics, it is important to know students' physics and mathematics backgrounds. Sudweeks and Tolman (1993) caution against statistical analyses where groups have not been matched in terms of ability.

Studies have shown that up until adolescence, there are no differences in mathematical achievement and ability (Mura, Kimball & Cloutier, 1987; Shashaani, 1995). Gender differences however, increase substantially by age seventeen. The research on mathematical differences in ability and achievement are not consistent. In a review of this research, Kahle and Meece (1994) and Mura, et al., (1987) found that girls sometimes outperform boys on tests of computational skills; boys sometimes outperform girls on tests of problem solving and math reasoning; and both boys and girls perform similarly on tests of algebra and basic math knowledge. On achievement tests among high school students, boys tend to score moderately higher than girls. Specifically, males tend to perform better on standardized achievement tests which originate from outside the classroom, while girls and boys perform equally well if the test is based on in-school learning (Senk & Usiskin, 1983). In fact, if math grades are the focus, girls perform equally well or better than males. Kahle and Meece suggest that standardized tests may be biased against females.

In the 1970's, studies showed that differences in boys and girls scores on the Scholastic

Aptitude Math Test could be attributed to different enrollment patterns in high school mathematics (Pallas & Alexander, 1983; Mura, 1982; Wiggins, 1982). Shashaani (1995) shows that boys tend to enroll in more advanced math courses like calculus and trigonometry than girls. Mura, et al. (1987) suggest that when researchers match females and males on the number of math courses taken, any differences on standardized achievement tests become smaller or disappear.

If females then, perform well in the math courses they take, why do they shy away from mathematics in high school? Shashaani (1995) describes this situation as cyclic. She believes that there is a relationship between math experience and math liking and confidence. Because of the cumulative structure of math knowledge, students who do not enrol in as many math courses are more unfamiliar with the subject, which may lead to dislike and lack of confidence. These attitudes in turn, contribute to low enrollments. She also found that females had less confidence in math and were less interested in it. If females have low confidence in math, it is highly unlikely that they will have confidence in their ability to succeed in a subject requiring substantive amounts of mathematical knowledge.

Since learning approaches are being studied in relation to achievement and self-confidence, it is also important to obtain measures of both the self-confidence levels of students in physics, and their learning approach. Cavallo and Schafer (1994) found that a more meaningful learning orientation corresponded to more meaningful conceptual understanding. The purposes of this study were a) to determine if student learning approach was a variable that influenced achievement and self-confidence; b) to determine any gender differences in self-confidence; and c) to explore all possible interactions between gender, learning approach, self-confidence and achievement in physics.

Methodology

Sample

The sample consisted of 131 eleventh and twelfth grade (aged 15-17) high school students attending six public schools in rural Newfoundland communities. The students were enrolled in Physics 3204 in six classes taught by six different teachers (5 male and 1 female). Classroom groups were selected based on size and the willingness of classroom teachers to participate. Students missing any portion of treatment or testing were eliminated from that part of the data analysis.

Time Frame

This research was conducted in the winter semester of 1996, when the units on electrostatics and current electricity are normally taught in Physics 3204. All teachers taught these units according to specific intended learner outcomes, put forth by the Provincial Department of Education. Since all teachers presented these units in the same sequence, students could be expected to have similar background information before beginning the study. The implementation of tests, questionnaires and instruction, took place over a period of approximately four months.

Procedures and Instrumentation

Meaningful Learning Orientation

Research suggests that students may have a predetermined learning orientation as either rote or meaningful, and that this orientation can be identified. Donn (1989) used a Likert-type instrument to distinguish between rote and meaningful learners, and found vast differences in their approach to learning. This study used a modified form of the Learning Approach Questionnaire (Cavallo, 1996; Donn, 1989) to determine students' meaningful learning approach.

Learning Approach Questionnaire

Prior to physics instruction in the chosen units, students were given the Learning Approach Questionnaire (LAQ). In this study 123 students completed the LAQ (75 males and 48 females). The LAQ is a 50-item Likert instrument for measuring students' tendency to learn meaningfully or by rote, and their epistemological views of science (Donn, 1989; Edmonson, 1989; Entwistle & Ramsden, 1983). A Cronbach alpha internal consistency coefficient for this instrument was reported as 0.77 (Boujaoude, 1992) for a sample of eleventh grade chemistry students. This study used only those items that addressed students' meaningful or rote learning approach. Of these 24 items, Cavallo (1996) found that 20 items gave the most reliable measure of learning approach (r=0.80). For this study, a standardized item alpha of 0.79 was reported. The instrument asked students to respond to questions regarding how they learned, with responses ranging from A (always true) to E (never true).

Sample questions from the LAQ included the following;

Table 1.
Sample Items from the Learning Approach Questionnaire

	Always True				Never True
10. I often find myself questioning things that I hear in lectures or read in books.	A	B	C	D	E
17. I learn most things by rote going over and over them until I know them by heart.	A	B	C	D	E

Item 10 was a measure of a meaningful learning approach, and a response of always true indicated a strong tendency toward meaningful learning. On item 17, a response of always true indicated a strong tendency toward rote learning. 'Rote' item scores were reverse-scored so that a higher LAQ score was indicative of a more meaningful learning approach. After taking the LAQ, students' learning approaches were classified as meaningful if LAQ>60 and rote if LAQ≤60 (60 was chosen as a value close to the mean LAQ score of 60.33). These scores were used in the data analyses. Student learning approaches were also identified by their teachers. Teachers were sent an information package containing instructions on what features of learning constituted a rote or meaningful approach. As in Cavallo and Schafer (1994) teachers were asked to rate their students on a scale of 1 to 4: 4=more meaningful learners; 3=less meaningful learners; 2=less rote learners; 1=more rote learners. For a more representative measure of learning approach, Cavallo and Schafer only analysed data for those students whose teacher rating matched their own from the LAQ. In the present study, only

36 students' ratings matched their teachers' ratings. This may have been due to the teachers' lack of personal training sessions with the researcher. Also, teachers may see their students differently than students see themselves. In this study, the student ratings were seen as more relevant. If there is a relationship between learning approach and self-confidence, then how students rate their own learning approach would be more important to how they feel about their own ability in physics, particularly if teacher beliefs are unknown to the student. Hence the decision to define a meaningful learner as one who scores more than 60 on the LAQ.

Approach to Physics Questionnaire

This instrument is a 12-item Likert questionnaire designed to measure students' perceived ability, and performance and learning goal orientations. In this study, the same questionnaire was administered at four different points throughout the study. At point A, 115 students responded (68 male and 47 female); at point B, 120 students responded (72 male and 48 female); at point C, 123 students (75 male and 48 female); and at point D, 131 students (80 male and 51 female). Though the perceived ability subscale was comprised of only four questions, the reliability for this subscale was reported as $r=0.86$ (Miller, Cavallo & Blackburn, 1996). In this study, the reliability for this subscale for the four different questionnaire administrations were 0.73, 0.82, 0.73 and 0.95 respectively. Reliabilities at points B and D may be higher because these questionnaires were administered within two days of questionnaires A and C. However, there was a two-month time gap between the administration of questionnaires B and C. The instrument asked students to respond to questions regarding their feelings about learning physics. Sample questions from this questionnaire included;

Table 2.
Sample Items from the Approach to Physics Questionnaire

	Strongly Disagree				Strongly Agree
1. One of my primary goals in this class is to understand the science activities we do.	A	B	C	D	E
2. I am confident I can do well on the science problems we are given in this class.	A	B	C	D	E
3. One of my primary goals in this class is to do better than other students.	A	B	C	D	E

Item 1 was a measure of a learning goal orientation to learning, item 2 was a measure of perceived ability and item 3 was a measure of a performance goal orientation. A high score on either of these subscales indicated either high self-confidence or a strong learning or performance goal orientation. In this study the perceived ability subscale was utilized in the data analysis.

Measuring the Attainment of Meaningful Understanding

To determine whether students had attained meaningful understandings, two multiple choice unit tests were constructed, one for the unit on electrostatics and one for the unit on current electricity. In this study, 128 students (79 males and 49 females) wrote the electrostatics unit test, while 123 students (75 males and 48 females) wrote the current electricity unit test. Topics covered in the electrostatics unit included atomic structure, methods of charging, Coulomb's Law, lightning, and the laws of electric charges. In the current electricity unit, topic coverage included AC and DC current, composition of batteries, motors and generators, Ohm's Law and Kirchoff's circuit rules. Overall, the electrostatics unit was much more descriptive than the unit on current electricity. These particular units were chosen because it was expected that boys' and girls' prior experiences would be approximately equal in electrostatics, but that this would not be the case for current electricity. Any 'gaps' in experience could factor into a relationship between learning approach, achievement, and self-confidence for boys and girls.

These unit tests were checked for construct validity by three physics teachers, and modified accordingly. The 30-item electrostatics test had a reported reliability of $r=0.69$, while the 28-item current electricity test had a Cronbach alpha of $r=0.76$. (In the data analysis, two questions were dropped from the current electricity test due to ambiguous wording.) These tests were designed so that the first fifteen (or fourteen) questions would measure knowledge level objectives, while the last half of the test would measure the higher order skills of application, analysis, synthesis and evaluation (Bloom, 1956). The last half of the test required students to relate and connect concepts, as opposed to just stating definitions or formulas. Students learning by rote should have been able to achieve on the first half of the tests but not the second. Students possessing a more meaningful learning approach however, should have been able to perform well on the whole test. Reliabilities were also calculated for each half of the unit tests. For the first and second halves of the electrostatics test, reliabilities were 0.53 and 0.57 respectively. For the first and second halves of the current electricity test, reliabilities were 0.63 and 0.60 respectively. Because these were tests of knowledge rather than attitude, the reliabilities though low, were reasonable. Due to subject availability, no test-retest reliabilities were performed. Sample questions from the electrostatics test included;

Table 3.
Sample Items from the Electrostatics unit test

15. What term is used to describe the region of interaction between two objects that are not touching?

(A) field
(B) high pressure area
(C) proof plane
(D) space

28. If there is no net force on Y because X and Z attract Y equally, how do the charges on the objects compare?

O 4r O r O

(A) Y is less than the charge on either X or Z
(B) Y is greater than the charge on either X or Z
(C) X is 4 times greater than the charge on Z
(D) X is 16 times greater than the charge on Z

Question 15 required students to memorize the definition of an electric field. Question 28 however, required students to connect the concepts of electric force and the inverse square law of forces between charged objects - it was not simply a matter of remembering facts, but of understanding the connections between those facts. Sample questions from the current electricity unit test included;

Table 4.
Sample items from the Current Electricity unit test

3. Which of these devices uses light emitting diodes in its operation?

(A) AC generator
(B) battery
(C) light bulb
(D) smoke detector

17. The resistance in an electrical circuit is tripled. In order to keep the current the same, how must the voltage applied to the circuit be altered?

