Losing Students in the Terrain of Physics:
A Practical Inquiry-based Response to the Declining Enrollment in Physics

By

Jeffrey Horncastle

Diploma in Secondary Teacher Education, 2013
Bachelor of Science, 2011
Diploma in Computer Systems Technology, 2002

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Abstract

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Declining enrollment in secondary and post secondary science is a problem that many countries around the world are facing. Research has been done to explore this problem in the United States (Gunstone, McKittrick & Mulhall, 1999), Canada (Amgen Canada, 2013), New Zealand (Smaill & Coghill, 2011), China (Zhang & Ding, 2013) and the United Kingdom (Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). From the review of the literature done in this area, I have identified three key themes to be affecting declining enrollment: (i) a lack of interest and engagement in the subject; (ii) myths that science is difficult, boring and irrelevant in our lives (Gunstone, McKittrick, & Mulhall, 1999); and (iii) that the targeted demographic of science students needs to be broadened to be more inclusive (Slawinski Blessing, Miller & Schwartz, 2006). Declining enrollment in physics is also being seen in the high school that I teach at, Parkland Secondary, in Saanich, British Columbia. In response to this decline, I have created an Introduction to Electronics course that attempts to respond to these three themes by providing hands-on inquiry-based experiences. It is my intention that by providing students with experiences that engage them with theories and concepts of physics without the difficult

mathematics, student enrollment in physics will increase. It is also my hope that this course will increase student interest in physic by increasing understanding of the relevancy of science in the student's daily lives.

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Acknowledgements

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Last and not least, I'd like to thank my beautiful and talented wife, Kirsten McMenamie. I could not have finished this paper, let alone start it, if it was not for you. You encouraged me when I wanted to give up, helped proofread every sentence I wrote, and put up with my complaining. You are the most amazing women I have ever met.

Dedication

I dedicate this paper to my first physics teacher, Mr. Hook. The engaging opportunities that I experienced in your class instilled a passion for the subject of physics. This passion was so ingrained in me that when I decided to pursue a career in teaching six years after leaving high school, I chose physics. You made a difference in my life and I hope to do the same for my students.

Chapter 1: Declining Enrollment in Science

Preamble

In the opening chapter of this project, I provide an overview of the rationale, objectives and purpose. I share with the reader how past experiences of my childhood helped me to develop a deep passion for learning and specifically learning about physics and how these experiences shape my understanding of physics and the learning process. I then explain how this understanding shaped my teaching pedagogy and led to an interest in this project. I conclude with some key factors that are affecting the decline in enrollment in the subject of physics and how the planned curriculum that I developed for my Introduction to Electronics class can serve as a potential model to solve some of these challenges.

Introduction

Like most children, I was an inquisitive child. I pestered my parents incessantly with questions: "How old is that tree?"; "Why is the sky blue?"; "How do Water Skeeters walk on the water?" My parents did their best to provide me with answers, but as I matured so too did my questions. I vividly remember going for a drive with my parents one day; I must have been around the age of six. We were driving down Somenos Road in the Cowichan Valley and I was looking out the window at all the telephone poles. From my seat in the car it looked like all the telephone poles were moving backwards and I wondered where they were all going. I asked my Dad about the observation and he clarified that the telephone poles were not moving, they were not going anywhere, but rather it was us who were moving and going somewhere. I did not say anything, but I remember being confused by this answer because to me the telephone poles looked like they were moving backwards but, as my Dad had explained, we were the ones moving in the car. The answer was simply handed to me and I was expected to accept it. But I could not; not without understanding, first, how one comes to the conclusion that this is the answer. So I was forced to sit with the answer and ponder it.

As I continued to grow older, my questioning did not stop and my parents eventually got frustrated enough that they bought a set of encyclopedia. From that day on, my parents responses to my questions became the same; “Go look it up in the encyclopedia”. I spent many hours reading the encyclopaedias, looking for answers to my questions. Unlike today, it was not possible to simply go to the internet and instantly find the answer to just about any question. I had to think about my question and think about what topic to look up to find information relating to my questions. The encyclopaedias did not necessarily provide me with direct answers to my questions, but instead provided me with knowledge that allowed me to draw conclusions about what the answers to my questions may be. For example, I could not look up telephone poles moving backwards in an encyclopedia, but I could look up motion, which could lead to information about Issac Newton’s universal laws of motion. This new information caused my question to change and evolve over the process; with each new discovery, more questions emerged. Sometimes I would find an answer to my question and sometimes I would be only left with even still, more questions! This process compelled me to spend time with my questions, to ponder them, to test out theories and to sit with them.

Gregory Bateson (1972) elaborates on a quote by Alfred Korzybski, which says, “the map is not the territory” (p. 455). Bateson looks at what makes the map different from the territory and asks the question “what is it in the territory that gets onto the map?" (p. 458), meaning how do we decide, as map makers, what to highlight on the map. He notes that a map highlights differences such as differences in elevation and differences in terrain. The problem is that we cannot portray every difference on the map. So we must decide the differences that are important; and in order to determine this we must look at the “differences which make a difference” (p. 460). This means, then, that the purpose of a map is to provide an overview of the land, making particular distinctions while ignoring or obscuring other aspects of the landscape that are deemed less important. It is used to navigate a traveller on a route from point A to point B. By creating a route, one focuses only on the destination. This can cause the traveller to miss what is in between point A and point B. The physical environment that exists between point A and point B is the territory. Bateson (1972) believes that when we do not solely follow the map, an opportunity to interact with the territory and for it to interact with us arises; and this is where deep learning can happen.

When my parents were answering my questions, they were treating the learning process as a map. The purpose was to arrive at the final destination or answer. The path I took to get there was not important. This did not provide deep understanding of concepts, but rather just surface level knowledge. When my parents decided to buy the encyclopaedias and make me look for the answers myself, they were treating the learning process as a territory, allowing me to find my way own way through it. They may not have realized this, but they were changing my learning environment from one that focused on a destination (using a map) to one that focused on the journey. Much like how a lost person wanders through a forest looking for their camp, I wandered with my question looking for ways to arrive at an answer; searching for something that may or may not exist. This wandering is a wonderful thing. Instead of being given the answer and skipping to the end of the learning process, I was allowed to explore and understand my questions. I still found answers to my questions, but because I was not given the answer, I had to learn how to get the answer for myself. This gave me ownership over the learning that was happening and I learned how to learn on my own. This also led to a perpetuating cycle of exploring my questions. This type of learning is similar to Chris Argyris' double loop learning model (1976).

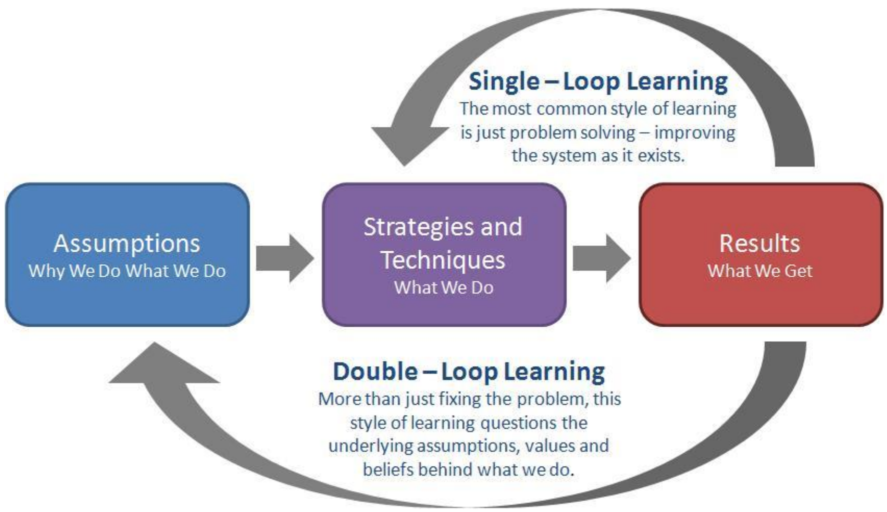

Figure 1. Single Loop Double Loop Learning

In this model the learner participates in a perpetuating learning cycle moving between assumptions, strategies and techniques, and results.

This experience of sitting and being comfortable with questions and journeying to the answers is what led me to become a physics teacher. I developed a passion for understanding how things worked and this passion led me to taking physics in high school. My physics teacher, Mr. Hook, understood that physics was not just about mathematics and memorizing a textbook full of theories. He taught me that physics was something that we must interact with; we must experience it out in the world. He taught me that physics is the pursuit of understanding our universe. The key term here is pursuit. Mr. Hook knew that great physicists are always pushing to have a deeper more complete understanding of the universe.

One of the most elusive passions of physicists is to the Theory of Everything. This theory, according to Stephen W. Hawking in “The Theory of Everything”, says that we can fully understand and explain everything in the universe with a single set of equations (2002). This theory requires us to fully understand how everything in the universe works and relates to each other. Many great physicists have pursued this theory, including Albert Einstein and Stephen Hawking. To me, this pursuit is what encapsulates physics. The idea that we can get to a point where we understand how everything works and interrelates seems impossible. Fortunately, physics is not about achieving an understanding of everything, but rather the pursuit of it. It is about sitting with questions and wandering through the territory of understanding; searching for answers and for more questions.

I think the best physicists are the ones that never grew out of that inquisitive child phase. They are the ones that are unsatisfied with the answers they are given. Just as I wanted to understand why the telephone poles looked like they were moving, great physicists seek to always find deeper understanding of what we observe. Physics as a science is about always looking deeper into our understanding and not being satisfied with just an answer. Just as J. J. Thompson was not satisfied with the knowledge that atoms were indivisible and pursued experiments that discovered a smaller particle, the electron, so too should our students be unsatisfied with any answer we give them in physics. I became a physics teacher not to teach students various concepts and theories, but instead to instill an unsatisfactory feeling that spurs curiosity and sparks a passion for understanding and learning.

Rationale

In the British Columbia (BC) education system, I find we treat the learning process in the same way Bateson conceives of the map; we focus on getting students through our course with good grades. This outcome based education system requires reporting on student learning through letter grades and standardized exams, and students are not permitted to proceed to new courses without completing previous requirements. The problem with this approach is that it focuses students' attention on learning specific prescribed learning outcomes, or using Korzybski's metaphor of the "map", destinations (Bateson, 1972, p. 455). These destinations are like items on a checklist that students can move through and check off. Their success in a course is thus deeply connected to any grade they receive for each prescribed learning outcome, rather than the student's ability to master the subject through inquiry and fully explore the territory of the subject.

Teachers are equally preoccupied with grades and tests, which can result in teachers rushing through course material to ensure the courses' checklist is completed and so that students can be successful on the exam. This limits the teacher's ability to allow students time to explore the subject on their own, to immerse themselves in the course material, and to find their own ways through the questions. Instead teachers spend too much time trying to get students to learn the correct answer to questions and provide those answers on tests. This model resembles a learning process that focuses on memorization and regurgitation. It is narrow in its focus as it teaches students to replicate and copy what they see. Though it is important to learn what has already been discovered, it is not the only thing that students need to understand to be successful in their learning and in physics.

Alternatively, when we treat the learning process as territory, we focus on teaching students to find their own way through a question to an answer (and potentially answers); the result is an inquiry-based model. An inquiry learning model allows students to interact with the learning outcomes of a course through a questioning and discovery process. This process is supported by the teacher, as a guide and facilitator of activities for the students. The model may range from a structured procedural lab that the teacher creates, to a student created experiment. But in all of these models, the students change from passive recipients of knowledge to active members in the learning system, which fosters the co-creation of knowledge between the students and teacher. This allows students to wander off the path of prescribed learning outcomes and explore the territory of the topic they are learning about more fully.

Helen Gibson and Christopher Chase (2002) have found inquiry-based models to successfully maintain a positive attitude towards sciences in middle school students. This model provides students with guidance to help them arrive at answers on their own instead of providing them with the answers directly. With this model the answer(s) that a student arrives at is not more important as the way in which the student arrives at that answer.

This approach is an appropriate one for teaching physics, as I believe it is the line of questioning and the logical train of thought that the student uses that is what needs to be developed to become successful in physics. This is often taken to be true for all sciences. The work of scientists is not memorizing facts and formulas, but rather to pursue a deeper understanding of the universe and make new discoveries. It is not about memorizing that telephone poles do not move, but rather understanding why they appear to move and why that appearance is important.

I have been teaching at Parkland Secondary in the Saanich School District (SD 63) for just over two years now; teaching mathematics and science based courses. Through interactions with my colleagues and time spent with students in the classroom, I have noticed a trend developing in high school physics. There is a focus on preparing students for the rigors of university physics. This focuses a lot of the students' time on solving problems and practicing various mathematical methods, such as systems of equations. In doing so, an education system that acts as a pipeline is created; one which focuses on tailoring a course for students who are continuing on in the field, rather than a system that fosters learning for all students regardless of their future goals.

At Parkland Secondary, the upper level physics teacher has an online bank of over 100 questions for each chapter of his Physics 11 and Physics 12 courses. This bank of questions are used to create tests. Students also use the bank to study in order to be proficient at solving physics problems and earn good grades. The focus of his teaching is to prepare his students for the rigors of university level physics. This approach does prepare student for the rigors of university very well. In fact, a number of this teacher's students have come back to visit and said that their first year classes were easier than his Physics 12 class and that they were thankful for his style of teaching. I have the utmost respect for this teacher and the fact that he has students coming back to visit him speaks loudly to the positive relationships he builds with them and although many students find this style helpful in finding success in university physics, this model of teaching and learning physics is problematic for several reasons. The pressure of preparing students for the rigors of university creates a model that limits opportunities for students to engage and have fun with the theories that they are using. It does not provide the space necessary to spark a passion or interest for the subject in students that do not currently have that passion. Also, students that are not taking physics, perhaps because of the difficult mathematics or its lack of relevance to their future goals, never learn that physics is an incredibly interesting field and a subject worth learning about for the simple sake of learning. The students that do learn through this more traditional pipeline model do not learn that a large part of physics is questioning theories, creating new hypotheses, and testing these hypotheses. Consequently, there is limited opportunity for students to learn what it means to have fun with in physics.

This problem is not unique to physics. In Canada we are seeing a decline in enrollment for all sciences as students progress through high school (Amgen Canada Inc, 2013). Students are choosing not to take sciences as they find science difficult and irrelevant (Amgen Canada Inc, 2013). In order to increase enrollment, teachers must address these student preconceptions of science. Walter Hellman (1992) examined continuation rates in physics classes in Oregon high schools. He found the continuation rates of students were linked to engaging opportunities in the subject. In Hellman’s study, he found that students who came from schools with multiple courses in the subject of physics had higher continuation rates, opposed to schools which only offered either a single introductory course or a single advance course in Physics. This led Hellman to conclude that in order to increase student enrollment in physics, more diverse opportunities in high school that enable students to engage and learn about physics is necessary.

In China, Zhang and Ding surveyed 1318 students across grade 8 to 12. They used the Colorado Learning Attitudes Survey about Science (CLASS) and translated it into Mandarin through a rigorous trans-adaption process. Zhang and Ding correlated the results of the surveys to varying times of stress in student's lives. In this study, Zhang and Ding (2013) identified two key belief structures that students hold about physics. The first, key belief structure deals with surface-level learning and normally emerges when students feel stressed or when they are struggling with learning the concepts. The second belief structure includes expert-like learning and emerges when students are given space and time to engage with the concepts. From this study, they have found that students held the second belief structure associated with expert-like learning when they were least stressed and the first belief structure associated with surface-level learning when they were more stressed. In addition, they found the second belief structure to be associated with times where the students' interest levels for physics were the highest.

In both these studies the researchers found student interest in physics increased when students were provided with diverse opportunities to engage with the subject and when they were not focused on attaining grades and prerequisites for future course work. Hellman found this was provided to students through the diversity of course selections, while Zhang and Ding found this through diversifying the belief structure of the class. Increase in interest in physics was directly linked to continuation rates in both these studies. The common thread that these and other studies have is giving students the freedom to explore physics; in other words to allow students to wander through the territory and not focus on any final destination.

These studies and others have provided the grounding for the development of this project. For this project, I have developed an electronics curriculum, which is intended to increase student interest in physics and enrollment in the subject at a high school level. It is my intent that through this curriculum students will be provided opportunities to engage and have fun with high level physics concepts in an environment that does not focus on grades. The lack of focus on grades is created in the course not just by the curriculum, but also due to the course being offered as an elective and is not a requirement for any future course work. This means that any grade acquired in the course has little importance in high school or university.

The course is designed with the intent of providing a wide variety of opportunities to be exposed to the theories of physics, without needing to be exposed to the complex mathematics used to solve physics problems. This provides students with a safe environment to play with the concepts and develop a deeper understanding of them. This idea of play, as an important aspect of deep learning has been explored by David Jardine (Misgeld & Jardine, 1989). Jardine argues that our education system has removed the action of play from learning in order to secure marketable skills for our students to prepare them for the work force. This unfortunately has led to surface level learning where students are not fully exploring concepts and developing deep understanding. Jardine believes that this type of understanding happens when students are put in an environment that they feel safe to play in and explore. I believe that by providing students with such an opportunity to play with complex physics theories, students' interest and engagement in physics will increase. I believe that in addition the students that go on to do physics will be better thinkers and will learn not only how to solve questions that they have seen before, but also be able to come up with their own questions and perhaps even new methods to solve them.

Student interest and engagement in physics is a factor that researchers have found to be a cause for the decrease in enrollment in physics. Christopher Williams, Martin Stanisstreet, Katie Spall, Eddie Boyes, and Dominic Dickson (2003) explore the relationship between student interests and the specific course content with in physics. In this study, the authors showed that the students found electromagnetism, energy, and any mathematical aspect of the course difficult and this led to a disinterest in the course.

With such findings in mind, as well as my own experiences in both learning and teaching these ideas, the concept of electromagnetism, which students found uninteresting and difficult, is one of the concepts that I focus on teaching students about in my electronics curriculum. In my course, students are able to play with the theories of electromagnetism while they make electromagnets and speakers. They do not learn how to solve problems mechanically carrying out formal or abstract mathematics, but instead experience the mathematics as it unfolds when they generate magnetic field using a coil of wire and a current. The learning of the concept and the conceptual learning happens with and in the application or doing physics; the students explore the concepts while applying or enacting these theories as they work on the projects. In the electronics curriculum, students also learn about electric circuits, sound waves, torques and gear ratios. This provides the students with real hands-on and context-rich experiences of complex physics concepts.

These experiences can spark interest in a subject that may otherwise be rejected if too formal or abstract, due to the difficult mathematics involved. It is my hope that by providing these experiences, students will not shy away from physics because it is perceived as hard and boring, but, will rather see it as an interesting challenge that is worth the pursuit.

Summary

This project explores the work I have done in developing the curriculum for the electronics class and applying the theories of inquiry-based learning. This document outlines my research and reflections on the project. It consists of four main chapters; the introduction, which you are reading right now; a review of the literature that is focused on exploring declining student enrollment in the sciences, with a focus on physics both in the high school and university classrooms; an explanation of the curriculum document for the electronics course I developed; and my reflection after having taught the course twice. This project will continue to evolve with each opportunity to teach it, as student feedback enables continuous reflection and further development of the course. There are several potential places to continue this work. I would like to see future work on some of the other junior sciences curriculums to enable more flexibility to provide students with hands-on experiences to get them excited about not just physics, but also chemistry and biology.

Chapter 2: Literature Review

Introduction

As stated in Chapter 1, I believe physics is the pursuit of understanding the inner workings of our natural world and universe. This understanding provides our society with many technological advances that people today take for granted. For example, without physics, we would not have electricity, airplanes, bridges, or eye glasses. More precisely and perhaps more germane to this capstone, without those who study physics (i.e., students, teachers and practicing physicists), we would not have knowledgeable and qualified people to design and build these comforts.

This chapter outlines the literature review for my capstone project and explores the literature on declining enrollment in high school and university science classes, with a focus on physics based courses. Upon review of the literature, three main themes emerge that indicate the reason for this decline, including (i) a lack of interest and engagement in the subject; (ii) myths that science is difficult, boring and irrelevant; (iii) that the targeted demographic of science students needs to be broadened to be more inclusive. I first explore why the decline in enrollment is a problem within the current discussion of physics education and then explore the three themes identified above across the literature. I then identify limitations of the research as well as future areas of inquiry, and finally, I discuss how the curriculum that I developed for my electronics course works to address these themes and explore them more deeply.

Declining Enrollment

Declining enrollment in the science classroom - and specifically in the area of physics - is not a new phenomenon. Since the 1920s, it has been shown that physics enrollment in

American high schools is steadily declining (Pallrand, 1985). This decline in enrollment is not just a concern in the United States, as similar research from other nations (Gunstone, McKittrick & Mulhall, 1999) has been done to investigate the decline in enrollment in other science classrooms, specifically in Canada (Amgen Canada, 2013), New Zealand (Smaill & Coghill, 2011), China (Zhang & Ding, 2013) and the United Kingdom (Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). These authors agree that the decline is a serious concern, as science, and specifically physics, delivers skills and knowledge that are fundamental for students going into engineering, information technology, medicine and scientific research.

As has been identified, science and engineering is responsible for producing the people who create and maintain many comforts our society enjoys such as bridges, eyeglasses and computers. But the science classroom does more than just produce engineers, doctors, scientists and IT Technicians. The science classroom also teaches students how to think differently and specifically, such as how to analytically break down a complex problem. It teaches students how to logically gather evidence and use that evidence to create hypothesis. It teaches students how to test hypothesis and how to learn that a failed attempt is often a necessary step required to create a new approach that may lead to success.

However, science education is not just a pipeline model to create more people for the specific career paths of science. These skills explored and developed in science clasrooms are not just useful in the field of science, but rather can be seen as integral for success in just about any area of life. A carpenter needs to be able to logically analyze a set of plans and materials before creating a beautiful and functional place to live. Politicians must gather large amounts of information about their constituencies, analyze the most pressing issues and make decisions about how best to serve the people and land they represent. And, everyone at some point in their life must learn from their failures and use that knowledge to reassess and try a new approach in order to find success. In fact, the increased complexity we face as members of a democratic society demand that we have such skills for full participation (Amgen Canada Inc., 2013). Science provides an opportunity for students to learn these skills and the decline in enrollment in these classes should be worrisome, not just because our societies will suffer from a shortage of engineers, scientists, doctors, and technicians, but also because our society will lose a prominent space where students can develop analytical, logical and unbiased constructive thought.