(A) kept the same
(B) made one third as large
(C) made three times as large
(D) made nine times as large

Question 3 required students to memorize the uses for light emitting diodes. Question 17 however, required students to use Ohm's Law in a way that did not involve 'plugging in' numbers.

Scoring Procedures

The multiple-choice unit tests were scored by each individual teacher and then reviewed by the researcher. All students' tests were marked with identification numbers to that students' identities were unknown. The tests were scored in whole and in halves so that students received separate scores for the rote and meaningful portions of the test. Each item was marked as correct (1) or incorrect (0).

All other instruments were scored by the researcher only. The Approach to Learning Physics Questionnaire items were scored on a scale of 1 to 5, with strongly disagree rating 1 and strongly agree rating 5. This scoring procedure was reversed for items 8 and 12. The subscale of perceived ability was comprised of items 2, 4, 8 and 12 with the highest possible score being 20. A higher score on this questionnaire subscale indicated higher perceived ability.

The Learning Approach Questionnaire was also scored from 1 to 5, with the highest possible score being 100. For this instrument, always true received a score of 5 for the 'meaningful' items, and a score of 1 for the 'rote' items. A high score on this questionnaire corresponded to a more meaningful learning approach.

Experimental Design

	Instrument Codes		
Male	LAQ	T_1	O_{1a}
			O_1
			O_{1b}
Female	LAQ	T_1	O_{1a}
			O_1
			O_{1b}

	Instrument Codes		
Male	LAQ	T_2	O_{1c}
			O_2
			O_{1d}
Female	LAQ	T_2	O_{1c}
			O_2
			O_{1d}

LAQ: Learning Approach Questionnaire

T_1: Treatment 1 (Electrostatics instruction)

T_2: Treatment 2 (Current Electricity instruction)

O_1: Unit Test (Electrostatics)

O_2: Unit Test (Current Electricity)

O_{1a}: Confidence Test before electrostatics test

O_{1b}: Confidence Test after electrostatics test

O_{1c}: Confidence Test before current elec. test

O_{1d}: Confidence Test after current elec.test

The experimental design of the study was a one-group pretest-posttest design (Campbell & Stanley, 1963). This study did not involve specific treatments or control groups, but looked at how normal classroom instruction interacted with students' meaningful or rote understandings of the topics addressed, and their achievement and self-confidence in those understandings. Students were first given the LAQ to determine their learning approach. Then students received normal classroom instruction on the electrostatics unit of Physics 3204. Once the unit was complete students were given two identical confidence tests (Approach to Physics Questionnaire) - one was administered the day before the unit test, while the second was administered immediately after writing the unit test. Starting with instruction for current electricity, the same sequence was repeated. In the test administration and in the data analysis, each unit was treated separately. The rationale for doing this was that there was a one to two-month time interval between administration of the second and third Approach to Physics Questionnaires. Also, the content of both units was different enough to avoid overlap of topic coverage. Thus even though feelings about the electrostatics test could carry over into the current electricity unit, it is likely that these effects would be negligible. To control for differential prior knowledge, marks were obtained from Physics 2204, Mathematics 1201, 1300, 2201 and 2200. These marks when factored into the analyses did not change the results of the study. Also, course taking patterns were so different for participants, it was difficult to match students on prior courses (i.e. subgroups would have been too small). For these reasons, previous marks were omitted from the data analysis.

Pretests

Students were given the Learning Approach Questionnaire to assess their learning orientation. They were also given the Approach to Learning Physics Questionnaire, on the day before writing the respective unit tests.

Instructional Treatments

Students were given instruction on electrostatics and current electricity (separate treatments) by their respective classroom teachers. Though instructional methods varied from teacher to teacher, all utilized the intended learner outcomes specified in the curriculum guide. As well, all teachers taught the required units in the same sequence. While there were required laboratories for these units, it is unknown whether all teachers did these labs. Some teachers may have been more traditional in their methods while others may have been more dynamic. An important commonality though, is that all teachers were preparing their students for a public examination and thus were concentrating on the same content. The multiple-choice unit tests were administered at the end of the unit after the instruction, and were counted as part of the normal evaluation for the course in all classrooms. Students were aware that these tests would contribute to their final course grade.

Posttests

In the last five minutes of the class for the unit tests, students were given the same Approach to Physics Questionnaire as in the pretest. It was administered in this way, so that student discussions about the test would not affect their feelings about their own ability. In this way it could be determined whether students' self-confidence changed after writing the unit test.

Chapter Four

Results

Distribution of Learning Orientation

Of the 123 students who responded to the Learning Approach Questionnaire, 60 were identified as having a meaningful learning orientation, while 63 were identified as having a rote learning orientation. Table 5 shows the gender breakdown for these learning approaches.

Table 5.
Frequency of learning approach by gender.

	Male	Female
Rote	36 (29%)	27 (22%)
Meaningful	39 (32%)	21 (17%)

Table 6 shows the distribution of learning approach with gender for each unit test.

Table 6.
Frequency of learning approach by gender for unit tests.

		Male	Female
Electrostatics	Rote	36 (30%)	27 (22%)
	Meaningful	38 (31%)	20 (17%)
Current Electricity	Rote	35 (30%)	27 (23%)
	Meaningful	37 (31%)	19 (16%)

Statistical Analyses

The relationship between learning orientation and unit test scores.

Relationships between learning orientation and whole and half test scores for electrostatics and current electricity are shown in a correlation table (see Table 7).

Table 7.
Correlation of learning orientation with whole and half test scores.

Variable	Elecscore	Elec115	Elec1630	Curscore	Cur114	Cur1528
LAQ	.2671*	.1674	.2816*	.3241*	.1828*	.3874*

* $p<.05$

Note: Elecscore-whole electrostatics test score; Elec115-first half electrostatics test score; Elec1630-second half electrostatics test score; Curscore-whole current electricity test score; Cur114-first half current electricity test score; Cur1528-second half current electricity test score; LAQ-Learning Approach Questionnaire score.

As indicated by the correlations, there was a significant positive correlation, at the $p<.05$ level, between students' learning orientation and whole electrostatics test score, the last half of the electrostatics test, the whole current electricity test, and both halves of the current electricity test. For these tests, a meaningful learning approach was correlated with a higher test score. Learning orientation was not significantly correlated, at the $p<.05$ level, with the first half of the electrostatics test.

The relationship between pretest self-confidence and achievement.

Relationships between self-confidence before each unit test and achievement on that test, are shown in correlation tables 8 and 9.

Table 8.
Correlation of self-confidence with whole and half test scores for electrostatics.

Variable	Elecscore	Elec115	Elec1630
ctaconf	.4806*	.3448*	.4605*

*p<.05

Note: ctaconf-the confidence level before writing the electrostatics test.

Table 9.
Correlation of self-confidence with whole and half test scores for current electricity.

Variable	Curscore	Cur114	Cur1528
ctcconf	.5278*	.4284*	.5087*

*p<.05

Note: ctcconf-the confidence level before writing the current electricity test.

As indicated by the correlations, there was a significant positive correlation, at the $p<.05$ level, between self-confidence before the electrostatics test, and whole and half electrostatics test scores. There was also a significant positive correlation between self-confidence before the current electricity test and whole and half current electricity test scores. A higher level of self-confidence before the tests corresponded to a higher test score in all cases.

The relationship between achievement and posttest self-confidence.

Relationships between achievement on the unit tests and self-confidence after writing the unit tests are shown in a correlation table (see Table 10).

Table 10
Correlation of achievement with self-confidence after the electrostatics unit test.

Variable	Elecscore	Elec115	Elec1630
ctbconf	.4517*	.3859*	.3825*

* $p < .05$

Note: ctbconf-confidence level after writing the electrostatics unit test.

As indicated by the correlations, there was a significant positive correlation, at the $p < .05$ level, between achievement and self-confidence after writing the electrostatics unit test. Higher achievement corresponded to higher self-confidence.

Table 11.
Correlation of achievement with self-confidence after the current electricity unit test.

Variable	Curscore	Cur114	Cur1528
ctdconf	.2648*	.1747	.2935*

* $p < .05$

Note: ctdconf-confidence level after writing the current electricity unit test.

For the current electricity unit test, there were significant positive correlations at the $p < .05$ level, for the whole and last half of the unit test with achievement. Higher achievement corresponded to higher self-confidence. The correlation between achievement on the first half of the current electricity unit test and self-confidence after that test, was positive but not significant as shown in Table 11.

The correlations presented thus far have indicated the existence of some kind of relationship between learning approach, self-confidence and achievement. Statistical analyses including analyses of variance and multiple regressions were used to decipher the nature of this relationship with respect to gender.

The relationship between learning approach and gender.

The relationship between learning approach and gender is shown in a cross tabulation table.

Table 12.
The relationship between learning approach and gender.

		Gender	
		Male	Female
Learning Approach	Rote	36 48.0%	27 56.3%
	Meaningful	39 52.0%	21 43.8%

Chi Square	Value	DF	Significance
Pearson	.79730	1	.37190
Continuity Correction	.50129	1	.47893
Liklihood Ratio	.79882	1	.37145
Linear-by-Linear Association	.79082	1	.37385
Fisher's Exact Test			
One-Tail			.23962
Two-Tail			.45997

*p<.05

A two-dimensional chi-square analysis revealed that there were no significant differences, at the p<.05 level, between males' and females' learning approach. Males were just as likely to be rote learners as females.

The relationship between pretest self-confidence and gender.

The relationship between levels of self-confidence before writing the unit tests and gender, is shown in an analysis of variance table (see Table 13).

Table 13.
Variance of self-confidence by gender prior to writing the unit tests.

Variable	Group	F-ratio	F-prob	Count	Mean	SD	SE
ctaconf	Male	7.5653	.0069*	68	14.3676	3.1853	.3863
	Female	7.5653	.0069*	47	12.808	2.6755	.3903
ctcconf	Male	5.9737	.0160*	75	13.626	2.9536	.3410
	Female	5.9737	.0160*	48	12.3125	2.8371	.4095

*$p<.05$

The results indicate that, at the $p<.05$ level, males were significantly more confident than females. Without controlling for any other variables, gender was a significant predictor of self-confidence before writing the unit tests.