In addition to the decline in enrollment we are seeing in Canada (Amgen Canada Inc., 2013), we are also seeing a decline in our international performance in science and math. The Program for International School Assessment (PISA) is one of the main international programs used to evaluate countries education systems. PISA evaluates the literacy in reading, mathematics, and science of 15-year old students in over 65 countries by testing students' abilities to apply the knowledge they learn to real life situations. Canada's PISA scores in science and mathematics "have shown statistically significant declines since 2006" (Expert Panel on the State of Canada's Science Culture, 2014, p. 178), raising concerns that in the near future we may begin to experience a shortage in qualified experts in science and math related careers, as well as qualified experts to teach these subjects.

This is a situation that New Zealand is also currently facing, as they are experiencing a shortage in engineers and qualified people to teach the required courses, such as physics (Smaill & Coghill, 2011). This creates a whole new problem for a nation such as New Zealand, as they need to import experts from other countries in order to train new engineers. I believe that we are not yet at this point here in Canada, but if we do not act now and try to reverse this decline in science enrollment we may face the same situation as New Zealand, making the problem of declining enrollment in the sciences even more difficult to address.

In order to effectively respond to declining enrollment, we must first analyze and discover where in our education system the decline seems to be taking place, and then why it is happening. The general consensus in Canada indicates that we have high interest in science during younger grades, but that interest declines as students approach high school (Expert Panel on the State of Canada's Science Culture, 2014). Specifically, after grade 10 we see significant declines in enrollment in the sciences (Amgen Canada, 2013). As Milford (2014) has concluded our efforts to address the declining enrollment in physics and the other sciences should be focused at the high school level.

Gender

Enrollment in physics and the other sciences has declined and a logical question to ask, in order to try to increase enrollment, is who is currently taking the courses and who is not. A key demographic that is underrepresented in physics and the sciences is women. In the United States, women are a minority in post-secondary science programs (Slawinski, Blessing, Miller & Schwartz, 2006). In 2000, only 21% of baccalaureate degrees and only 14% of Ph.D. students in the field of physics were women (McCullough, 2007). In high school, however, the male to female ratio is split fifty-fifty. This indicates that something happens in the transition from high school physics to post-secondary studies.

Response to declining enrollments

Here in Canada, we see this trend emerging as surveys report a declining interest in the sciences by women (Expert Panel on the State of Canada's Science Culture, 2014). One possible reason for this drop is due to a lack of role models for women in the field. Only 31% of high school teachers in the United States are women, and in post-secondary institutions women make up only 14% of the faculty (Slawinski, Blessing, Miller & Schwartz, 2006). Also, "it appears that females' rejection of science is not related to a perception that it is too hard or not fitting the female gender role; they simply do not find it interesting or relevant to their life goals" (Slawinski, Miller, Blessing & Schwartz, 2006, p. 377). Therefore, the argument is made that we need to be intentional about providing women in the sciences with examples of how their life goals and the knowledge learned in science classes can be mutually beneficial. One way suggested to do this is to provide women in science with role models (McCullough, 2007). This can be done by highlighting contributions made in science by female scientists in our classrooms to raise awareness about the role women have played in science (McCullough, 2007).

Lack of female role models was also found to be a factor in declining enrollment of females in the sciences and maths at the secondary level. In British Columbian high schools, research was conducted by Stanford (1998) that investigated the lack of female student enrollment in mathematics and science. Through questionnaires to principals, counsellors and other school officials, the study found themes of role modelling, school philosophy, gender views and perceptions of mathematics and science contributed to females not continuing on with senior and post-secondary sciences and mathematics. This indicates that it is important in the secondary level to provide role models to female students that positively impact their view of gender in mathematics and the sciences.

It has also been found that females seem to benefit more from hands-on work. In a study on grade 10 students, Burkam, Lee and Smerdon (1997) found that co-operative and hands-on laboratory work caused a 20% reduction in the gender gap for the physical sciences. Again, this indicates that another possible way to increase enrollment of females in the sciences is to provide more hands-on and co-operative opportunities for students to learn through. It should also be noted that this study found positive increases across the board for all students, not just females (Burkam, Lee & Smerdon, 1997).

Due to efforts such as the ones listed above, we are starting to see significant changes in the figures surrounding female enrollment in graduate science programs. A study done in Illinois, reported that female enrollment in graduate science and engineering is increasing at a greater rate than males, with a 5% increase to female enrollment versus 3.5% to males. This increases the proportion of female science and engineering graduates from 36% to 42% and was captured over the ten year span ranging from 1993 to 2003 (Britner, 2008).

Another consideration when looking at enrollment based on gender is the current trend towards breaking down conceptions of the male and female gender binary. Emerging from this breakdown is an understanding that gender exists on a spectrum, where people's identities are not limited by a binary understanding of male and female and includes a rejection of conceptions of gender that are based solely on specific characteristic typically associated both male and female. Jesse Bering (2010) further breaks the idea of gender down into three separate spectrums. These spectrums separate an individual's biological sex, gender identity, and sexual orientation. This conception of gender allows for more diverse and complex identities; recognizing that traditional and binary conceptions of gender are limited in their ability to help us understand or reach out to students. This wider understanding of gender cautions us to avoid creating targeted strategies to increase enrollment based on traditional conceptions of binary genders. Instead, we should focus on creating more inclusive strategies that do not depend on gender stereotypes and that appeal to everyone regardless of gender.

Interest

The bulk of research on increasing student enrollment in the sciences is focused on determining why students lose interest in these courses. While high interest levels are reported for younger students in elementary school, there is a steady decline as students get older and enter high school (Amgen Canada, 2013; Simpson & Oliver, 1990; Simpson & Troost, 1982). The gender of the students seems to be a factor for this decline. As previously explored in the Gender section of this paper, females seem to lose interest in science more than males (Blessing, Miller, & Schwartz, 2006). Also, the demographic background of a student's family also seems to impact the classes they are interested in. Higher interest levels in the sciences are reported for students with parents that have high incomes, education levels, and that come from non-Caucasian households (Expert Panel on the State of Canada's Science Culture, 2014, p. 182). Lack of interest in the sciences seems to stem from a belief that what students learn in these courses is boring and not relevant to their future careers and lives. A survey completed in the early 2000s investigated student interest in the sciences in six schools in England (Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003). This survey reported a decline in interest in the sciences as students progressed through the tenth year at high school. Specifically, the survey found that student interest in physics declined due to a belief that physics was difficult, abstract, boring, and not relevant. These observations that students found the sciences boring, difficult and irrelevant are echoed in studies done here in Canada (Amgen Canada, 2013), in the United States (Hirsch, Kimmel, Rockland, & Bloom, 2005), and in New Zealand (Smaill & Coghill, 2011).

In order to address this disinterest, many educators and researchers have been looking at altering the traditional way of teaching science. Traditionally, science and mathematics has been taught through lectures, practice problem sets, and laboratory work where students follow a set of pre-designed procedures in order to reproduce an experiment (i.e., cookbook labs). This traditional method of teaching is meant to provide students with the vast amount of background knowledge that is required in becoming an expert in the field (Willingham, 2009). However, where it seems to be lacking for students is that it fails to give students the opportunity to experience what scientists really do in their work. Students do not experience the hands-on experimentation of science or the creation of new knowledge (Willingham, 2009). The suggestion, by many researchers, is that in order to increase student interest in science, we must provide them experiences that resemble what scientists really do in practice (Goodnough & Cashion, 2006). This means providing students with more hands-on learning experiences.

Currently the hands-on learning models that are gaining interest with in the field are inquiry-based learning and problem-based learning. Inquiry-based learning can be defined as a teaching model where students engage in learning through questioning and investigation. Inquiry-based learning usually utilizes a facilitator to pose a problem to investigate and to guide the students through a questioning and investigation process (Martin-Hansen, 2002;

Windschitl, 2003). This approach is divided into three types: open inquiry, guided inquiry, and structured inquiry (Martin-Hansen, 2002; Windschitl, 2003). Open inquiry allows students to create their own questions and experiments to test those questions, based on a theme provided from the teacher. In guided inquiry, the teacher provides the students with the question and then the students create experiments to test that question. Finally, in structured inquiry, the students follow procedures for an experiment in order to validate known scientific principles (Martin-Hansen, 2002; Windschitl, 2003). In problem based learning the traditional learning model is flipped. Instead of being taught the knowledge needed to solve problems, students are first given the problem and must determine what knowledge they need to learn in order to find the solution (West, 1992).

Both of these models include a new aspect to learning that the traditional model leaves out. They give the students an opportunity to create knowledge on their own. In inquiry-based learning, students do not know the outcome of an experiment until they have done it and in problem based learning students must discover what they need to know in order to solve a particular problem. In both of these models, students engage genuinely as scientists. They are attempting to create knowledge through questioning assumptions, experimentation and reflection. By engaging students using these models, teachers enable students to experience science. This ensures that student opinions of science are accurately based on what it is like to practise science.

Many studies have been completed using hands-on interactive models, such as these, in teaching in order to increase student interest in the sciences. Paris, Yambor and Packard (1998) look at the interest and cognitive learning levels of grade 3, 4 and 5 students in science. The study provided a set of students the opportunity for hands on learning such as, growing their own plants and speaking directly with scientists. Through these experiences, they found that students who had hands on learning experience gained greater analytical thinking skills, greater interest in science, and greater cognitive abilities in the subject. In their study, Louden, Wallace, Wildy and Geelan (2004) found that student gained a deeper learning in a high school physics class due to an inquiry-based teaching model. Burkam, Lee and Smerdon (1997) found that student interest was increased in the physical sciences due to hands-on laboratory work, and was specifically positive for increasing interest in the female students. Gunstone, McKittrick and Mulhall (1999) found that inquiry-based learning increased the engagement of students in science and the conceptual understanding of the topics taught. Hill and Hounshell (2002) did a five-year study in North Carolina Department of Public Instruction and found that through providing more hands-on learning opportunities in the classroom and afterschool, student interest and ability increased in science and mathematics.

This research supports the idea that hands-on learning models should be incorporated into our teaching practices in order to increase student interest in science. But it does not indicate to what degree these models should be incorporated. Learning must remain the main focus of our classroom, and from this research we only have evidence to support the increase in student interest, engagement, and motivation. For students to learn and be successful in their chosen field of interest they must not simply be engaged, they also be given the knowledge and tools to succeed.

Willingham writes that experts in science and mathematics are able to create knowledge through inquiry-based approaches only because of the vast amount of knowledge they already possess (2009). He indicates that this vast amount of background knowledge cannot be taught through inquiry-based approaches and must use a more traditional model to teach it (Willingham, 2009). Other researchers have also found that problem based learning (Colliver, 2000; Goodnaugh & Cashion, 2006) and inquiry-based learning models (Campbell, Zhang & Neilson, 2010) do not enhance student learning in sciences. Campbell, Zhang, and Neilson found that teachers had trouble keeping students on track with the learning objectives using an inquiry-based model (2010). The teachers reported that some students who they thought were doing experiments, were actually not attending to the work at hand and consequently, not meeting the learning outcomes. This leads to the question of how these models are to be incorporated into one's teaching. It is suggested by researchers that these models be incorporated into the curriculum in conjunction with traditional models of teaching in order to provide a more holistic learning of science (Campbell, Zhang & Neilson, 2010). This will allow teachers to maximize both the retention of knowledge and interest of the subject in their students (Willingham, 2009).

Irrelevance and Difficulty

The final theme that comes out of the literature of declining interest in the sciences is that students hold beliefs that the sciences are irrelevant and too difficult (Amgen Canada, 2013). Traditionally, physics is thought to be the most difficult of the sciences as it relies heavily on a student's mathematical ability to analyze, break down and solve complex problems. Due to the complexity of the problems presented within physics, students who complete the course often leave with a poor conceptual understanding of the topics and a lack of understanding how relevant physics is in their everyday lives (Gunstone, McKittrick, & Mulhall, 1999). This problem becomes more amplified as students enter post-secondary education as the concepts become more abstract and the problems become more complex.