Table 14.
Variance of self-confidence by gender after writing the unit tests.

Variable	Group	F-ratio	F-prob	Count	Mean	SD	SE
ctbconf	Male	9.2006	.0030*	72	14.3194	3.7335	.4400
	Female	9.2006	.0030*	48	12.416	2.7198	.3926
ctdconf	Male	1.7254	.1913	80	15.0125	6.3275	.7074
	Female	1.7254	.1913	51	13.5294	2.2589	.8764

*$p<.05$

Interestingly, the same trends hold true for self-confidence after writing the electrostatics unit test, but not after writing the current electricity test (see Table 14). The table shows that while males were still more confident than females after writing the current electricity test, the difference in means was not significant at the $p<.05$ level.

The relationship between achievement and gender.

The relationship between achievement and gender is shown in an analysis of variance table (see Table 15).

Table 15.
Variance of achievement by gender.

Variable	Group	F-ratio	F-prob	Count	Mean	SD	SE
Elecscore	Male	.0234	.8788	79	19.0759	4.2450	.4776
	Female	.0234	.8788	49	18.9592	4.1279	.5897
Elec115	Male	.5529	.4585	79	10.0000	2.4019	.2702
	Female	.5529	.4585	49	10.3265	2.4357	.3480
Elec1630	Male	.9491	.3318	79	9.0759	2.5709	.2892
	Female	.9491	.3318	49	8.6327	2.3865	.3409
Curscore	Male	.5088	.4770	75	20.2533	4.4694	.5161
	Female	.5088	.4770	48	19.6875	3.9955	.5767
Cur114	Male	.2966	.5870	75	10.6667	2.3385	.2700
	Female	.2966	.5870	48	10.8958	2.1757	.3140
Cur1528	Male	2.9760	.0871	75	9.5867	2.6102	.3014
	Female	2.9760	.0871	48	8.7917	2.2967	.3315

*$p<.05$

The results indicated that at the $p<.05$ level, there were no significant gender differences in achievement for whole or half test scores. Though not significant, males did have higher mean scores than females on all except the first halves of the unit tests for both electrostatics and current electricity. These 'first halves' corresponded to the rote portions of the tests.

The relationship between learning approach and achievement.

The relationship between learning approach and achievement has already been presented in a correlation table (see Table 7). Here, the relationship is shown in an analysis of variance table (see Table 16).

Table 16.
Variance of achievement by learning approach.

Variable	Group	F-ratio	F-prob	Count	Mean	SD	SE
Elecscore	Rote	7.5369	.0070 *	63	18.2381	3.7619	.4740
	Meaningful	7.5369	.0070 *	58	20.2586	4.3309	.5687
Elec115	Rote	1.0583	.3057	63	10.0000	2.3071	.2907
	Meaningful	1.0583	.3057	58	10.4483	2.4863	.3265
Elec1630	Rote	12.9807	.0005 *	63	8.2381	2.2122	.2787
	Meaningful	12.9807	.0005 *	58	9.8103	2.5851	.3394
Curscore	Rote	7.5325	.0070 *	62	19.0000	4.2658	.5418
	Meaningful	7.5325	.0070 *	56	21.1250	4.1256	.5513
Cur114	Rote	1.4092	.2376	62	10.5000	2.2958	.2916
	Meaningful	1.4092	.2376	56	11.0000	2.2724	.3037
Cur1528	Rote	13.4195	.0004 *	62	8.5000	2.4005	.3049
	Meaningful	13.4195	.0004 *	56	10.1250	2.4126	.3224

*$p < .05$

The results indicated that at the $p<.05$ level, there was a significant difference between the performance of rote and meaningful learners on the whole electrostatics and current electricity tests, as well as on the 'meaningful' portions of those tests. Students identified as rote learners performed more poorly on these parts of the test than did students identified as meaningful learners. The results also showed that rote learners had lower mean scores on the 'rote' portions of both tests, though these differences were not significant at the $p<.05$ level.

The relationship between learning approach and self-confidence.

The relationship between learning approach and self-confidence is shown in an analysis of variance table (see Table 17).

Table 17.
Variance of self-confidence by learning approach.

Variable	Group	F-ratio	F-prob	Count	Mean	SD	SE
ctaconf	Rote	9.6909	.0024 *	59	12.9153	2.9612	.3855
	Meaningful	9.6909	.0024 *	53	14.6792	3.0304	.4163
ctbconf	Rote	12.7388	.0005 *	60	12.5000	3.3824	.4367
	Meaningful	12.7388	.0005 *	55	14.7455	3.3567	.4526
ctcconf	Rote	14.3773	.0002 *	60	12.1333	2.4039	.3103
	Meaningful	14.3773	.0002 *	57	14.1404	3.2757	.4339
ctdconf	Rote	3.6613	.0581	63	13.1746	5.8352	.7352
	Meaningful	3.6613	.0581	60	15.1833	5.8032	.7492

*$p<.05$

The results indicated that at the $p<.05$ level, learning approach was significant in predicting all confidence levels except the confidence level after the current electricity test. Rote learners had lower self-confidence than meaningful learners.

The results of a multiple regression in table 18 show the self-confidence levels after each unit test, controlling for the self-confidence level before the test and the learning approach.

Table 18.
Regression of self-confidence after writing the unit tests with learning approach and self-confidence before writing the unit tests.

Variable	DF	R^2	F	Predictor	Beta	Sig T
ctbconf	2	.42626	39.74788	learning approach	.178139	.0213*
				ctaconf	.580560	.0000*
ctdconf	2	.31901	26.70227	learning approach	-.107275	.1933
				ctcconf	.591446	.0000 *

* $p<.05$

Because of the time interval (1½-2 months) between the measurement of self-confidence after the electrostatics unit test and before the current electricity unit test, these units were treated separately. Thus there was no control for ctaconf and ctbconf on ctdconf. The results indicated that the regression model accounted for 43% and 32% of the variance in self-confidence. Both learning approach and self-confidence before the test were significant predictors at the $p<.05$ level, of self-confidence after writing the electrostatics unit test. For self-confidence after the current electricity test however, the beta weights became negative for learning approach which was no longer a significant predictor of self-confidence. Though not significant, rote learners had higher self-confidence after writing the current electricity unit test than did meaningful learners, even though their actual test performance was significantly lower. Self-confidence before writing the current electricity test was still a significant predictor of self-confidence after writing the test.

Learning approach and gender as predictors of students' self-confidence.

Results of multiple regressions with LAQ scores and gender as predictors of students' self-confidence before and after writing the unit tests are shown in Table 19.

Table 19.
Regression of self-confidence with gender and learning approach.

Variable	DF	R^2	F	Predictor	Beta	Sig T
ctaconf	2	.13276	8.34326	gender	-.228750	.0121*
				learning approach	.261530	.0043*
ctbconf	3	.44049	27.81694	gender	-.123830	.1036
				learning approach	.174499	.0230*
				ctaconf	.548495	.0000*
ctcconf	2	.14234	9.45958	gender	-.177293	.0440*
				learning approach	.318397	.0004*
ctdconf	3	.32117	17.82070	gender	-.047394	.5507
				learning approach	-.108145	.1911
				ctcconf	.582060	.0000*

*$p<.05$

Students' gender and learning approach both significantly predicted self-confidence before writing the electrostatics and the current electricity unit tests. Males had higher self-confidence than females, while rote learners had lower self-confidence than meaningful learners. When self-confidence before writing the unit test was factored into the regression model, gender was no longer significant. This regression model accounted for 44% and 32% of the variance in post-test self-confidence. Learning approach and self-confidence before writing the unit test were both significant predictors of self-confidence after writing the unit test on electrostatics. Rote learners still had lower self-confidence after writing the test. Students with high self-confidence going into the test also had high self-confidence afterward. Gender was not significant in predicting self-confidence after the unit test. The beta weights did indicate however, that males still had higher mean scores for self-confidence after writing the unit test. For the current electricity unit, only prior self-confidence predicted self-confidence after writing the test. Learning approach and gender were not significant in predicting post-test self-confidence.

The relationship between learning approach, gender, pretest self-confidence and achievement.

Results of multiple regressions with Learning Approach Questionnaire scores, gender, and self-confidence levels before writing the unit tests as predictors of students' achievement on those unit tests are shown in table 20.

Table 20.
Regression of test scores with gender, learning approach, and pretest self-confidence.

Variable	DF	R^2	F	Predictor	Beta	Sig T
elecscore	3	.24603	11.74731	gender	.078928	.3633
				learning approach	.109234	.2130
				ctaconf	.468345	.0000*
elec115	3	.13627	5.67984	gender	.138644	.1370
				learning approach	-.015339	.8698
				ctaconf	.383189	.0001*
elec1630	3	.24449	11.64988	gender	-.0006381	.9941
				learning approach	.191574	.0303*
				ctaconf	.404404	.0000*
curscore	3	.30285	16.21800	gender	.032694	.6854
				learning approach	.045738	.5877
				ctcconf	.538358	.0000*
cur114	3	.22480	10.82607	gender	.124768	.1443
				learning approach	-.072907	.4129
				ctcconf	.501912	.0000*
cur1528	3	.29323	15.48942	gender	-.57142	.4822
				learning approach	.143399	.0932
				ctcconf	.460342	.0000*

* $p<.05$

The results indicated that gender was not a significant factor in predicting either whole or half test scores. For each test though, the beta weights indicated that males were doing better than females on the 'meaningful' portions of the unit tests. Learning approach was significant only in predicting the meaningful portion of the electrostatics unit test. Though not significant, rote learners had higher mean scores than meaningful learners on the first half of both the electrostatics and current electricity unit tests. Meaningful learners had higher mean scores on the second halves. Self-confidence before writing the unit tests was highly significant at the $p<.05$ level, in predicting test scores in all cases. Thus, a person who had high self-confidence before writing the unit test had a better score on the test. These combined results indicate that it was not gender which contributed most to success on the unit tests, but rather some combination of learning approach and self-confidence. Since the values of R^2 are low, other factors like ability, may also factor into the regression to increase the predictive ability of this model.

These results are also depicted in correlation Table 21.

Table 21.
Correlation of unit test scores with gender, learning approach and self-confidence before writing the unit tests.