Adamuti-Trache, Bluman and Tiedje (2003) looked at what factors lead to high dropout rates of physics in university. They believe that these high rates could be due to students feeling unprepared for the challenges in university level physics. Their study sampled 4,569 students from 110 BC high schools and found that students who went to high school near their post-secondary institution had higher success rates and lower dropout rates. These rates had no correlation to student ranking in high school and the authors concluded that the higher success rate was due to the relationships that form between high schools and universities when they are in close proximity (Adamuti-Trache, Bluman & Tiedje, 2013). The authors believe that these schools had a better understanding of what students face when they enter post-secondary studies and therefore were better able to prepare their students for those challenges (Adamuti-Trache, Bluman & Tiedje, 2013).

Preparing students for the rigors of post-secondary education is only one part of a teacher's job at high school. Another part is building students up to that point by giving them achievable steps in their learning. From grade 9 through 12, students in North America are offered a science curriculum that is intended to expose them to various fields of science and to develop analytical and logical ways of thinking. One question that is being asked by researchers, specifically David Sousa (1996), is whether we are offering the correct courses and in the correct order to achieve this goal. In Sousa's work, "Are we Teaching Science Backwards", he looks at altering the overall layout of how we teach science at the post-secondary level. Sousa believes that what students need to learn first in science is dependable and consistent universal laws that are easy to experiment with. Moreover, he believes physics to be the science that is most able to provide this experience. Our current focus in the sciences predominantly starts with biology and earth science and then moves on into chemistry and physics in the senior years. It is suggested then that we are currently teaching science backwards and should instead start with physics and chemistry (Sousa, 1996). By reversing the order students will see a logical progression of the sciences “from forces and the movement of objects to molecular structures, and finally, to the development of simple and complex life forms” (Sousa, 1996, p. 13). By moving a focus of the junior sciences to physics, we can strip down the level of mathematics in physics and instead put more emphases on conceptual understanding and developing students’ analytical and logical thinking. This would provide strong foundational learning that students could than build upon later on in their senior secondary science classes, which would address the lack of conceptual understanding that Gunstone, McKittrick, and Mulhall (1999) have found in their research and hopefully provide students with the right set of skills needed to tackle more complex and abstract problems.

Reorganizing the order in which we teach the sciences is not the only research being done that looks at the overall course structure of the sciences. Walter Hellman conducted a survey in Oregon in the 1990s looking at the continuation rates of students in physics (Hellman, 1992). The survey found that of 590 students who attended high school level physics courses, about half of them continued on or had the intention of continuing on with physics in post-secondary (Hellman, 1992). The students who continued on in the field came predominately from schools that offered multiple courses in the subject of physics, as opposed to schools that only offered either a single introductory course or a single advance course in physics. Hellman concluded that in order to increase student enrollment in physics we need to provide students with more opportunities in high school to engage and learn about the subject.

In addition to students believing science to be too difficult, we also have to address the student belief that science is not relevant to their future life goals (Amgen Canada, 2013). To address this, researchers have looked at better integrating everyday applications of science concepts in the classroom (Hirsch, Kimmel, Rockland, & Bloom, 2005). These authors provided information and training on how to include engineering concepts in their teaching, such as electricity, digital circuitry, chemical engineering, and linking mathematics directly to engineering applications. Their research found that students gain better conceptual understanding of the concepts being taught as well as a greater understanding of how many of these concepts would be useful in their everyday life (Hirsch, Kimmel, Rockland, & Bloom, 2005). If students are going to change their beliefs about the relevancy of science in their lives then they need to see this relevance in action; not just in the classroom, but outside the classroom as well.

In Canada, only 60% of men and 40% of women say they are interested in new scientific discoveries (Expert Panel on the State of Canada’s Science Culture, 2014, Pg. 181). If this is the culture that our students are living in, then in order to change our students’ beliefs we must also work to change that of the culture. Hill and Hounshell attack the issue of student enrollment in the sciences by not just reforming classroom practices, but also by adding after school programs and providing professional development opportunities to all school officials and community leaders (Hill & Hounshell, 2002). Taking the issue of science relevancy outside the classroom and moving it into the community showing students that science plays an important part in everyone's daily life, not just their science teachers.

Limitations and Future Research

From my review of the literature, four key areas stand out as requiring further research: (a) widening the target audience of the sciences beyond that of the male and female binaries; (b) changing the overall secondary science curriculum to provide more diverse opportunities to students; (c) finding the right implementation strategy of traditional and hands-on learning models to present to student; (d) further exploring ways to change the disinterest of science in our culture that surrounds our students.

The idea of widening our target audience of science to include both males and females is a topic that has been widely researched. McCullough is one such researcher that has suggested a number of ways to increase female enrollment in the sciences, specifically in physics (2007). The most notable approach is to intentionally provide female students with female role models in the field and more hands-on interactive experiences (McCullough, 2007). While this may be true, it neglects the fact that some females may be finding that male role models and traditional teaching strategies are providing them with the motivation to continue on in the subject. The concept of gender is evolving and the male-female binary is being broken down. Emerging from this break down is a gender spectrum, where people are forming identities that do not fall under the category of solely male and female. For this reason, potentially more attention should be given to ensuring that the sciences provide both interest and role models that transcend the stereotypical gender binaries of male and female and instead appeal to all genders.

Finding the right order in which to present and teach science to students is an area that needs further research as well. Sousa suggests that reversing the order in which the sciences are taught, starting with physics and working on to biology, is a more logical order that will show students the logical progression of science (1996). Likewise, Hellman's survey in Oregon suggests that high schools with high continuation rates in physics are ones that offer multiple courses at multiple levels (1992). These studies do not go into detail as to the exact order that will provide the highest enrollment rates or higher success rates of learning. Also, neither study indicates whether a linear or parallel offering of courses is better. I believe research could be done to determine if a combination of classes in theoretical and experimental sciences increases the interest level of students and the enrollment rates of students in both high school and university. From my experience teaching the electronics curriculum, I have found that students are receptive to learning high level concepts. The part of science that interests students is the part that instills a sense of awe and wonder in them. It is learning about why the sky is blue, what a black hole is, and how speakers work. If we want to increase the enrollment in our science classes, the question I believe we should be asking is why our current junior secondary science classes are not instilling this spark in students. Perhaps the solution is not about re-organizing the order in which we teach the sciences or add extra courses but rather re-evaluate the concepts that we are teaching our students and the way in which we teach them.

When looking at the studies focusing on hands-on teaching strategies, such as inquiry-based and problem based learning, predominately, I see a need for discussion concerning whether these strategies add to the overall learning of our students. The research seems to indicate that these strategies add engagement and increase interest in our students for the subjects. However, there does not seem to be conclusive evidence to show that these strategies, by themselves, increase the depth of conceptual understanding of our students. The research does imply that by including these strategies in conjunction with traditional teaching strategies that students do develop deeper conceptual understanding. Further research can be done to analyze how these strategies can be included into classroom teaching so as to maximize the learning of students.

Finally, further consideration could also be given to the idea that developing a good relationship between high school science classes and the community around them can help students see the relevancy of science in their everyday live. And that this can transform the student belief that science is too difficult to an understanding that science is a challenge worth pursuing. Adamuti-Trache, Bluman and Tiedje (2003) suggested that students that do best in post-secondary institutions in science come from schools that have strong relationships to those institutions. Also, Hill and Hounshell found that by providing more training in the sciences to school and community officials as well as providing more after school programs to help science students, they were able to increase interest, enrollment and success rates of their students (2002). I believe more research should be done to explore to what extent the beliefs of the community surrounding our schools affect our students' belief about science relevancy and how the belief of science relevancy affects student motivation to take on the challenges that science offers. For example, will a community that regards science with high esteem or further still, one that promotes its relevance and importance produce students who are more interested motivated to take science classes and continue on in science related careers.

Application of Themes

The electronic curriculum that I have developed both for this capstone and for my own teaching addresses all three themes identified in the research to be causing the decline in enrollment in the sciences, specifically in physics. This curriculum is targeted for students at the grade 9 level, which is the time where the declining interest has been found to start (Amgen Canada, 2013). The research shows that students become disinterested in physics because they find certain topics difficult and irrelevant, and females choose not to take physics due to the lack of hands-on learning opportunities (Expert Panel on the State of Canada's Science Culture, 2014). I believe that making high school physics easier is not the answer to this problem, as the research has also indicated that in order for students to be successful, at a university level in physics, they need to be properly prepared for the work load (Adamuti-Trache, Bluman & Tiedje, 2013). Therefore, in order to increase student interest and enrolment, it is necessary to find ways of making the topics that students find irrelevant, relevant.

To do this, I designed and ran a course that aims to increase interest in physics at the grade 9 and grade 10 levels. The course predominately addresses the topic of electricity and it provides students with practical hands-on opportunities to engage in this topic. Electricity is a topic that has been reported by the research as being difficult and boring (Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). My goal is to combine the study of electricity with electrical circuits, a topic that students find more interesting (Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). By combining these two topics, students will see that electricity is interesting and relevant in their lives. This is done by getting them to interact with the concepts taught in electricity through activities such as building useful circuits using different electronic components. By building these circuits the students interact with the concepts that they normally would find boring. The circuits that students are to build can be found in everyday devices and this provides relevant applications of different physics concepts. Though this course focuses on the topic of electricity, it also provides a section on robotics that allows students to interact with the topics of torque and circular motion. It is my hope that the course will increase interest in these topics, and provide a template of how we can teach other topics in physics in a way that increases student interest and engagement. Once students start to see physics as being interesting and relevant, I believe that the difficult aspects of physics will start to be seen as challenges to accomplish rather than challenges that foster feelings of self-defeat.

By running a practical course in parallel with traditional physics courses, I hope to increase student interest in physics while also providing students with the necessary background knowledge they will need to succeed in the post-secondary sciences. It is my hope that we will see an increase in new students taking introductory level physics. This would happen due to the increase interest level in students for physics, the more inclusive targeted demographic of the course, and decrease belief that physics is irrelevant. In addition, by becoming more interested in physics, I believe that students will change their belief that physics is too difficult. They will instead believe that it is a pursuit worthy of any extra work.

Chapter 3: Electronic Curriculum Document

Introduction

As previously stated, I have always been incredibly inquisitive about the world around me. I was never satisfied with simply seeing things for what they appeared to be, but rather I searched for a deeper understanding of their existence and how those things worked. I wanted to know why the sky was blue, how speakers emitted sound, and why the earth was round. It was through the knowledge and the training of how to think analytically that I gained in science class in school that I was able to seek out answers to these questions. When I decided to become a physics teacher, it was because I wanted to instill in my students the same passion for understanding how our world worked and teach them how to think critically in order to seek out deeper understandings of their passions.