Variable	Gender	Learning Approach	Ctaconf	Ctcconf
Elecscore	-.052	.235*	.479*	-----
Elec115	.042	.080	.343*	-----
Elec1630	-.123	.307*	.459*	-----
Curscore	-.077	.229*	-----	.548*
Cur114	.034	.089	-----	.452*
Cur1528	-.161*	.308*	-----	.521*

*$p<.05$

The correlation table showed that gender was significantly correlated with achievement for the second half of the current electricity test with males doing better than females. Perhaps females were more unfamiliar with these concepts than males, and found it more difficult to attain understandings beyond a rote level. This correlation though was quite low. Combined with the regression analysis (see Table 20) it was likely that there were few gender differences in achievement. It was interesting to note that the trends for the whole score on the unit tests in the regression model were reversed in the correlation table, with males doing better than females. However, neither the correlations or the regressions were significant in this case. As well, the correlations and beta weights were quite small for these measures. The correlation table also showed high correlations which were all significant at the $p<.05$ level, for the relationship between self-confidence before writing the test and the test score. These positive correlations indicated that a high level of self-confidence before writing the unit tests corresponded to a high test score. Though the correlation table showed that rote learners performed more poorly on the first halves of the tests than did meaningful learners, the regression analysis showed the opposite trend. As in the regression model, the correlation table indicated that a meaningful learning orientation was correlated with higher test scores. Though significances varied from the regression model to the correlations, all values indicated that on the whole and second half test scores rote learners performed more poorly than meaningful learners.

The relationship between learning approach, gender, achievement and posttest self-confidence.

Results of multiple regressions with LAQ scores, gender and whole and half unit test scores as predictors of students' self-confidence after writing the unit tests, are shown in table 22.

Table 22.
Regression of posttest self-confidence with gender, learning approach, pretest self-confidence and whole and half test scores.

Variable	DF	R^2	F	Predictor	Beta	Sig T
ctbconf	4	.46707	23.00643	gender	-.140632	.0612
				learning approach	.151848	.0450*
				ctaconf	.457943	.0000*
				elecscore	.189293	.0241*
ctbconf	4	.47291	23.55219	gender	-.154233	.0409*
				learning approach	.174471	.0199*
				ctaconf	.469630	.0000*
				elec115	.195681	.0125*
ctbconf	4	.44794	21.29897	gender	-.123898	.1028
				learning approach	.155232	.0470*
				ctaconf	.508339	.0000*
				elec1630	.099306	.2366
ctdconf	4	.32094	13.11559	gender	-.048085	.5483
				learning approach	-.109163	.1938
				ctcconf	.603816	.0000*
				curscore	-.039033	.6777
ctdconf	4	.32646	13.44996	gender	-.037873	.6378
				learning approach	-.117662	.1606
				ctcconf	.629020	.0000*
				cur114	-.092084	.3002
ctdconf	4	.32035	13.08010	gender	-.047885	.5507
				learning approach	-.114653	.1775
				ctcconf	.570908	.0000*
				cur1528	.025838	.7818

* $p<.05$

These regressions were performed to determine whether self-confidence levels after writing the unit tests might change due to students' perceived performance on the tests. The regression model accounted for approximately 46% and 32% of the variance observed in post-test self-confidence. When combined with the first half electrostatics test score in the regression model, gender was significant for predicting self-confidence, with males having higher self-confidence than females. For all other cases, gender was not a significant predictor of self-confidence after writing the unit tests. Learning approach was found to be a significant predictor of self-confidence for the electrostatics unit, but not for the current electricity unit. For the whole and half electrostatics test scores, positive beta weights indicated that meaningful learners had higher self-confidence after writing the unit test than rote learners. The most significant factor in predicting self-confidence after both unit tests however, was the self-confidence level before writing the tests. Thus, if a student had a high level of self-confidence before writing either unit test, they also had a high level of self-confidence afterward, regardless of their actual achievement on the tests. For the whole and first half electrostatics test scores, achievement was significant with higher test scores corresponding to higher self-confidence. For the current electricity unit, neither learning approach nor achievement were significant in predicting post-test self-confidence. Table 23 is a correlation table depicting these results.

Table 23.
Correlation of self-confidence after writing the electrostatics unit test with gender, learning approach, and achievement

Variable	Gender	Ctaconf	Learning Approach	Elecscore	Elec115	Elec1630
ctbconf	-.288*	.630*	.339*	.457*	.375*	.395*

* $p<.05$

Table 24
Correlation of self-confidence after writing the current electricity unit test with gender, learning approach and achievement

Variable	Gender	Ctcconf	Learning Approach	Curscore	Cur114	Cur1528
ctdconf	-.152	.554*	.095	.270*	.181*	.296*

*p<.05

Unlike the regression table (see Table 22), the correlation table for the electrostatics unit indicated that males had higher self-confidence after writing the unit test, and that this difference was significant. The same trend was revealed in the regression analysis, but there it was only significant when combined with the first half electrostatics test score. Again, self-confidence before writing both unit tests was highly and significantly correlated with self-confidence after writing these tests. Learning approach was significantly correlated with self-confidence after writing the electrostatics test, but not for the current electricity test. Test scores for both units were significantly correlated with self-confidence, but the correlations for the current electricity unit were low.

Summary

Results of this study have shown that gender was not significantly related to achievement or to learning orientation in physics. However, females were found initially, to be less self-confident in physics than males. Results also indicated that learning orientation was significant in predicting pretest self-confidence, which in turn was significant in predicting achievement in physics. The highest achievement in physics occurred when students were meaningful learners with high self-confidence, while the lowest achievement was a result of a rote learning approach and low self-confidence. These self-confidence ratings remained stable after the testing process.

Chapter Five

Discussion

This study explored possible relationships between gender, learning approach, self-confidence and achievement for physics students. The first three research questions centered on identifying whether there was a relationship between these variables, or whether one variable uniquely explained all observed differences in the other variables. Simple correlations showed that both learning approach and self-confidence before the unit tests were correlated with test scores. Similarly, achievement was significantly correlated with self-confidence after writing the unit tests. From these correlations, it was reasonable to assume the existence of a relationship between these variables as hypothesized. The remainder of the research questions focused on the nature of this relationship with respect to gender differences.

The fourth research question focused on whether there were any gender differences in learning approach for this sample of physics students. Ridley and Novak (1983) indicated that females learned science information by rote more than did males. Similarly, Novak and Musonda (1991) did a twelve year long longitudinal study of students' understanding of science concepts. Using concept mapping as a measure of conceptual understanding, they found that females tended to have a less connected understanding of science concepts. While it was hypothesized that females were more likely to learn by rote than males, this hypothesis was not supported in this study. A chi-square analysis revealed that males were just as likely as females to be rote learners. In a study of 140 high school biology students, Cavallo (1994) found that teachers rated females as being more rote learners than males. When students rated themselves however, there were no significant differences between males' and females' learning orientations. Other classroom-based self-report studies also report few gender differences in learning orientation. Anderman and Young (1994) studied a group of sixth and seventh graders' reported use of meaningful learning strategies in science. They found no gender differences in this area. Meece and Jones (1996) studied 213 fifth and sixth grade students to find no gender differences in students' self reports of learning strategies. While it is possible that differences develop in later grades, this idea is not supported by the results of this study. These results are important in highlighting differential findings depending on the type of measurement taken. It may also be indicative of gender bias in the classroom. Shepardson and Pizzini (1992) found gender bias among teachers who rated males as more 'cognitively intellectual' than females.

To determine whether the teachers' or students' evaluation of learning approach was more accurate, the fifth hypothesis centered on whether there were any gender differences in achievement. Because the unit tests designed to measure achievement were split into 'rote' and 'meaningful' halves, student learning approach was also reflected in these scores. The results of an analysis of variance indicated that there were no gender differences on either whole or half test scores. While this may not indicate statistical significance, it is interesting for educational purposes to note that the means show males doing better than females on all except the first halves of both the electrostatics and current electricity tests. The first halves were designed to measure rote knowledge of these topics. It is possible that in their study, females pay more attention to rote items in their desire to please their teachers.

Ridley and Novak (1983) maintain that rote learning for girls is a result of socialization. They argue that girls are socialized to be passive and conforming while boys are socialized to be risk takers. Sadker, Sadker and Klein (1991) state that teachers allow boys to interrupt class by calling out, while girls have to be polite and wait their turn. Holden (1993) indicated that "boys talked twice as much or almost twice as much as the girls, and that the types of questions addressed to the boys were typically of a more open and challenging nature than were those addressed to the girls, which were more often rhetorical or requiring only a yes/no answer" (p. 180). Haggerty (1987) studied students in a Canadian ninth grade science class. She found that when girls asked questions they were more concerned about the right answer than were boys. Also, girls came to class well prepared with notebooks neatly organized. Boys however, were unwilling to memorize science facts which were meaningless to them: "Girls appeared to be more concerned with meeting the teacher's expectations with respect to providing correct answers and completing assigned tasks" (Haggerty, 1987, p. 278). For these reasons it was hypothesized that females would do better on the rote portions of the test, and more poorly on the meaningful portions. In this study, any differences found were not significant.

The sixth hypothesis looked at whether there were any differences in achievement between rote and meaningful learners. It was hypothesized that meaningful learners would have higher test scores, particularly on the meaningful portions of the test. An analysis of variance showed that for whole and 'meaningful' test scores, this hypothesis was supported.

Meaningful learners performed significantly better than rote learners on both unit tests. These results were promising because they indicated that it was learning orientation and not gender which influenced achievement. Novak and Gowin (1984) highlight the importance of this finding with their belief that students can learn to 'learn meaningfully'. Gender on the other hand, is constant. Cavallo and Schafer (1994) also found that meaningful learners had a greater understanding of biology concepts: "The more meaningful the students' learning orientation, the more meaningful the understandings they tended to attain. Thus, science learning may not be restricted by a students' particular aptitude, and may be more a factor of how they learn" (p. 415). If all students can learn to 'learn meaningfully' in order to improve their achievement, than thinking skills are something which should be considered in school curricula. Entwistle and Ramsden (1983) state that meaningful learners respond to 'novel problems' by connecting and expanding ideas, while rote learners state definitions and cannot elaborate concepts. Rote learners are not strategic - they fail to utilize task appropriate strategies. However, students can be taught to learn strategically through specific learning strategies like keyword mnemonic, mental imagery, concept mapping, analogies, elaborative interrogation and self-instruction. In fact, meaningful learners have a variety of strategies at their disposal. They also know how to regulate the appropriate use of these strategies. Our role as educators is to focus not only on teaching students *what* to learn, but also to "focus on techniques and strategies students can use to accomplish learning" (Weinstein & Mayer, 1986, p. 315). Palincsar and Brown (1987) also indicate the necessity of helping students to identify and use strategies which will promote and monitor learning. "Helping students to develop effective ways to handle the barrage of information coming from the environment, as well as their own thinking processes, is a major goal of our educational system that will only increase in importance in the future" (Weinstein & Mayer, 1986, p. 315).