Unfortunately, this love for science that is so innate in my life is not shared by all, and perhaps as a result we are seeing fewer and fewer students take physics in secondary school (Amgen Canada Inc, 2013). I want to change this by instilling that passion and excitement for the subject in students that would not normally take the course. In order to do this, I created the Introduction to Electronics Curriculum that is detailed in this chapter and is available in full as an appendix of this project. The curriculum addresses the three themes found in the research to be factors in the declining enrollment of physics: (i) a lack of interest and engagement in the subject (Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003); (ii) myths that science is difficult, boring and irrelevant (Gunstone, McKittrick, & Mulhall, 1999); and (iii) that the targeted demographic of science students needs to be broadened to be more inclusive (Miller, Blessing & Schwartz, 2006, p. 377). These three themes are addressed by providing students with practical and relevant opportunities to engage in physics. These opportunities are hands-on and focus just on the conceptual understanding of physics topics, not simply through the more traditional solving problems mathematically. This course also allows students, who would not normally take physics, the opportunity to be exposed to physics and it is my desire that this sparks a passion in them for the subject. Through this course, it is my hope that we begin to see more students enroll in physics and the other sciences, as well as see our students better trained in analytical thinking. This will benefit the students regardless of whether they pursue a career in science.

For the remainder of this chapter I will go through the basic structure of the curriculum document and provide a rationale for each of the sections. I will also connect this to my personal teaching pedagogy. The curriculum document begins with a preface to provide the reader with the overarching pedagogy of the course. It then presents the reader with the curriculum for the course. This curriculum is broken up into five Learning Outcome Areas, which are further divided into Individual Learning Outcomes and Learning Outcome Indicators. The final section of the document presents the reader with some suggested learning resources that I have found helpful while teaching the course.

Curriculum Document Structure

The Electronic Curriculum Document was modelled on the structure of the BC Physics 11 and 12 Curriculum Document (British Columbia Ministry of Education, 2006) in order to provide new teachers to the course some continuity with other curriculum documents they have used. Curriculum documents provide teachers with specific learning outcomes that they are expected to teach in their courses. This ensures that every student across the province in a specific course, such as Physics 11, learns the same material. The document also acts as a resource for teachers, giving them suggested assessment strategies as well as suggested resources.

The intention of creating this document is to provide teachers with structural information to support them in introducing secondary level students to the subject area of electronics. This document also gives some consistency and continuity for the teaching of the course, so that it can be taught by various teachers. This has become important in my context, as currently, another teacher at Parkland Secondary is teaching this course.

The curriculum document begins with a preface, as seen in Figure 2, to introduce teachers with the overarching pedagogy of the course and provides some background context for its design. It discusses the need for more knowledge in the area of electronics, as we are becoming immersed in technology in our society and should have a basic understanding of how this technology is created. The preface also informs teachers that this course is meant to be taught as a practical entry point for physics and should focus on conceptual understanding, not mathematical ability. For example, a student should understand what happens to the flow of electricity as more paths and resistors are added into a circuit but they should be taught how to mathematically calculate this change in resistance. This section, then, is meant to give teachers a deeper understanding of the purpose of the course.

Preface

Technology courses have become more than just a stream that provides career options for our students. Today students use technology to socially interact, to relax, and to learn. Technology has become ingrained and ubiquitous in our culture. This means that in the near future, a basic understanding of how electronics work will be a necessity for anyone in our society. It is the purpose of this course to give students a basic understanding of how electricity, electronics, digital logic and robotics work. From this knowledge students will have an increased opportunity to pursue a career in these fields, as well as have a basic understanding of how to trouble shoot and fix common electronic issues.

Figure 2. Preface for Electronics Curriculum Document

The document is then divided up into five key Learning Outcome Areas: Electric Theory; Electronic Components; Applied Electronics; Digital Logic; and Robotics. An example of one of these key learning outcome areas can be seen in Figure 3. These areas represent the course's five separate units. This is intended to help teachers plan and structure how they are going to deliver the material to the students. Though the course units can be offered as separate units they could also be combined to offer a more integrated flow for the course. For example, as students learn about how batteries work in the electric theory section, they can also be working with hooking up a battery in a simple circuit to turn on an LED. Within each of these key Learning Outcome Areas I provide a rationale for that specific area, as well as suggested assessment strategies. These are meant to provide a more overarching understanding of the purpose of the Learning Outcome Area as well as to provide support for the assessment of these.

Learning Outcomes A: Electric Theory

Rationale: *This outcome area is designed to give students a basic understanding of the concepts that electronics is based on. These concepts tend to be routed in physics, which traditionally includes complex mathematics. The learning outcomes in this area do not focus on teaching the complex mathematics, but rather focus on providing students with the knowledge required to test out the concepts in a hands-on environment.*

Suggested Assessment Strategies: *In this area teachers should focus on inquiry-based learning activities in order to allow students to explore the concepts and see how they work in real world situations. For example, when learning about how a battery works students can use galvanized nails, a copper coin, and a lemon in order to create their own batteries. Students should be assessed on their understanding of the theory of the concepts and not their ability to implement this knowledge.*

Figure 3. Learning Outcome Area

The Learning Outcome Areas are then further divided up into Individual Learning Outcomes and Performance Indicators, as seen in Figure 4. These individual learning outcomes give teachers the structure to form daily lessons. The Learning Indicators for each outcome allow the teacher to easily identify the knowledge that the students should be learning and what they should be assessing. For example in Figure 4, the Learning Outcome A1: Atom, found under Learning Outcome Area A: Electric Theory, has been broken up into four Learning Indicators: the three subatomic particles, the nucleus, outer orbits, and size and charge of the subatomic particles.

The Individual Learning Outcome Rationale provides the reasoning for teaching the concept, which is meant to help guide the teacher's overall assessment and teaching strategies. For example, as seen in Figure 4, the rationale provided for Learning Outcome A1 states, "the Atom provides the fundamental particle that is responsible for creating electricity"; teachers can use this rationale to guide their lessons and assessment strategies to ensure that their students understand this overarching concept. This allows the layout to be flexible for both a confident teacher and newer teacher to the course. A confident teacher may only need to look at the Individual Learning Outcome Rationale to deliver an excellent lesson, while a newer teacher can still deliver an excellent lesson by using the Performance Indicators to guide their teaching.

Learning Outcome	Learning Indicators
A1: The Atom *Rationale: The Atom provides the fundamental particle necessary for creating electricity - the Electron. Before students can interact with electrical components they should have a basic understanding of the Electron and its fellow subatomic particles. It is therefore important for students to understand the Atom.*	***It is expected that students demonstrate understanding of:*** - the three subatomic particles that make up the atom (electron, proton, neutron) - the nucleus of an atom and that it is composed of neutrons and protons - an atoms outer orbits and that they are composed of electrons - electron, proton and neutrons relative sizes and charges to each other

Figure 4. Individual Learning outcome and indicator

Typically curriculum documents end with a Learning Resources section to provide teachers with suggested, videos and other teaching aids. Following this model, I have provided resources that I found helpful within my own teaching of this Introduction to Electronics course. These resources include a textbook filled with excellent practical project-based lessons (as seen in Figure 5), a company website for any online ordering of electronic components, and two different robotics kits that allow students to construct and program various types of robots. The textbook I found to be a bit dated and text heavy, which makes it difficult for the students to follow, but it is filled with excellent projects and ideas that the teacher can recreate and update to make more relevant and engaging. The ABRA Company has every type of electronics component you need to teach this course (http://abra-electronics.com). The components are well priced and they offer discounts for bulk orders. I have not fully explored the SUMO robotics kit, but they are fully programmable and are filled with servos, motors, and sensors (https://www.parallax.com/product/27402). The VEX robotics kits are an excellent educational tool (http://www.vexrobotics.com/). The students easily pick up how to construct the robot and the programming interface is very user friendly. I have also recently found out that these VEX robotics kits are also being used by the engineering department at the University of Victoria, which makes the course especially relevant for students who do wish to continue on with physics.

Suggested Resources

Electronic Circuits for the Evil Genius

This textbook is full of practical project based lessons that get students working with the electronic components from the very beginning. The projects start off with a basic battery, resistor, and LED circuit and it works up through capacitors, transistors and all the way up to CMOS IC chips. At the end of the book it has a variety of more advanced projects for students who are racing ahead of the class.

Cutcher, D. (2005). *Electronic circuits for the evil genius*. New York: McGraw-Hill.

Figure 5. Suggested Resources

The entire curriculum document can be seen in Appendix A. This current iteration of the document was created in the spring of 2014. There has been a strong showing of students interested in continuing on in the Introduction to Electronics class and taking a senior version of this course. I plan on creating a Senior Electronics Curriculum Document this summer. The creation of this document may change the Introductory to Electronics Curriculum as we will endeavour to create continuity through the concepts taught. This may cause new concepts to be added to, or existing concepts to be taken out of the Introductory to Electronics course. This will be further explored as the courses are developed and refined.

The Map vs. The Territory

One thing that must be made clear is that this curriculum document is only a map for the Introduction to Electronics course. It highlights certain topics in electronics while casting a shadow on others and it lays out a path in which to teach and evaluate the learning of these topics. But, in order to be effective at teaching this course and any other course, in my opinion, teachers and their students must be allowed to wander through the material, to explore other topics, and see connections to other disciplines.

As a map, this document attempts to give teachers potential sites along a path to follow so that they can act as guides for students. It does this by providing learning outcomes, assessment strategies, and resources. But in order to make this course successful, the teacher must provoke and respond to their students' curiosities as well as adapt the course as the class wanders through the terrain of Electronics. This means that a teacher themselves must have a deep, grounded, and flexible understanding of the subject matter in order to be comfortable wandering off the path; guiding students as they explore material that does not exist within the map or curriculum document. The students must also be encouraged to freely wander outside and within identified learning outcomes in order to develop a deeper understanding of the material. This requires a particular amount of motivation and interest from the student, which can be fostered by the teacher modeling such interest and excitement in the material. These are critical differences that do not make it on to the map because they happen in situ moment to moment. The planned curriculum, (Aoki, 1993), as a document this is thus just one of a handful of tools that must be available and engaged with to make this class a success.

Conclusion

The Introduction to Electronics course is currently being offered to students in grades 9 through 12 at Parkland Secondary, but I am hopeful that next year we will be able to offer a senior electronics course. This will reduce the demographics of the Introduction to Electronics course to be predominately students in grade 9 and 10, though students from all grades in the school will still be welcomed. I found, this curriculum helped me structure the units and lessons for the course. It acted as an excellent guide keeping me on track and giving me some accountability. Currently we have another teacher using this curriculum and my lessons to teach the course. He is finding the resources very helpful, as he is traditionally a metal work teacher and has limited experience with electronics. I would like to continue to add resources and perhaps even some sample lessons to this document in order to make it even more of a support resource for teachers.

Chapter 4: Reflection

Introduction

Since I was a child, I have wanted to understand how the universe worked. This still continues on into my adult life and is the main reason for my decision to study physics and become a physics teacher. Physics, to me, is not about memorizing formulas or concepts. Physics, I believe, is about pursuing an understanding of how our universe works. The key term here is pursuing. Physics is about the pursuit of understanding, not necessarily attaining it. We are currently seeing a decline in enrollment in physics and the sciences here in Canada (Amgen Canada Inc, 2013). The research has indicated that this decline is due to three main themes: a lack of interest and engagement in the subject (Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003); myths that science is difficult, boring and irrelevant in our lives (Gunstone, McKittrick, & Mulhall, 1999); and that the targeted demographic of science students needs to be broadened to be more inclusive (Miller, Blessing & Schwartz, 2006). My electronics curriculum addresses these themes by providing an engaging, hands-on opportunity to experience a high level physics topic that is usually thought of as boring, difficult and irrelevant (Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003). My curriculum is also offered to students at a pivotal time in their lives, when they are forming opinions of the relevance of science and interests in particular fields of study. This is seen in the research as the decline in enrollment of students in sciences begins to drop at grade 10 (Amgen Canada, 2013). By increasing interest and providing more relevant applications of physics, I hope to see an increase in the enrollment of students in the senior grade 11 and 12 physics classes at our school.

Currently, our British Columbian education system only provides three opportunities for students to learn about electronics in their high school education: briefly during the Science 9 (British Columbia Ministry of Education, 2006) and Physics 12 (British Columbia Ministry of Education, 2006) curriculums and, if offered, in the Education Technology 11 & 12 course (British Columbia Ministry of Education, 2002). The Science 9 curriculum focuses on giving students a wide range of exposure to various fields of science including electricity and electronics. The problem with the structure of this course is that due to the wide range there is not enough time to develop and explore the topics fully.

The Physics 12 curriculum is also packed with a wide range of topics and students are busy getting prepared for university physics, which means that students are not as interested in seeing the application of the concepts taught in the course, but rather just want opportunities to practice so that they can attain high marks. The Education Technology 11 and 12 curriculum document shares similar concepts as my document, but there is a greater focus on preparing students for careers in the trades and less of a focus on teaching students the science behind the applications of electronics. Also, it is possible that Education Technology courses can be taught by a shop teacher who may not have the background knowledge to teach the science related to electronics. What the Introduction to Electronics curriculum provides that these other courses do not is a bridge between the practical applications of science and the theoretical understanding of the concepts. It does this by providing students with hands-on inquiry-based activities that explore many complex electromagnetic physics concepts. For example, students construct a speaker using only a coil of wire, two paper plates and a magnet. From this activity the students learn how to generate a magnetic field using an electric current.

This course has been broken up into three main areas: Electric Theory, Electronic Components and Applied Electronics, and Digital Logic and Robotics. The structure and implementation of these three main areas was created to address the main themes found in the literature to affect student enrollment in the sciences: a lack of interest and engagement in the subject (Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003); myths that science is difficult, boring and irrelevant in students lives (Gunstone, McKittrick, & Mulhall, 1999); and that the targeted demographic of science students needs to be broadened to be more inclusive (Miller, Blessing & Schwartz, 2006, p. 377). This reflection will look at how the implementation of this course addresses each of the three themes found in the literature and what further can be done to improve student enrollment in the sciences, specifically physics.

Electric Theory

In the area of Electric Theory, I focused on giving students the background that they need in order to understand how to build electrical circuits. This includes a basic understanding of the atom and how the electron is the particle that is responsible for electricity. I also introduced them to theories of energy conservation and electromagnetism. My goal is to purely get the students to engage with these topics by providing practical activities that allowed them to play around with the concepts taught. These types of inquiry-based hands-on activities have been found to increase the engagement and interests of students within the concepts taught (Bright & Bush, 1926; Fang, 2013; McKittrick & Mulhall, 1999). These activities included creating a current from a piece of fruit to learn about the makeup of batteries; an LED helmet to learn about how computers use electricity to form logical signals; and a speaker to learn about the properties of electro-magnetism. These activities allowed students, who would normally never take a course in physics to engage and be exposed to the application of difficult high level physics concepts. Also, due to the physical aspect of construction associated with these activities, students often ran into problems. This forced students to develop problem solving skills in order to analyze and resolve problems.

The final phase of this section was an all-inclusive pencil and paper test. Traditional tests are a method of assessing what knowledge a student has learned, however, I wanted to transform this traditional method of assessment in order to make it more hands-on and inquiry-based. I did not want this test to assess what students had learned, but rather, what students could learn. I wanted to evaluate their analytical and logical ability to think and problem solve. In order to do this, I gave students the permission to access the internet and ask anyone any questions they wanted. Students had 24 hours to complete the test, and could take it home and work together. The only rule was that they could not ask me, the teacher, for help. It was interesting to see how the students handled this freedom. At first, they thought this test was a joke and a lot of the students started calling the test a homework assignment, stating they would do it later at home. It was only after they started looking at the difficulty level of the questions that they started taking it seriously.

Due to the collaborative design of the test, students were able to share knowledge with each other, but often the students had different answers and had to figure out how to resolve this contradictory knowledge. This forced students to question and analyze the knowledge they had acquired in the course with each other and through research. I often noticed students in discussion about their answers trying to prove to the other that he/she was correct. A group of three students, at one point, were arguing over whether the anode terminal in a battery was negative or positive. One student stated that it must be positive as this terminal is losing negative charges. Another stated that it is negative because the negative charges were being attracted to the other positive terminal. The third student had no idea and was confused as his notes said it was negative, but a website online said it was positive.

It was great to see these students struggle with this question and together try to determine the answer. As the students struggled they had to use their analytical thinking to work through the question. They began to understand the question more fully and in the end it was not so important that these students got the answer right or wrong, because through this process of inquiry they gained a deeper understanding of the chemical processes that were going on in the battery. They demonstrated that they understood how the battery worked, which is the spirit of the whole question.

After marking the tests, I gave it back to the students for another day where they were allowed to make corrections for half of the marks they missed. The purpose of this was to show students that failure is part of the learning process and part of the scientific method. I wanted students to see that something valuable can be learned from failed attempts. Too often students experience failure and see it as the result of an ineffective learning process. This experience discourages them from future attempts to learn. Therefore, I want my students to see that failure is not the end of the learning process, but rather an integral part that is embedded throughout the process. It is the place we all start off at before we begin to explore and learn a new concept and it is the place we repeatedly visit as we wander through the terrain of learning.

In the end, I believe this transformed test successfully evaluated what students could learn as well as create an opportunity to reaffirm or relearn concepts that students had forgotten. The three students who were struggling with whether the anode terminal was negative or positive now know that it is negative and I am confident they will not forget it.

By stripping away any difficult mathematics and designing the Electric Theory section to be inquiry-based and full of hands-on activities, I was able to provide an easily accessible opportunity to learn about physics. Students through this section gained a deep understanding of many high level physics concepts, as well as an in depth understanding of how to analytically break down a problem and logically come to a solution. This analytical and logical thinking that the students must do are the fundamental skills of math. This means that although formal mathematics have been stripped away from the course, there are plenty of opportunities for students to informally use mathematics to solve problems.

In order to further develop this section of the course, I would like to incorporate a section on electromagnetic waves where students can learn about the properties of radio waves and light. Both radio and light waves are commonly used in electronics in order to transmit signals and energy. Teaching the students about these concepts would give them a deeper understanding of how the AM radio they build in the applied electronics and electronic component section work, as well as how the wireless controller and sensors work in the robotics section. It would also be an excellent jumping off point to explain how scientists analyze the frequency, amplitude and period of electromagnetic waves in our universe to search for other solar systems, planets and life.

Applied Electronics and Electronic Components

I start the Applied Electronics and Electronic Component section by telling the students a story about how I was able to fix a 42” flat screen TV for my father-in-law. The TV had stopped working and it was going to cost over $200 to get it repaired. My father-in-law knew that I had some skills with electronics and so he asked me to take a look. Now, I do have some skills with electronics, but I have no idea how those TVs work. Nevertheless, I took it apart and looked at the components inside. Immediately it was obvious to me that one of the capacitors had blown. It was burnt and had burst open. I de-soldered it and soldered in a new one. At this point in the story, I ask the students how much they think a new capacitor costs. Some students make guesses around the $20 range. The new capacitor cost 34 cents. This story nicely illustrates to that students that the knowledge and skills they are learning in this class and section of the course are relevant for their lives. It will help them save money, reduce waste in our world, and it will impress in-laws.

In the Applied Electronics and Electronic Components section, students apply what they learn in the Electric Theory section and create a number of useful practical circuits. Students start by using the basic electronic components: batteries, resistors and LEDs to create a simple circuit that turns an LED light on. They then progress through to more complex components: transistors and IC chips and develop more complex circuits such as an AM radio. Through these hands-on practical projects, I saw the students develop a deeper understanding of the scientific theory taught in the first section, but I also saw them using their analytical and logical thinking techniques. A simple example is when students were trying to figure out how to connect the speaker to the AM radio circuit board. Because we went through the theory of how the speaker worked, students were quickly able to figure out that either of the two wires of the speaker could be connected to the negative or positive terminals on the board. The projects in this course were chosen to build upon each other and develop this deeper understanding and analytical way of thinking. Students start off with a simple circuit and have to trouble shoot simple problems, such as a component hooked up backwards. As the projects become more complex, so to do the problems that they may encounter.

In a future evolution of the course I would like to incorporate a self-designed project. I tried incorporating this past spring after first designing the course. Students, in this first iteration of the course, were given the option to research online and develop their own circuit. Some students excelled at this task, producing lie detectors and solar powered cell phone chargers, however other students floundered and were unable to produce any project. The students who floundered either were not engaged in the task and therefore did not participate or were over ambitious with what they thought they were able to accomplish. I believe that this exercise is still a valuable learning task, but it may be more suited to a senior class that have more working knowledge in electronics and science, as well as have a higher level of maturity for the subject. It is clear though, that further considerations need to be made, as to how to better support and guide students through a self-directed project.

Digital Logic and Robotics

This final section of the course is designed to link all the knowledge and experiences that students gained in the previous sections with more complex applications that they will pursue if they continue on with physics and electronics. To do this students learn a basic understanding of logic gates, binary, logic statements and then apply this knowledge through constructing task specific remote controlled robots. Our school has a set of VEX robotics kits that my class utilizes for this section. The kits are set up similar to LEGO. There are a variety of pieces including wheels, motors, servos, gears, chains and steal struts that can be put together and taken apart. This system allows students to either follow a set of plans or design and construct their own unique robot. Once the physical construction of the robot is finished students then use software to program the robot to respond to certain commands from a remote control.

In this section, I have time to get the students to build three different robots. Each robot that the students must build is associated with a task that the robot must complete. The students demonstrate the robot accomplishing this task through a day of competition, which I call, Robot Wars. The first robot that the students must build is just a basic driving robot. It uses four motors to drive four wheels and has a basic body structure. The students are given plans for this robot, which I encourage them to follow, but I do allow them to design their own version of the robot if they wish. The task that the students must accomplish with their robot is an obstacle course. This course is full of rough terrain, narrow bridges and steep inclines. The students are timed in the completion of this course and are awarded points for each obstacle they overcome.

The second robot that the students must construct is a delivery robot. This robot not only has to be able to drive, it must also be able to pick up, lift and put down objects. The students are not given any additional motors, so they must use either the gears or chains in order to drive four wheels with just two motors. The other two motors must be used to pick up, lift and put down objects. The students are given plans for a robot that will accomplish this task, but I encourage them to alter the design of the claw that picks up and puts down objects. The task the robot must accomplish is to pick up three objects of various weight, size and frailness and then deliver those objects to a platform. The robots are pitted against each other in a round robin tournament where the first robot to complete the task wins.

The third and final robot that the students must construct is a robot that can drive up a set of stairs. There are no plans given to students for this robot, but they are given time to use the internet to research designs of other robots. For this task, the students are given full access to all the robot parts and some of the students even went into the metal workshops to construct and alter components for their design. This task was very challenging for the students and though none of them were successful, I did see a number of promising designs. The most notable was a robot with three independent axels. Each axel had the ability to move up and down, which allowed the robot to lift each set of wheels up to the next stair while supporting the overall weight distribution of the body. I believe that a number of students could have completed this task had there been more time in the course. This is an excellent exercise for teaching students how to adapt and learn from failure. The difficulty level of the challenge combined with the lack of instructions forced the student groups to continually evolve their design; to test them and learn from failure. Though no group completed the challenge, all the groups learned how to adapt an idea and gain knowledge from a failed attempt.