The utilization of learning strategies which promote more meaningful learning may even improve the desire to learn. Novak (1988) found that students expressed positive feelings when engaged in meaningful learning: "When skilled performance is accompanied by understanding the meaning of the event, we observe the greatest expression of positive feelings (the 'Oh wow that's neat!')" (p. 95). The present study was also concerned with how students' self-confidence might factor into learning physics. Thus, the seventh hypothesis focused on whether there were any gender differences in self-confidence before and after writing the unit tests. It was hypothesized that in both cases females would have lower levels of self-confidence than males. Analyses of variance indicated that before writing the unit tests, males were significantly more confident than females. Furthermore, these trends held true after writing the unit tests, even though there were no significant gender differences in achievement. After writing the unit test for current electricity, males were still more confident, but the difference was not significant. These trends in self-confidence are supported by other studies (Anderman & Young, 1994; Simpson & Oliver, 1990). Dweck (1986) states that "knowledge of past successes does not appear to arm them (girls) for confrontations with future challenges" (p. 1043). Campbell (1991) studied Asian-American and Anglo-American boys and girls who were Westinghouse talent search winners. He found that Anglo-American girls scored significantly lower than other groups on a combination of variables referred to as 'technical orientation'. Science self-concept was included in this measure. Campbell stated that this difference could be due to the socialization of these girls. Since self-confidence was found to be correlated with achievement, it is important that girls develop a belief in their own ability to succeed.

The eighth hypothesis extended the measurement of differences in self-confidence to learning approach. It was hypothesized that students identified as rote learners would have less self-confidence than those identified as meaningful learners. Analyses of variance indicated that learning approach was significant in predicting all measured self-confidence levels, with the exception of the measurement taken after the current electricity test. For the current electricity test rote learners were still less confident than meaningful learners, but the difference was not significant at the $p<.05$ level ($p=.0581$). Rote learners did tend to have significantly lower self-confidence than meaningful learners in three out of four cases. This may be because rote learners experience increased frustration due to the limitations of their learning orientation for higher order questioning - if a question is not from the text or notes, they feel that they will not know how to analyse it. In a study of undergraduate and graduate students, Novak (1988) found that many students had spent 12-18 years in school learning by rote and doing well: "Although they typically report frustration in their studies and especially in their ability to recall later and to use knowledge previously learned, they did not know that their problems derived from an ineffective learning strategy" (p. 91). This finding supports Halloun's (1996) contention that students' physics ideas are "disconnected, incoherent and inconsistent" (p. 1019). He argues that physics students view problems only as tasks for selecting mathematical formulae. A consequence of this is that students suffer from feelings of low self-efficacy which persist even after instruction. Whether male or female, students adopting a predominantly rote learning approach in this study experienced lower self-confidence and achievement.

The purpose of this study was to determine the nature of the relationship between learning approach, self-confidence and achievement with regard to gender differences. A series of multiple regressions were performed to determine how these variables might interact with one another. For hypothesis nine, multiple regressions of learning approach and gender as predictors of self-confidence before and after writing the unit tests were performed. Regression analyses showed that both learning approach and gender were significant predictors of self-confidence before writing the electrostatics and current electricity unit tests. Males had higher self-confidence than females, and meaningful learners had higher self-confidence than rote learners. Learning approach and self-confidence before writing the test were significant predictors of self-confidence after writing the electrostatics unit test. For the current electricity unit however, only pretest self-confidence was significant. When pretest self-confidence was factored into the regression it became the most important predictor of self-confidence after the unit test. It appeared that both gender and learning approach were both important to establishing an initial level of self-confidence. This study supports the idea that once a certain level of self-confidence is attained, it remains stable. Rasenen (1992) states that "...problem connections...have an influence on how students are able to solve physics problems as well as on their self-confidence in solving the problems" (p. 86). Thus it is important to promote meaningful learning orientations in students in order to establish a high initial level of self-confidence.

Achievement must also be factored into the relationship between learning approach, gender and self-confidence. Hypotheses ten and eleven centered on the nature of this relationship with all variables taken into consideration. Hypothesis ten stated that students who are female, rote learners, and low in self-confidence will perform more poorly on the unit tests than students who are male, meaningful learners, and high in self-confidence. An interesting finding from these multiple regressions was that gender was not a significant predictor of achievement for either the unit test on electrostatics or on current electricity. Self-confidence before writing the unit tests was highly significant in predicting achievement. Learning approach however, was found to be significant only in predicting achievement on the 'meaningful' portion of the electrostatics unit test. For that part of the test, rote learners performed more poorly than meaningful learners. Correlations however, show that learning approach is significantly correlated with all but the first half of both unit tests. It appears that learning approach is most important in relation to test scores which reflect meaningful conceptual understandings. This may be because both rote and meaningful learners should be able to do well on the rote portions of the test. Trends identified in the multiple regressions and the correlations indicate that students who possess a meaningful learning orientation and who are confident in their ability, are more likely to achieve in the units tested. As could be expected from the analyses of variance, gender had no effect on test scores, even controlling for other variables. The results suggest that it is not masculinity or femininity which affect success in physics, but rather some combination of self-confidence and learning approach. Since it appears that learning approach is a factor contributing to self-confidence, then meaningful learning orientations should be fostered in students.

Why do some students develop a meaningful learning approach, while others adopt a rote learning style? Perhaps their choice is based on previous successes or failures in other courses. The home environment may also play a role in concept introduction as a predecessor of meaningful learning. Novak (1988) argues that in children concepts are formed through repeated encounters with different objects. Lack of exposure to a variety of concept ideas may leave a child unable to link and assimilate subsequent concepts at the school level. A definite answer to the proposed question is beyond the scope of present research, but should be addressed in future studies. What is clear from this study however, is that the answer is not gender.

Results of multiple regressions performed on self-confidence levels after writing the unit tests, indicate that gender was only significant in predicting self-confidence after the electrostatics unit test, when controlling for the first half electrostatics test score. Self-confidence before writing the unit test was the major predictor of self-confidence after writing the unit test. Interestingly, the test scores for the whole and first half electrostatics tests were also significant predictors of self-confidence after writing the test. It should be recalled though, that self-reports of confidence levels after writing the test were not based on actual test results, but on perceived test performance. Thus, a high or low score on either unit test will not necessarily affect self-confidence right after the test. It may be that a student can perceive a high performance and experience high self-confidence when in actual fact, the performance was poor. Conversely, a student can perceive a poor performance and have low self-confidence even when their performance was actually good. Bandura and Dweck (as cited in Dweck, 1986) found that children having low self-confidence had higher test scores than children having higher levels of self-confidence: "...being a high achiever..does not appear to translate directly into high confidence in one's abilities when faced with future challenges or current difficulties" (p. 1044). In fact, complex motivational patterns make the interpretation of test scores very complex.

Learning approach was significant in predicting self-confidence after writing the electrostatics test but not the current electricity test. Rote learners had lower self-confidence than meaningful learners both before and after writing the unit test in electrostatics. Though not significant, rote learners actually had higher levels of self-confidence than meaningful learners after writing the current electricity unit test, even though their performance on the test was poorer than that of meaningful learners. Perhaps these students perceived their test performance to be higher than it actually was. The correlations show a small positive but nonsignificant correlation between learning approach and self-confidence after writing the current electricity test. For both analyses, the results are not significant.

It appears that the self-confidence a student possesses before writing a test will predict the self-confidence possessed after writing the test. The results on learning approach are inconclusive. While learning approach alone does predict whole and meaningful test scores for both units, this predictive capability is lost in all but the second half score of the electrostatics unit, when gender and prior self-confidence are controlled for. Learning approach alone does predict self-confidence prior to both unit tests. It appears that learning approach contributes to self-confidence, which in turn contributes to achievement. Furthermore, self-confidence prior to writing the unit tests remains stable after writing the unit tests regardless of actual achievement. This may indicate that improving students' self-confidence will involve more than a good performance on one or two tests. Instead it will involve challenging students' ineffective learning orientations. Cavallo and Schafer (1994) found that a meaningful learning orientation in biology contributed to the attainment of meaningful conceptual understanding, independent of aptitude and achievement motivation.

To summarize the relationship between gender, learning approach, self-confidence and achievement, it is of primary importance to note the lack of gender differences. The only gender differences observed were in levels of self-confidence. There were no gender differences in learning approach or achievement. Clark (1991) indicates that data obtained in Newfoundland and Labrador do not seem to agree with national and international trends showing gender differences in achievement. He states that "in nearly all Newfoundland data, participation and achievement are essentially equal for males and females at the high school level" (p. 13). He adds that the gender differences in physics public examination scores (favouring boys by about 2%) are too small to be meaningful (one tenth of a standard deviation). However, Clark also states that even though females have the background to enter science, particularly physics, programs at Memorial University of Newfoundland there has not been an increase in female science majors. Furthermore, those females who do enter physics programs experience high attrition rates: "The total number of graduates in physical sciences at MUN in the years 1987, 1988 and 1989 was 117. Of these, 16% (19) were women" (Clark, 1991, p. 15). Clark's ideas are supported by the findings of this study, which extends his ideas to explore why capable women are not entering physics-related programs of study in post-secondary institutions.

This study points to the role of self-confidence in resolving this problem. Results have shown high correlations between self-confidence and achievement in physics. Furthermore, the level of self-confidence possessed before being tested in physics remains stable after being tested. Learning approach can also help determine what that initial level of self-confidence is. As educators, a primary concern should be to promote self-confidence in all students. One way to do this may be to teach all students how to learn meaningfully as suggested by Novak and Gowin (1984).