Through these challenging tasks, students are able to use their scientific knowledge and analytical thinking in an exciting, fun and practical activity. All assessments of the robots in this section are made based on the design, construction and functionality of the robots. No merit is given based on how well the students do during the competition days. These competition days only give the students the ability to test their designs and constructions in order to learn and adapt for the next challenge. Students love this section of the course and, for many of them, it is the main reason they take the course. Regardless of why they take the course, this section really illustrates the usefulness of scientific knowledge in our world, as well as how interesting and exciting physics can be.

Further Expansion

This course has become very popular at Parkland Secondary. Last spring we had 22 students register for it, and this year we had 56, which allowed us to offer the course both in the fall and the spring. Unfortunately, I was only able to teach the course in the fall and another teacher is teaching it in the spring, but I have already had a number of students come up and ask me what the course will look like if they take it again next year. This has given me justification to start designing a more senior level version of the course. In a senior electronics course, I could build upon the knowledge that the students would have gained in the introduction to electronics course and expand on each of the sections already in place. Also, since the students taking a senior electronics course would have had to elect to take it as well as the introduction to electronics course I believe that they would have an increased level of interest and engagement in the course. I believe that this increased interest and engagement would make it easier to provide more freedom for self-directed learning.

In the Electric Theory section, I would delve deeper into the theory and construction of more complex electronic components such as: transformers and transformer theory, and the electromagnetic spectrum of radio waves and light. In the Application of Electronics, I would include more self-directed projects, such as the one I tried to incorporate in the spring where students research and design their own circuits. Finally, in the robotics sections I would introduce sensors that allow for automated programming of the robots.

The design of this course is intended to address the declining enrollment of students in physics by providing students with hands-on relevant applications of electromagnetic concepts. It is too soon to see if this course has had any effect on students taking physics, as the predominant demographic of the students are still in the 9^{th} or 10^{th} grade. I do believe though that the design of the course does address all three themes identified in research to be factors in the declining enrollment in the sciences. The course provides students with experience that show the relevancy of physics in our everyday life and its usefulness. The course provides exciting and fun tasks that increase students' interests in the field. Finally, the course addresses these themes through activities that have been shown to appeal to all genders and demographics. I hope to continue to develop this course and work to increase the enrollment in the sciences as I believe that the knowledge and skills that students learn here are important life skills, applicable to just about every area of life.

Though I believe that this course will increase the enrollment of physics at Parkland Secondary, I am aware of a number of limitations of the course. The most notably is that this course predominantly addresses only the topic of electricity and electric circuits. If increasing student interest in physics is linked to providing them practical ways of engaging in the topics then there must be ways to provide the same experiences so that students gain in this electronics course for the other various topics and courses. Having separate practical hands-on based courses for each of the topics taught is not practical. This means that as teachers at Parkland Secondary, we may have to rethink how we implement practical hands-on experiences for students in our classes. Perhaps it would be better to include these experiences and dedicate more time to them within each of the science curriculums.

Another limitation of this course seems to be increasing student interest and enrollment across all genders. This course is still fairly new, but at this point only three of my students have been female. The females that took this course did find it very engaging and excelled at the material, but I would like to find ways to increase these numbers and see a more equitable demographic appeal. This may require more work promoting science and the electronics course in particular to the middle school students that feed our school.

Conclusion

One of the things I love about physics and science is that it is ever changing and evolving. Scientists are always looking to gain a deeper understanding through questioning theories that most people believe to be true. For example, gravity has been looked at and questioned heavily over the years. Isaac Newton was the first to gain some insight on how gravity works, but his theory was altered and added to by Albert Einstein in the mid 1900's. We currently have a theory of gravity that works pretty well for most cases, but it is still flawed and cannot account for all situations. It does not work for objects that are really small (quantum size) or really big (galaxy size). We are still questioning gravity trying to gain a deeper understanding of it. This skill of questioning and searching is what I believe is missing in our science curriculums in high school. We are seeing a declining enrollment in the sciences because we are not really providing students with the opportunities to truly experience science. Science is not about answering paper and pencil questions on a test. It is about questioning how things work and creating experiments to test out theories in practice. We are seeing a decline in enrollment in the sciences, and the research says this is due to a lack of interest in the courses, a sense of irrelevancy for the material, and poor promotion of the classes to a wider demographic. In order to increase enrollment, we must create curriculums that show how interesting and relevant science can be to everyone.

This is what I intend to do with my electronics class. The class attempts to increase student enrollment in physics through providing students with hands-on practical opportunities to engage in some of the more difficult topics taught in senior secondary physics. Through these opportunities it is my intention that students develop an understanding that the knowledge they learn in science and physics is relevant, interesting, and exciting. This understanding, I hope, is gained from all students regardless of gender or demographic. More time and research needs to be done to determine the impact of this course, but I look forward to further develop this course and find ways to increase student interest and enrollment in the sciences.

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Appendix A: Curriculum Document

Introduction to Electronics

Grades 9 – 12

Preface

Technology courses have become more than just a stream that provides career options for our students. Today students use technology to socially interact, to relax, and to learn. Technology has become ingrained and ubiquitous in our culture. This means that in the near future, a basic understanding of how electronics work will be a necessity for anyone in our society. It is the purpose of this course to give students a basic understanding of how electricity, electronics, digital logic and robotics work. From this knowledge students will have an increased opportunity to pursue a career in these fields, as well as have a basic understanding of how to trouble shoot and fix common electronic issues.

If a school in British Columbia does not offer an electronics course, a student's only opportunities to learn about electronics is briefly during the Science 9 curriculum or as part of the Physics 12 curriculum. This means that if a student is interested in this field, he/she has to take Physics 11 and Physics 12. These courses are very difficult for students as they rely heavy on mathematical ability to solve complex problems. This difficulty may discourage students from pursuing an interest in electronics. By offering a separate course in electronics, such as this one, students who may not take a course in physics can have the opportunities to learn about electrical systems and circuits. In addition, by exposing these students to the practical aspects of the electrical concepts, students are given the opportunity to be exposed to high level physics concepts without doing any math. This may increase student interest in the subject of physics, which may lead to them taking a physics course and be more willing to engage in the difficult mathematics.

This document provides teachers with basic information to support them in introducing secondary level students to the subject area of electronics. The document is split into five key learning outcome areas: electric theory, electronic components, applied electronics, digital logic, and robotics. These five key areas are further divided into individual learning outcomes with performance indicators. From this document teachers should be able to easily construct individual lesson plans as well as an overarching semester plan to teach electronics.

Learning Outcomes A: Electric Theory	
***Rationale**: This outcome area is designed to give students a basic understanding of the concepts that electronics is based on. These concepts tend to be routed in physics, which traditionally includes complex mathematics. The learning outcomes in this area do not focus on teaching the complex mathematics, but rather focus on providing students with the knowledge required to test out the concepts in a hands-on environment.* ***Suggested Assessment Strategies:** In this area teachers should focus on inquiry-based learning activities in order to allow students to explore the concepts and see how they work in real world situations. For example, when learning about how a battery works students can use galvanized nails, a copper coin, and a lemon in order to create their own batteries. Students should be assessed on their understanding of the theory of the concepts and not their ability to implement this knowledge.*	
Learning Outcome	**Learning Indicators**
A1: The Atom *Rationale: The Atom provides the fundamental particle necessary for creating electricity - the Electron. Before students can interact with electrical components t hey should have a basic understanding of the Electron and its fellow subatomic particles. It is therefore important for students to understand the Atom.*	***It is expected that students demonstrate understanding of:*** - the three subatomic particles that make up the atom (electron, proton, neutron) - the nucleus of an atom and that it is composed of neutrons and protons - an atoms outer orbits and that they are composed of electrons - electron, proton and neutrons relative sizes and charges to each other
A2: The Ion *Rationale: The Ion is the result of the movement of electrons. This movement is what creates electricity. It is important for students to understand this process in order to understand how electricity works.*	***It is expected that students demonstrate understanding of:*** - the difference between an Ion and an Atom - the process of creating an Ion through acquiring an additional electron or through giving an electron up.

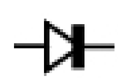
	- the difficulty of moving a proton, which allows for an understanding of why it is the electron that moves to create an Ion, not the proton.
A3: Static Electricity *Rationale: Static Electricity is one form of electricity. In this form electrons are displaced but remain stationary after this displacement. Understanding static electricity is the first step to understanding electricity in the more common form – current through wires.*	***It is expected that students demonstrate understanding of:*** - how to charge an object through friction, induction, and conduction - conductors and their ability to transfers charge easily. Students should also be able to provide examples of conductors. - insulators and how they do not transfer charges easily. Students should also be able to provide examples of insulators.
A4: Electricity *Rationale: Students need to understand how electricity is generated, and moves throughout insulators and conductors before they can utilize electronic components for various purposes.*	***It is expected that students demonstrate understanding of:*** - how opposite charges attract and like charges repel. - how to create electricity through hydro-electric dams, nuclear fission, and various turbine applications - how to store electricity in chemical cells
A5: Battery *Rationale: Once students learn how electricity can be generated the next logical step is to learn how to store it. Students need to understand how batteries store electricity.*	***It is expected that students demonstrate understanding of:*** - how a battery changes chemical energy into electrical energy - the three components needed in a battery: Anode, Cathode, and electrolytic fluid

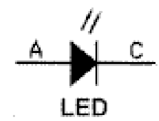
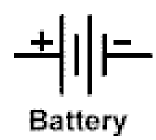
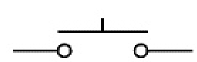
	- the differences between primary and secondary cells - different examples of these types of batteries
A6: Current *Rationale: There are two types of current in electrical systems – Alternating and Direct current. Students need to understand how each of these types of electrical currents moves through a circuit and why both types are necessary for electronics.*	***It is expected that students demonstrate understanding of:*** - direct current and alternating current - the applications of these different currents
A7: Electromagnetism *Rationale: Electromagnetism is an advance physics concept that shows how electricity and magnetism are created by the movement of electrons. This concept will be important for students to learn in order to work with various electrical components such as speakers, motors, and generators. This learning outcome only intends for the students to learn the practical applications of this theory and not the mathematicsbehind it.*	***It is expected that students demonstrate understanding of:*** - how a current running through a coil of wire can create a magnetic field - how a magnetic field moving through a coil of wire can induce a current to flow in the wire - how to harness this electromagnetic phenomenon to create speakers, motors and electro magnets
A8: Safety *Rationale: Electricity can cause harm and injury. For this reason students must learn how to safely interact with electricity before they get comfortable working with electrical components.*	***It is expected that students demonstrate understanding of:*** - how much current is required to injure an individual - where these amounts of current can be found in the average house - how we can avoid injury when working with electricity

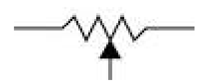
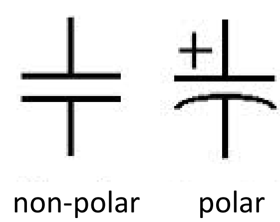
Learning Outcomes B: Electronic Components

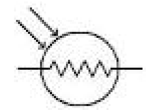
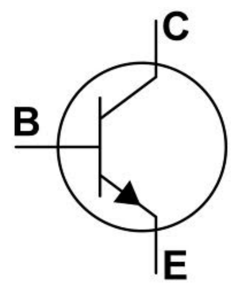
Rationale: *This outcome area focuses on learning the various electronic components names, symbols and purposes. In order for students to continue with electronics and see success in this subject they must acquire basic knowledge to interact with circuit components.*

Suggested Assessment Strategies: *This area is best taught in conjunction with the applied electronics area. Teachers should introduce the students to a component and its functions, and then have the students interact with the component in hands-on activities before moving on to learning about the next component. Students should be assessed on their knowledge of what each component does, its symbol and its purpose with in a circuit.*

Learning Outcome	Learning Indicators
B1: Tools and Equipment *Rationale: Various tools and equipment are used to create and troubleshoot electrical circuits. Students need to feel comfortable with using these tools and equipment*	***It is expected that students demonstrate understanding of:*** - how to use a Multi-meter to measure voltage, current and resistance - how to use a Bread Board and the necessity to use a Bread Board in order to test electrical circuits - how to read the colour codes of a resistor to determine its resistance
B2: Basic Components *Rationale: These electrical components are almost always used to create a circuit. Students must learn what these components are, how they are represented, and how they work.*	***It is expected that students learn the purpose and symbol for the following electrical components:*** - **Diode** Purpose: *restricts the flow of electricity to one direction* Symbol: 

	- **Resistor** Purpose: *Converts electrical energy into heat energy. Can be used to change the voltage in a circuit.* Symbol:  - **LED** Purpose: *a diode that emits light* Symbol:  - **Battery** Purpose: *a group of electric cells that provide power to a circuit.* Symbol:  - **Push Buttons** Purpose: *a component used to open or close a circuit.* Symbol: 
B3: Potentiometer *Rationale: The potentiometer is a component that will be worked with in class. It is also commonly used in circuits as a volume controls for speakers and as a dimmer for a light fixtures.*	***It is expected that students demonstrate an understanding of:*** - how the internal structure of a potentiometer works and how to test for its maximum resistance

	- the potentiometer's symbol and how to use it as a variable resistor Symbol: 
B4: Capacitor *Rationale: The capacitor is a component that we will be worked with in the class. Capacitors are used to store charge for short periods of time and can be combined with resistors to form a timing sub-circuit.*	***It is expected that students demonstrate an understanding of:*** - polar and non polar capacitors and their ability to store a charge for a short period of time - how the polar capacitors use electrolytic materials to help hold large amounts of charge. - the symbol for polar and non polar capacitors and how to use them as timers in an RC circuit Symbol: 
B5: Light Dependent Resistor (LDR) *Rationale: The Light Dependent Resistor is a component that will be worked with in the class. Its sensitivity to light makes it a useful variable resistor that can be used as a light trigger for circuits.*	***It is expected that students demonstrate an understanding of:*** - how the LDR has a low resistance in the light and a high resistance in the dark - the LDR's symbol and how to use it in a circuit as a light sensitive switch

	Symbol: 
B6: Transistor *Rationale: The Transistor is a component that will be worked with in the class. It acts like an electrically triggered button to control the flow of electricity. The development of this component in the twentieth century is what made logic gates possible and therefore computers. Students must learn how this component works if they wish to continue on in the field of electronics.*	***It is expected that students demonstrate an understanding of:*** - the NPN and PNP transistors and how they are similar to electrical push buttons - the importance of the development of this component in the advancements of computer electronics - the transistors symbol and how to use it in a circuit as an electrically controlled button 

Learning Outcomes C: Applied Electronics

Rationale: *This outcome area makes use of the previous areas and allows students more freedom to design and build circuits. This area also teaches students basic diagnostic skills in order to trouble shoot problematic circuits.*

Suggested Assessment Strategies: *In this area, students can be given more freedom to create and design their own projects. It is suggested that students either build a project from an existing circuit diagram or create their own circuit outlining the materials they will be using, a timeline for the project, and what skills from the course they will be using. Students should be assessed on their ability to design, follow and create a circuit that incorporates components from Learning Outcomes B. A key skill that students need to demonstrate is their ability to solder components together and on a circuit board as this skill is a necessary for any future courses in electronics.*

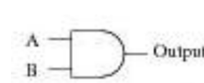
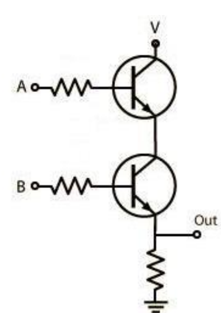
Learning Outcome	Learning Indicators
C1: Circuit Diagram *Rationale: Circuit diagrams are the blueprints for our circuits. Students must learn how to read a circuit diagram in order to build their circuits as well as how to draw a circuit diagram in order to share their circuits with others.*	***It is expected that students demonstrate an understanding of:*** - how to read a circuit diagram and identify individual components - how to Bread Board a circuit given only a circuit diagram - how to design and create a circuit diagram for an individual project
C2: Design *Rationale: Designing circuits is a way for students to take ownership over the concepts they have learned and apply them to a creation of their choice.*	***It is expected that students demonstrate an understanding of:*** - how to design a circuit to solve a practical problem
C3: Soldering and Circuit Boards *Rationale: Soldering circuits together and onto circuit boards is how we make our circuits permanent. Students need to learn these skills in order to take their creations out of the laboratory and into the real world.*	***It is expected that students demonstrate an understanding of:*** - how to use a solder iron to join components together - how to solder onto a circuit board

	- how to remove solder using a solder sucker - how to care for a soldering iron
C4: Trouble Shoot *Rationale: A broken connection, a burnt out component, or a dead battery are just a few things that could be wrong while building a circuit. Students must learn how to use analytical thought to isolate problems in their circuits and fix them.*	***It is expected that students demonstrate an understanding of:*** - how to analytically trouble shoot circuits in order to isolate a problem with a component or in the circuit design

Learning Outcomes D: Digital Logic

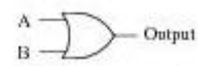
Rationale: *This outcome area begins to introduce topics and lessons that students require to understand how a computer works on a hardware level. Students are introduced to binary, logic gates, and IC chips. In this area students can begin constructing more advance circuits that have certain logic operations built into their hardware design.*

Suggested Assessment Strategies: *In this area students initially need direct instruction as they must be careful handling the various IC chips. It is suggested that students first build a NAND Gate Oscillator circuit and then be given the freedom to explore other IC chip circuits. Students should be assessed on their ability to successfully utilize logic gates in their circuits.*

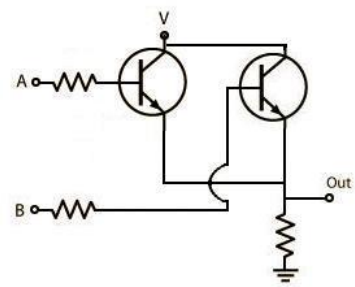
Learning Outcome	Learning Indicators
D1: Binary *Rationale: Digital Logic is based on the binary language of 1s and 0s. Students must learn this language in order to understand how digital logic components work.*	***It is expected that students demonstrate an understanding of:*** - how to represents numbers, and ascii letters in binary code - how to represents the different states of 1 and 0 using high and low voltages
D2: Logic Gates *Rationale: The following logic gates will be worked with in the class. A logic gate is an electronic component that is used to execute logic commands. Students must learn how these gates work and what components go into creating their internal structures.*	***It is expected that students demonstrate an understanding of:*** - digital logic statements involving AND, OR, and NOT - the internal structures of an AND gate , its symbol, and how it can be used in a circuit to execute digital logic Symbol:  Internal Structure: 

- the internal structures of an OR gate , its symbol, and how it can be used in a circuit to execute digital logic

  Symbol:

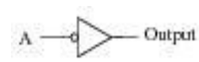


  Internal Structure:

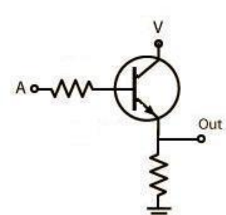


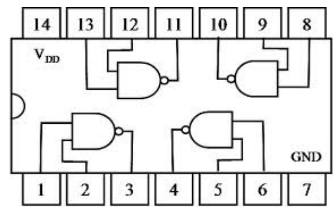
- the internal structure of a NOT gate, its symbol and how it can be used in a circuit to execute digital logic

  Symbol:



  Internal Structure:



D3: CMOS series IC chips *Rationale: These Chips are what contain the digital logic gates that we will be working with in class. Students must learn how the internal structure of these various chips are set up in order to build circuits with them.*	***It is expected that students demonstrate an understanding of:*** - the delicateness of using IC chips and how to safely incorporate them into circuits - the pin configuration and internal structure of a 4011 dual quad NAND IC Chip Internal Structure:  - various other IC 4000 series CMOS chips, and how to read their schematics

Learning Outcomes E: Robotics

Rationale: *This outcome area introduces students to the growing field of robotics. In this outcome area, students will learn how to mechanically construct a robot, how the hardware provides digital logic to this construction and how software can be programmed to control the robot.*

Suggested Assessment Strategies: *Students should initially build a predesigned robot so that they can learn how to attach and work with the various parts, motors and sensors. Once students are comfortable with the basic construction and programming of a predesigned robot then they can be given the freedom to build purpose based robots. This would involve giving students problems that they must solve with a robot. For example it might involve creating a robot that can go into an environment that would be harmful to humans and retrieve some item. Students should be assessed on their ability to construct and program a working robot.*

Learning Outcome	Learning Indicators
E1: Construction *Rationale: The construction of robots involves understanding structural stability and how gears and pulleys work. Students must understand the physical limitations of any particular design.*	***It is expected that students demonstrate an understanding of:*** - how to build structurally stable robot body with the ability to mount motors and actuators for purpose driven motors - how to utilize motors for various tasks, including movement, picking up objects and dropping objects
E2: Signaling and Sensors *Rationale: Signaling and sensors provide the robot with commands that can be used for movement and navigation. Students need to be able to effectively utilize various communication systems to command their robots.*	***It is expected that students demonstrate an understanding of:*** - signaling commands to a robot through tethered and wireless systems - how to utilize laser, light and radio sensors in to control a robot through a maze
E3: Programming *Rationale: Programming a robot provides the connection between the physical mechanics of the robot design, the signals and sensors that the user wants the robot to respond to.*	***It is expected that students demonstrate an understanding of:*** - how to program basic commands and upload them to the robot so that it can execute the program remotely without user interface.

Suggested Resources

Electronic Circuits for the Evil Genius

This textbook is full of practical project based lessons that get students working with the electronic components from the very beginning. The projects start off with a basic battery, resistor, and LED circuit and it works up through capacitors, transistors and all the way up to CMOS IC chips. At the end of the book it has a variety of more advanced projects for students who are racing ahead of the class.

Cutcher, D. (2005). *Electronic circuits for the evil genius*. New York: McGraw-Hill.

ABRA Electronics

This is a great company that carries every electronics component that a student could want. It is a wholesaler and so it is great for schools that have popular electronic programs and require large quantities of LED's, resistors, push buttons, etc.

https://www.abra-electronics.com/

Sumo Bots

These are perfect starter robots for students to learn from. These robots are autonomous and use sensors mounted on their top and bottom in order to steer. The robots are programmed to seek out other Sumo Bots and then push them out of a fighting ring. For a class it is a great project that teaches students how to construct the robot, and troubleshoot.

http://www.parallax.com/product/27402

Vex Robotics

These robot kits are very versatile and give students the freedom to build robots that can do just about anything. The system utilizes metal framing, motors and a wireless remote control system. Student can construct their robots to look anyway they want and then they can program it using a robot version of C. Vex also organizes competitions where students can build purpose driven robots to compete in regional and national games.

http://www.vexrobotics.com/