There has been considerable debate in the literature as to whether students can be taught to 'think critically'. Critical thinking can be likened to Ausubel's (1963) meaningful learning set in that critical thinkers not only have the ability to correctly assess statements, but also the tendency towards doing so (Ennis, 1989). The focus of this debate has been on domain specific versus generalizable thinking skills. Do students need to know specific learning skills for physics, or is there a set of skills useful to all subjects? McPeck (1981) believes that critical thinking skills are specific to different subject areas and "there is not-and cannot be-any single critical thinking skill that can be applied generally across subject-area domains" (Siegel, 1988, p. 18). In this respect, his view is in opposition to Ennis and Siegel and many other researchers in the field, who regard critical thinking as a generalized set of skills and abilities which can be applied across a variety of situations. At the same time however, Siegel does recognize that "logical knowledge...and subject-specific knowledge are both necessary; neither by itself is sufficient" (Siegel, 1988, p. 21). Niaz (1995) also concludes that the content-process dichotomy is misleading. He suggests that instead of being at separate ends of a continuum, the two could actually complement each other. It would be beneficial to students if they could apply techniques learned elsewhere to successfully solve physics problems, and conversely if they could use techniques learned in physics in other curriculum areas. This study has shown the benefits of promoting meaningful learning to all physics students.

Limitations of the Study

A problem with this study is in the use of self-report questionnaires to obtain measures of self-confidence and learning approach. Students may respond as they think they will be expected to respond, as opposed to how they truly feel. It is unknown whether the learning approaches and levels of self-confidence identified in this study are accurate measures. An attempt was made to match student ratings with teacher ratings, but the number of matches was low. Perhaps future research could endeavour to combine self-reports with some other form of assessment to form a more complete measure of learning approach and self-confidence.

Another variable that could not be controlled in this study was style of teaching for each classroom group. There were six different teachers teaching the Physics 3204 course. The qualifications, experience and teaching styles of these teachers were most likely different. Only one of the teachers was female which may have inspired a 'role model effect' for female students in that group. Some of the teachers had physics degrees while others were teaching the course because they were the most qualified person in their school. As well, some teachers may have been more dynamic and made the course more challenging than other teachers. These differences threaten the validity of the experiment. Teaching style and instructional strategies used by the different participating teachers however, cannot and should not be controlled for practical and ethical reasons. It was hoped that all teachers used a variety of instructional strategies requiring both rote and meaningful learning from their students.

The sample used may limit the generalizability of these results. Research was undertaken in five communities in rural Newfoundland, and may or may not apply to other more urban areas. Also, because the subjects come from already formed classroom groups, there is no guarantee that all groups are equivalent in terms of knowledge or ability. Originally, this was to be controlled for by obtaining prior marks in mathematics and physics. It turned out however, that the course taking patterns for the subjects were so different, that matching them on prior courses taken would substantially reduce subsample numbers. Also, no attempt was made to match students on ability.

There were also some problems with the testing instruments. Reliabilities for the split halves of the electrostatics test were quite low at 0.53 and 0.57. Because this unit was so descriptive with varied topic coverage, it is possible that different students concentrated on different areas in their study. It is also possible that the wording of the test items may have been ambiguous in some cases. Arguments have also been offered against multiple choice testing. Cavallo (1994) recommends utilizing testing instruments which measure students' understandings, including open-ended questions. She states that "knowledge and understanding may be revealed in students' explanations that may not be "tapped" by forced-choice questions" (Cavallo, 1994, p. 352). Further research in this area might necessitate a modification of this test, perhaps by doing a test-retest check of reliability before test administration. In this study the tests were checked for validity but the reliability check was performed after test administration. Test questions could also be structured to include more open-ended responses. The self-confidence test had a narrow range of possible test scores

(0-20). This narrow range makes it statistically more difficult to find significant results if they exist. However, the significant results obtained in the self-confidence area should be even more credible because of this problem. It is also important to reiterate that although the sample size was 131, the data analyses were mostly conducted on smaller numbers of students because of missing data and absenteeism. However, a lower sample size also makes it harder to find significant results, again making the results here more believable. This self-confidence test though, was administered at four different points in the study. It is possible that at the last administration, students may have become test-wise and simply answered according to memory rather than true feelings. Perhaps further research could rectify some of the problems in this study to provide further insights in this area.

Regardless of these difficulties, a relationship was found between learning approach, self-confidence and achievement. Interpretation of self-confidence however may be dependant upon factors other than those considered in this study. If for example students have a history of doing well on a certain type of test, they may discount the results of an anomalous test score because they feel they studied more or less or were lucky. In this case, self-confidence would be unlikely to change. It is impossible to tell from the results presented here what would happen if a test or a series of tests of more or less difficulty were administered. A more accurate interpretation of self-confidence might necessitate a more longitudinal type of study. It was clear however, that the relationship between self-confidence, learning approach, and achievement did not depend on gender. This fact alone has serious educational implications.

Educational Implications

The results of this study have varied educational implications for teachers, students and for science education as a whole. One of the main thrusts of the science education reform movement is the idea of 'constructivism'. Driver, Asoko, Leach, Mortimer and Scott (1994) state that central to a constructivist view is the idea that "knowledge is not transmitted directly from one knower to another, but is actively built upon by the learner" (p. 5). Meece and Jones (1996) argue that with a constructivist approach to teaching and learning, classrooms and learning activities will be less structured in the traditional sense. If students are expected to become active members of the learning process, traditionally rote learning activities (i.e. memorizing, lectures, etc.) will no longer be appropriate. Moreover, if rote learners have less self-confidence, they may have difficulty participating in 'meaningful' activities. Educators have a responsibility to become aware of how best to help their students learn. The results of this study indicate that one way to do this may be to promote students' self-confidence.

Self-confidence appears to be important to achievement in physics. Furthermore, the level of self-confidence possessed by students appears to be stable regardless of achievement on a particular test. To promote self-confidence, teachers and students need to avoid gender bias. If girls are given equal treatment in science classrooms they may feel more capable. "Social change in schools must focus on what is taught to students through example and through the formal curriculum" (Gaskell, et. al., 1989, p. 26). These changes must be more than just 'philosophical statements' if true gender equity is to be achieved (Larkin, 1994). At one level it is the responsibility of the school boards to deal with stereotyped materials (Gaskell, et. al., 1989). Textbooks should be more gender equitable in terms of illustrations, references to women's experiences and career choices (Sadker, et. al., 1991). At a second level more tangible to students, it is the responsibility of teachers to reduce stereotyping in the implemented curriculum.

This can be done by changing teacher actions and beliefs: "The changes required are difficult, for they are not only in terms of procedures, planning, and organization, but require changes in attitudes which lie deep in each person's own character and background" (Serbin, 1983, p. 213). A first step to change may be in implementing teacher training. Many times teachers are not even aware that they are perpetuating gender biases (Gaskell, et.al., 1989; Kelly, 1988). Some would argue that in democratic classrooms it is societal values which should be respected whether they include restrictions on women or not. Kelly (1988) however, indicates the need for teacher awareness which can be fostered through workshops and training sessions. Allen, Cantor, Foster, Grady and Hill (1994) discuss some teaching strategies enabling girls to be more active in the classroom. Acker (1990) points to the need for distribution of literature to increase teachers' awareness of the problem. Such awareness can be displayed through teacher language and actions in the classroom. Teachers need to adopt a more gender inclusive terminology. Weinburgh (1995) recommends using 'you' rather than 'the boy' or 'the girl' in giving examples and questioning. Language biases may in fact be reproductions of teachers' university training (Sadker, et.al., 1991). Perhaps teachers should be required at the university level to take some courses on gender issues.

Gaskell, et. al. (1989) suggest that producing equal learning may mean treating boys and girls differently. Girls for example, have been shown to benefit from cooperative learning, as opposed to competitive situations. These strategies will only be effective in enhancing self-confidence if teachers and students have a personal commitment to change. This committment will come from awareness of the problem and the benefits of addressing it.

A further implication of increasing students' self-confidence is to help them adopt a more meaningful learning approach. The results of this study indicate that more meaningful learners have higher levels of self-confidence and higher achievement. Thus it is important that we teach students how to 'meaningfully' understand information. Ausubel (1963) advocates that part of learning meaningfully is a desire to do so. Novak (1988) believes that rote and meaningful learning styles represent a continuum rather than a dichotomy: "The real issue in school learning is not whether new information will be learned meaningfully or by absolute rote; the problem centers on the extent of meaningfulness in new learning" (p. 80). He also believes that whether new information is learned by rote or meaningfully depends on the learner's conscious effort to make 'linkages': "...rote learning occurs when no conscious effort is made to associate new knowledge with a framework of concepts or knowledge elements already in the cognitive structure" (Novak, 1988, p. 81). This means that in order to promote meaningful learning, students must be encouraged and helped to make those linkages. This highlights the need for educators to present information in an interesting and creative manner which taps into prior knowledge structures. Another aspect of meaningful learning is teaching students how to think. Halloun (1996) believes that students can meaningfully learn science content if it is presented in the form of models: "...the pedagogic expectation is that by learning how to structure the content of physics theory around models, and how to solve problems by modelling, students will reach a meaningful understanding of physics..." (Halloun, 1996, p. 1020). Teachers can also promote meaningful learning by being cognizant of the types of questions asked of students in classroom discussions and in evaluation: "...emphasizing memorization of textbook definitions and facts is an outdated, ineffective teaching practice, and is contrary to the very nature of science" (Cavallo, 1994, p. 352). If students are only tested on recall of factual information, they will quickly learn that the easiest way to pass a test is to memorize. This kind of testing will promote rote learning.

Many students in physics classes may learn physics as a set of isolated facts to be memorized for a test and then forgotten. "Rote learning could make subsequent learning of science increasingly difficult and may deter many from continuing to take science courses or pursuing scientific careers" (Cavallo, 1996, p. 646). Combined with its relationship to self-confidence and subsequent achievement in physics, educators should take great care to help all their students learn more meaningfully. "Male and female students alike should be challenged to think at high levels, to solve problems, and to create new solutions and ideas in science" (Cavallo, 1994, p. 352). Further research in this area may provide teachers with more knowledge to help their students gain more meaningful understandings of physics, so that they may more confidently pursue physics-related careers.

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Appendix A
Learning Approach Questionnaire

Learning Approach Questionnaire

The following questions refer to how you study and learn about physics in this class. For each item there is a five point scale ranging from "Always True" to "Never True". On the answer sheet provided, fill in the letter that best fits your IMMEDIATE reaction. Do not spend a long time on each item; your first reaction is probably the best one.

Do not worry about projecting a good image. There are no "correct" answers. Your answers are confidential.

Answer every question - please do not leave any blank.

		Always True				Never True
1.	I try to relate new material, as I am learning it, to what I already know on that topic.	A	B	C	D	E
2.	I prefer to follow all "tried out" ways to solve problems rather than trying anything too adventurous.	A	B	C	D	E
3.	While I am studying, I often think of real life situations to which the material I am learning would be useful.	A	B	C	D	E
4.	I find I tend to remember things best if I concentrate on the order in which the teacher presented them.	A	B	C	D	E
5.	I find I have to concentrate on memorizing a good deal of what I have to learn.	A	B	C	D	E
6.	I go over important topics until I understand them completely.	A	B	C	D	E

7.	I find it best to accept the statements and ideas of my lectures and question them only under special circumstances.	A	B	C	D	E
8.	I prefer courses to be taught in a way that is clearly structured and highly organized.	A	B	C	D	E
9.	In reporting laboratory work, I like to try to work out several different ways of interpreting the findings.	A	B	C	D	E
10.	I often find myself questioning things that I hear in lectures or read in books.	A	B	C	D	E
11.	In trying to understand new topics, I explain them to myself in ways that other people don't seem to understand.	A	B	C	D	E
12.	I find it useful to get an overview of a new topic for myself, by seeing how the ideas fit together.	A	B	C	D	E
13.	I set out to understand thoroughly the meaning of what I am asked to read or learn in class.	A	B	C	D	E
14.	I try to relate what I have learned in one subject to that in another.	A	B	C	D	E
15.	The best way for me to understand what technical terms mean is to remember the text-book definition.	A	B	C	D	E

16.	I am very aware that teachers know a lot more than I do, and so I concentrate on what they say as important rather than rely on my own judgement.	A	B	C	D	E
17.	I learn most things by rote, going over and over them until I know them by heart.	A	B	C	D	E
18.	When I'm starting a new topic, I ask myself questions about it which the new information should answer.	A	B	C	D	E
19.	Although I generally remember facts and details, I find it difficult to fit them together into an overall picture.	A	B	C	D	E
20.	When I am reading an article or listening to other's ideas in class, I generally examine the evidence carefully to decide whether the conclusion is justified.	A	B	C	D	E

Appendix B
Approach to Physics Questionnaire

Approach to Physics Questionnaire

This questionnaire is intended to provide an overview of your views about studying physics. For each item there is a five point scale ranging from "Strongly Disagree" to "Strongly Agree". On the answer sheet provided, fill in the letter that best fits your personal view or approach to this physics class.

Do not worry about projecting a good image. There are no "correct" answers. Your answers are confidential.

Answer every question - please do not leave any blank.

		Strongly Disagree				Strongly Agree
1.	One of my primary goals in this class is to understand the science activities we do.	A	B	C	D	E
2.	I am confident I can do well on the science problems we are given in this class.	A	B	C	D	E
3.	One of my primary goals in this class is to do better than other students.	A	B	C	D	E
4.	I possess the skill needed to solve problems like the ones we are given in this class.	A	B	C	D	E
5.	One of my primary goals in this class is to not look foolish or stupid when doing the science activities.	A	B	C	D	E
6.	One of my primary goals in this class is to look smarter than other people.	A	B	C	D	E
7.	One of my primary goals in this class is to understand the material we study.	A	B	C	D	E
8.	If I were to try another science activity in this class I'm sure I would have trouble.	A	B	C	D	E
9.	One of my primary goals in this class is to improve my knowledge.	A	B	C	D	E
10.	One of my primary goals in this class is to not be the only one who cannot do the work.	A	B	C	D	E

11.	**One of my primary goals in this class is to understand what is happening during the science activity.**	**A**	**B**	**C**	**D**	**E**
12.	**Compared with other students in my class I'm not very good at these science activities.**	**A**	**B**	**C**	**D**	**E**

Perceived Ability Items: 2,4,8,12
Learning Goal Items: 1,7,9,11
Performance Goal Items: 3,5,6,10
***Note: r=0.86 for perceived ability subscale**

Appendix C
Electrostatics Unit Test

Physics 3204
Test Unit III

Circle the appropriate response on the answer sheet provided.

1. Two objects each having a charge of -2.0×10^{-5} C experience an electric force of 5.0×10^{3} N. What must their separation distance be?

   (a) 2.7×10^{-2} m
   (b) 7.2×10^{-4} m
   (c) 1.4×10^{-7} m
   (d) 5.6×10^{26} m

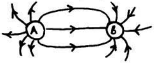
2. Object A and object B are rubbed together. If A gains electrons and B loses electrons, then;

   (a) A is +, B is -
   (b) A is -, B is +
   (c) both A and B are neutral
   (d) A is +, B is neutral

3. An object having a charge of 6.0 C has a(n) _______ of _____ electrons.

   (a) excess, 3.75×10^{19}
   (b) excess, 9.6×10^{-19}
   (c) deficiency, 3.75×10^{19}
   (d) deficiency, 9.6×10^{-19}

4. The charge on the following objects must be;



   (a) A +, B -
   (b) A +, B +
   (c) A -, B +
   (d) A -, B -

5. The electric field strength around a test charge of 2.0×10^{-6} C is 4.0×10^{3} N/C. What force must that test charge experience?

(a) 8.0×10^{-3} N
(b) 5.0×10^{-10} N
(c) 2.0×10^{9} N
(d) 3.2×10^{1} N

6. An electroscope is positively charged. If a positively charged object is brought near the electroscope;

(a) the leaves will collapse
(b) the leaves will repel further
(c) the leaves will stay the same
(d) one leaf will collapse

7. What amount of energy does a toaster use if it has 400 C of charge passing through it with a potential difference of 120 V?

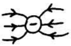
(a) 3.3 J
(b) 48000 J
(c) 0.3 J
(d) 280 J

8. Which diagram illustrates an equipotential line for a single negatively charged object?

(a)

(b)

(c)

(d)


9. What will happen to a grounded object when charging it by induction with a negatively charged bar?

(a) gain electrons from the bar
(b) gain electrons from the ground
(c) lose electrons to the bar
(d) lose electrons to the ground

10. How many excess electrons would a comb having a charge of -6.0×10^{3} C possess?

(a) 9.6×10^{-19}
(b) 2.7×10^{-23}
(c) 9.6×10^{3}
(d) 3.8×10^{22}

11. What is the electric field strength 25 cm away from a Van der Graff generator possessing a charge of 2.0×10^{4} C?

(a) 2.88×10^{15} N/C
(b) 2.88×10^{11} N/C
(c) 3.20×10^{5} N/C
(d) 7.20×10^{14} N/C

12. Why does a positively charged pith ball attract a neutral pith ball?

(a) exchange of charge from the neutral to the positive object.
(b) exchange of charge from the positive to the neutral object.
(c) redistribution of charge on the neutral object.
(d) redistribution of charge on the positive object.

13. If you wished to concentrate charge on part of an object, what shape should that part have?

(a) spherical
(b) pointed
(c) flat
(d) parabolic

14. Which subatomic particle carries no charge?

(a) electron
(b) ion
(c) neutron
(d) proton

15. What term is used to describe the region of interaction between two objects that are not touching?

(a) field
(b) high pressure area
(c) proof plane
(d) space

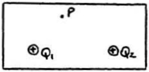
16. The electric force between two charged objects is 100 N. How far apart must you move the objects so that this force is 25 N?

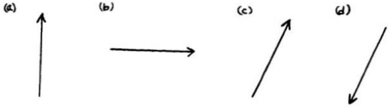
(a) twice as far
(b) half as far
(c) four times as far
(d) one fourth as far

17. A pith ball is attracted to a negatively charged rod. The charge on the pith ball must be;

(a) positive or negative
(b) negative or neutral
(c) positive or neutral
(d) neutral only

18. The diagram shows two positive charges with Q_1 two times greater in magnitude than Q_2. If positively charged point P is the same distance from Q_1 and Q_2 which vector is the direction of the electric field at P?





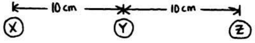
19. A comb that has been charged by rubbing it with cat's fur will have;

(a) an equal number of protons and electrons
(b) an excess of electrons
(c) a deficiency of electrons
(d) a net positive charge

20. Where is the best place to be in a lightning storm?

(a) on top of the CN tower
(b) under a tree
(c) in a car
(d) hugging a lightning rod

21. The diagram represents charged spheres X, Y and Z which are evenly spaced as shown. Spheres X and Y have identical charges. Sphere Z has a charge equal in magnitude but opposite in sign. If the electric force of X on Y is 4.0 N, what is the magnitude of the net electric force exerted on sphere Y?



(a) 0 N
(b) 2.0 N
(c) 4.0 N
(d) 8.0 N

Questions 22-26 refer to the following information:

Five small identical metal balls are hung from insulating silk threads and are handled only by the threads. They are not allowed to touch each other. It has previously been found that none of the balls is affected by a magnet, and it has been calculated that the gravitational force is negligible. Two of the balls at a time are brought near each other and the following observations are recorded.

1. Metal balls II and V exert no force on one another.
2. Metal balls I and III repel one another.
3. All other pairs of metal balls attract one another.

22. The above observations show that;

(a) I and III are not electrically charged.
(b) I and III carry electric charges of the same sign.
(c) I and III carry electric charges of opposite sign.
(d) II, IV, and V all carry charges of sign opposite to the charge on I.
(e) II, IV, and V all carry charges of the same sign as that on I.

23. All of the observations are consistent with the assumption that;

(a) None of the five balls carries an electric charge.
(b) II and V carry electric charges of opposite sign.
(c) II carries no electric charge.
(d) II is the only one of the balls that carries an electric charge.
(e) I is the only one of the balls that carries an electric charge.

24. On the basis of all the observations, it is certain that;

(a) V repels I, II, III and IV.
(b) V exerts no force on any of the balls.
(c) V attracts I, II, III and IV.
(d) V attracts I, III, and IV but exerts no force on II.
(e) None of the above statements are true.

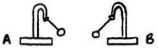
25. On the basis of all the observations the most complete conclusion concerning the metal ball IV is that it;

(a) carries electric charges of the same sign as the charge on I.
(b) is neutral.
(c) carries electric charges of the opposite sign to the charge on I.
(d) is either neutral or carries electric charges of the opposite sign to the charge on I.
(e) is either neutral or carries electric charges of the same sign as the charge on I.

26. On the basis of observation I above, which is true for all observed separations of the balls, any net charge carried by V must be;

(a) positive
(b) negative
(c) zero
(d) of opposite sign to any net charge on II.
(e) of the same sign as that of any net charge on II.

27. Two charged pith balls A and B are brought near one another and found to attract strongly. When a negatively charged rod is brought near ball B, the ball is repelled. What conclusion can be made about the charge on ball A?



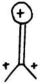
(a) it can be positive or neutral
(b) it is negatively charged
(c) it is positively charged
(d) it is unchanged

28. If there is no net force on Y because X and Z attract Y equally, how do the charges on the objects compare?

(a) Y is less than the charge on either X or Z.
(b) Y is greater than the charge on either X or Z.
(c) X is 4 times greater than the charge on Z.
(d) X is 16 times greater than the charge on Z.

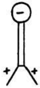
29. A negatively charged rod is held near the knob of an uncharged electroscope. Which diagram best represents the distribution of charge on the electroscope?

(a)

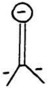


(b)

(c)



(d)



30. Why does an electrically charged comb attract small pieces of torn paper lying on a wooden desk?

(a) the comb induces a charge separation in the paper.
(b) the pieces of paper become charged
(c) the polar molecules of the paper cause a redistribution of the charge cn the comb.
(d) tearing the paper results in charge separation.

Appendix D
Current Electricity Unit Test

Physics 3204
Test - Unit IV

Circle the appropriate response on the answer sheet provided.

1. An electric heater operating on a 100 V supply has a resistance of 20 ohms. What is the current in the heater?

    (a) 0.20 A
    (b) 5.0 A
    (c) 8.0×10^{1} A
    (d) 1.2×10^{2} A

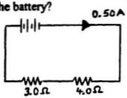
2. What is electric current?

    (a) The amount of charge that moves in a certain time past a point.
    (b) The energy used to move a charge past a certain point.
    (c) The force that moves a charge past a point.
    (d) The resistance to the movement of charge passing.

3. Which of these devices uses light emitting diodes in its operation?

    (a) AC generator
    (b) Battery
    (c) Light bulb
    (d) Smoke detector

4. This circuit contains two resistors connected to a battery. The current leaving the battery is 0.50 A. What is the voltage of the battery?

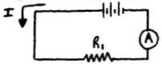


    (a) 1.5 V
    (b) 3.0 V
    (c) 3.5 V
    (d) 6.0 V

5. In what part of an electric circuit would a voltage <u>rise</u> occur?

   (a) Battery
   (b) Closed switch
   (c) Light bulb
   (d) Resistor

6. The following schematic diagram represents,



   (a) A parallel circuit
   (b) Electron Current
   (c) A short circuit
   (d) Conventional current

7. Which unit is equivalent to a Watt?

   (a) 1 C/s
   (b) 1 J/A
   (c) 1 J/C
   (d) 1 J/s

8. An electric toaster is rated 1500 W at 120 V. What is the resistance of the toaster?

   (a) 9.6 Ω
   (b) 13 Ω
   (c) 19 Ω
   (d) 1500 Ω

9. A material whose resistance drops to 0 at extremely low temperatures is called a,

   (a) semiconductor
   (b) superconductor
   (c) resistor
   (d) diode

10. What is the emf of a battery which produces a charge of 3.0 C and energy of 24.0 J?

(a) 0.8 V
(b) 3.0 V
(c) 8.0 V
(d) 72 V

11. A current of 0.7 A flows in a circuit for 7 s. During that time what is the charge transferred through the circuit?

(a) 0.1 C
(b) 0.5 C
(c) 1.0 C
(d) 5.0 C

12. A 12 ohm and a 6 ohm resistor are connected in series. What is the total resistance of the system?

(a) 2 ohms
(b) 4 ohms
(c) 6 ohms
(d) 18 ohms

13. When applying Ohm's law, how does the current vary?

(a) directly with voltage, and directly with resistance
(b) directly with voltage and inversely with resistance
(c) inversely with voltage and directly with resistance
(d) inversely with voltage and inversely with resistance

14. If 150 J of energy is expended to move a 60 C charge from point A to point B in a circuit, what will be the potential difference between A and B?

(a) 0.40 V
(b) 2.5 V
(c) 90 V
(d) 210 V

15. A total resistance of 3.0 ohms is to be produced by connecting an unknown resistance to a 12 ohm resistor. What must be the value of the unknown resistance and how should it be connected?

(a) 3.0Ω in parallel
(b) 3.0Ω in series
(c) 4.0Ω in parallel
(d) 4.0Ω in series

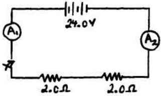
16. The resistance in an electrical circuit is tripled. In order to keep the current the same, how must the voltage applied to the circuit be altered?

(a) kept the same
(b) made one third as large
(c) made three times as large
(d) made nine times as large

17. What advantage is gained by connecting house lights in parallel instead of in series?

(a) Fewer amperes of current need to flow through each light.
(b) The current that flows through one light flows through all of the lights.
(c) The resistance in each filament is increased.
(d) The voltage across a given lamp is not affected by the other lamps.

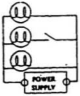
18. Using the circuit diagram, what is the reading on ammeter A_2?



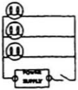
(a) 0 A
(b) 4.0 A
(c) 6.0 A
(d) 24.0 A

19. **A DC power supply is to be used for this circuit. Three bulbs are to be connected in parallel. This entire combination is to be connected in series with a switch. Which schematic represents the correct circuit?**

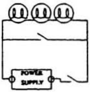
(a)



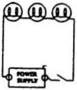
(b)



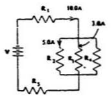
(c)



(d)



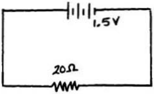
20. **What is the current in R_5?**



Current in R_1 = 10.0 A
Current in R_2 = 5.0 A
Current in R_3 = 3.0 A

(a) 2.0 A
(b) 5.0 A
(c) 8.0 A
(d) 10.0 A

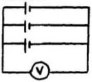
21. The circuit shown contains a dry cell and an ohmic conductor.



Which statement regarding the circuit is correct?

(a) The addition of a similiar resistor in series leaves the power dissipated by the resistor unchanged.
(b) The current flowing in the circuit is constant regardless of the voltage applied.
(c) The power dissipated by the resistor is constant regardless of the voltage applied.
(d) The resistance of the resistor remains unchanged if the voltage of the battery is doubled.

22. Assume that the potential difference across a single dry cell is 1.5 V. What is the reading on the voltmeter V in the circuit shown?



(a) 0.5 V
(b) 1.5 V
(c) 3.0 V
(d) 4.5 V

23. Using Ohm's law, if the voltage remains constant and the resistance is reduced by half, how is the current changed?

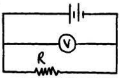
(a) reduced by a quarter
(b) reduced by a half
(c) multiplied by 2
(d) multiplied by 4

24. Which is best classified as a resistor?

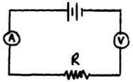
(a) a battery in a flashlight
(b) a current-carrying wire in a home
(c) a heating element on a stove
(d) an electroscope

25. Four circuits containing a battery and a load R are shown below. Some circuits contain both an ammeter and a voltmeter. Others contain only one of the two instruments. Which circuit shows the instrument or instruments connected correctly?

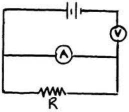
(a)



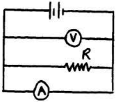
(b)



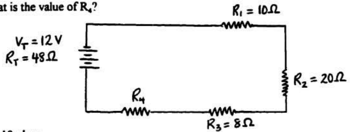
(c)



(d)

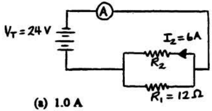


26. What is the value of R_4?



(a) 10 ohms
(b) 25 ohms
(c) 38 ohms
(d) 48 ohms

27. What is the current in ammeter A?



(a) 1.0 A
(b) 2.0 A
(c) 6.0 A
(d) 8.0 A

28. Mary says to Tom "Why does your piece of wire have a higher resistance than mine?" Which of the following reasons could **not** be a possible answer to Mary's question?

(a) Tom's wire is longer
(b) Tom's wire is cooler
(c) Tom's wire is thinner
(d) Tom's wire is made of a different material than Mary's

Appendix E
Sample Student Permission Letter

P.O. Box 549
Bonavista, NF.
A0C 1B0

November 16, 1995

Dear Student:

My name is Renee Pearce and I am a graduate student at Memorial University of Newfoundland. Presently, I am doing research on my thesis entitled, "The Relationship between Self-Confidence and Learning Approach in Physics". The aim of my research is to determine whether self-confidence affects learning approach in physics, or whether a particular learning approach affects self-confidence.

Your participation will consist of writing two multiple choice physics tests (30-40 minutes in length) consisting of items of varying levels of difficulty. These tests, addressing the units on electrostatics and current electricity, will be part of the normal evaluation scheme for the Physics 3204 course, and will be administered by your physics teacher (2 class periods). All physics students will write this test, whether they are involved in the research or not. Also, you will be asked to complete two questionnaires - one on how you approach learning physics (15 min), and the other on your self-confidence in physics (15 min). You are free to withdraw from the questionnaire portion of this study at any time. Your physics teacher will also be asked to submit your Physics 2204 and Mathematics marks from the previous year.

All information gathered by myself, as researcher in this study, will be strictly confidential and at no time will your name or school be identified. I am interested in the relationship between ways of learning and self-confidence levels, not in any individual student's performance. Participation is voluntary and you may withdraw at any time from any activities which do not constitute part of your normal instruction, without fear of prejudice. Upon completion of this study, raw data will be destroyed. This study has received the approval of the Faculty of Education's Ethics Review Committee. The results of my research will be made available to you upon request.

If you are in agreement with participating in this study, please sign below and return to your physics teacher. If you have any questions or concerns, please do not hesitate to contact me at 468-2323/1852. If at any time you wish to speak with my supervisor, please contact Dr. Glenn Clark at 737-7612. If at any time you wish to speak with a resource person not associated with the study, please contact Dr. Steve Norris, Associate Dean, Research and Development. Thank-you for your consideration of this request.

Sincerely yours,

Renée D. Pearce

I, ______________________________ understand that participation in the above described study is voluntary and that I may withdraw from the questionnaire portion of the study at any time. All information is strictly confidential and no individual student or school will be identified.

______________________ Date

____________________________________ Student's signature